Plumbing Engineer

Digital Hot Water Systems

From water temperature control to smart system monitoring and documentation.

By Paul Knight

Innovative new technology and timely new product development in water temperature control has delivered digital hardware and software that enables those responsible for hot water system design, operation and maintenance to comply with key performance and measurement components of a Standard of Care.

Digital Recirculating Valves controlling water temperatures within advanced hot water system design with companion software, which monitors and documents system performance, can reduce the scald risk and spread of disease for building occupants. In turn, this can enhance protection for facility designers, owners and operators against wrongful injury litigation.

The Digital Recirculation Valve (DRV) was introduced a decade ago based on the principle that a Thermostatic Mixing Valve (TMV) serving a pumped recirculating hot water system was an adaptation to an application which was inconsistent with the base product functional design.

The premise — a TMV is designed to mix hot water with cold water to deliver a mixed water temperature somewhere in between.

TMVs were not designed to mix hot water with hot water, but because that situation exists in a recirculating hot water system operating under low or zero fixture demand, many TMV piping schematics (Figure 1) suggest supplementary add-on devices such as manual throttling valves to control the amount of return water entering the water heater, which relieves the TMV of that responsibility and aqua stats to turn pumps off[1] to allow a system that is experiencing elevated temperatures to cool.

The primary standard for mixing valves applied for central recirculation system control is ASSE 1017-2009 "Performance Requirements for Temperature Actuated Mixing Valves for Hot Water Distribution Systems." There are two components of the standard that would benefit from a review and update.

First, mixing valves and packaged assemblies with flow capacities ≥ 40 gpm are permitted certification if they can control outlet water temperature within +/- 7 F of the set point. The position here is that a 14 F allowable temperature drift is not accurate enough control for bathing and showering. This concern would be particularly profound in facilities where there are user draw-off points in close proximity to the mixing valve.

Second, a mixing valve primarily destined to be installed in a recirculating hot water system is laboratory tested in a three-way dead leg configuration with an allowable differential between the cold inlet and mixed water outlet temperature ≥ 30 F — a dynamic that is not a norm in true application as it does not account for recirculated return water.[1]

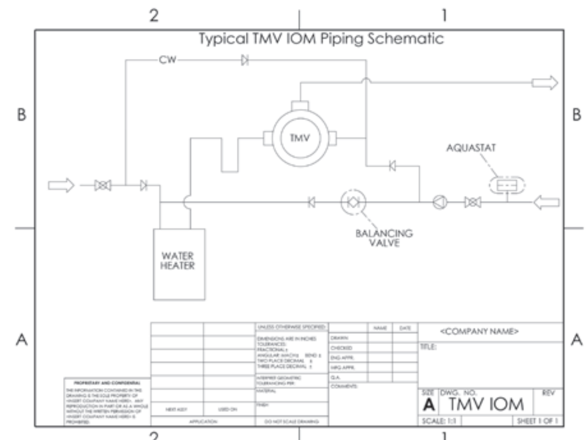

Figure 1

Digital technology creates a paradigm shift

The introduction and evolution of digital technology has changed the landscape. While using digital technology to optimize hot water system user comfort and safety was first advanced in 2006, the vision at the time was much more comprehensive. Digital technology in wider application such as mobile communication, automotive, medical equipment and now water temperature controls is essentially "information management." Collecting, interpreting and managing data input with a high level of speed and accuracy which yields a prescription that improves performance, and in the plumbing industry thousands of installations, verify that a DRV does exactly that.

A decade ago, there was strong resistance in the 100-year-old TMV industry to change to DRV. And while the president of one well known manufacturer dismissed digital as "fledgling technology," the adoption of DRV has been swift. A move toward electronic actuation of existing TMVs commenced almost immediately after digital water temperature control was invented and recently new market entrants who offer digital mixing

1 *Turning off a recirculation pump is a direct compromise of OSHA Technical Manual, Legionnaires Disease: Section V Controls C 4 c "Domestic hot-water recirculation pumps should run continuously. They should be excluded from energy conservation measures".*

valves and stations add merit to an argument that the central recirculation system space continues to progress from thermostatic to digital.

Today's advanced DRV feature a hydraulic design, which can operate with minimal inlet/outlet temperature differentials. With the addition of on board thermistor based temperature recognition componentry, and by deploying a series of algorithms to coordinate proportional blending, DRV deliver an entirely new level of hot water system temperature control.[2]

What is a Standard of Care?

A Standard of Care is defined as acknowledged applicable laws, standards and guidelines.

OSHA (1998), Joint Commission Environment of Care (2001), ASHRAE Guideline 12-2000, ASHRAE Standard 188-2015 and VA Directive 1061 (2014) are Standards of Care that include critical recommendations for establishing and monitoring hot water system temperature control limits.

Following a Standard of Care can minimize the risk of scald injury, Legionella-related illness and the associated litigation. Two important questions will need to be answered during a hot water system event interrogation:

1) To what Standard of Care do you operate the hot water system?

2) Do you have records which verify compliance?

Excerpts from sources credited below emphasize the increasing responsibilities and highlight a rapidly progressing reliance upon ASHRAE 188.

"In 2014 ASHRAE came out with consensus guidelines, it's actually a standard that is directed at primary prevention of Legionella growth and transmission in building water systems. It calls for building owners and managers to assess the water systems in their building, figure out where there are vulnerabilities, and come up with plans to monitor those." – *Laura Cooley, M.D., M.P.H. medical epidemiologist, Centers for Disease Control and Prevention*

"Compliance with the new ASHRAE standard likely will be viewed by courts as the standard of care in personal injury lawsuits involving exposure to Legionella. Adopting industry standard practices and complying with applicable law is the best defense. Conversely, failure to follow such standards and legal requirements could expose building owners and operators to potentially significant liability." – Law.com, July 2016

"Former guests of the Las Vegas Aria Resort & Casino can't seek punitive damages in a case alleging they contracted Legionnaires' disease from the hotel's water system, because management took adequate water safety steps, a Nevada federal judge ruled Monday." – Law 360 Legal News Service, 2015

What does ASHRAE require?

ASHRAE Guideline 12-2000

• 4.1.6 RECOMMENDED TREATMENT: Hot water stored above 140 F (60 C), minimum recirculated return 124 F (51 C).

ASHRAE Standard 188-2015 Legionellosis: Risk Management for Building Water Systems

• 6.1.3 CONTROL LIMITS: Establish limits within which a chemical or physical parameter must be monitored and maintained.

• 6.1.4 MONITORING: Establish a system for monitoring the parameters associated with the control limits established in 6.1.3.

• 6.1.7 DOCUMENTATION AND RECORDKEEPING: Establish documentation and maintain records.

Figure 2 Monitoring System Mobile Device Dashboard

Integrating hardware and software to maximize performance

The development and rapid acceptance of DRV immediately advanced the concept that the hot water system could be further integrated with a resident Building Automation System (BAS) beyond the placement of basic Resistive Temperature Devices (RTD).

The installation of the DRV into a hot water system designed with ASHRAE compliance in mind serves the 4.1.6 Recommended Treatment component of ASHRAE Guideline 12 as referenced in ASHRAE 188, but the standard suggests a lot more than obedience to water heating and system return temperature.

DRVs have integral connectivity capability ranging from on board Modbus to secondary component enabled interfaces, which contain specific protocessor cards for direct interface with a variety of BAS protocols.

While these advancements can offer enhanced hot water system visibility through the BAS and deliver remote set point adjustment, alerting, and a variety of features that enable the hot water system to comply with the monitoring component of ASHRAE 188 as indicated in the previously referenced 6.1.4, it's not as straightforward as it reads.

Integrating the hot water system with BAS can be expensive. Technicians provided by the BAS integrator can charge up to $1,000 per point for connectivity and hundreds of dollars an hour for programming, coding and the composition of the graphics package, system alert functions and report generation. The additional data storage requirements for systems designed to be operated in compliance with ASHRAE 188 section 6.1.7 DOCUMENTATION and RECORDKEEPING, will likely require the purchase or rental of expensive additional server capacity.

2 The term station is used to accommodate designs that are not actual DRV, but are instead a plumbed and wired together assembly of ball valves, controls and thermocouples.

The BAS in larger institutional facilities is a busy information highway and carries a lot of responsibility for data collection and interpretation within the building utility infrastructure. In other words, it is a highly active network and the greater the responsibility it is given, the more the operator is at risk for information overload. Alerts once considered vital to the operation of the building utility systems can report in with such frequency and with such volume that they are subject to triage based upon available resource. This could compromise hot water guideline compliance.

A DRV has the capability to use the exact same information it is collecting to make the decisions required to keep the water temperature at a programmed set point and use it to make the DRV an integral component of a hot water system safety risk management plan — a Standard of Care.

New software exists which seamlessly integrates with the DRV to provide dashboard monitoring (Figure 2) that can be both PC-based and mobile- (smartphone and tablet) enabled. Multiple hot water systems, buildings, campuses can be viewed simultaneously or filtered based upon setting preferences.

Alerts, whether they are DRV component self-diagnostics, service reminders or a hot water system setting compromise such as a hot water supply which has dropped below the 140 F prescribed by ASHRAE, can be received and managed in a variety of communications.

Data storage is cloud based, and can be maintained for as long as building management determines, which some legal experts would suggest extends to the seven-year statute of limitations prominent in personal injury law.

Reports (Figure 3) can be created on demand or with programmable frequency across any time period as determined by facility operations management.

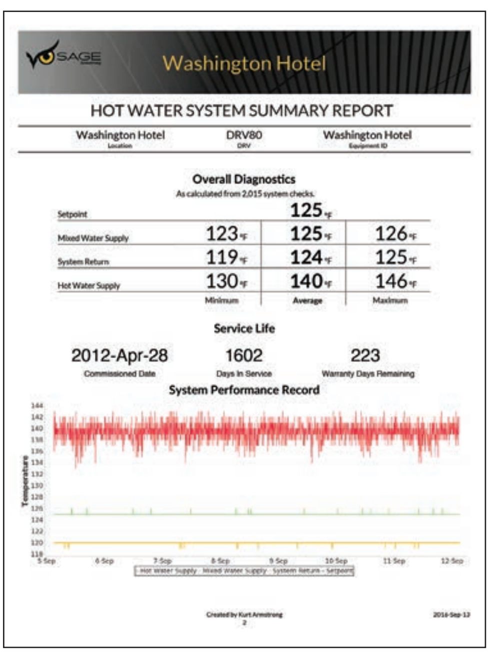

Figure 3: Hot Water System Summary Report

Clearly, the technological advances that produced digital water temperature control can be implemented in a broader spectrum of services well beyond the base plumbing device hardware. Information management, in the form of advanced software designed in concert with the DRV, can be deployed to support responsible hot water system management and enhance user safety.

Zoning hot water systems to optimize performance

As noted, perhaps the most important feature of a DRV is the capability to interpret the system return water temperature and precisely meter in a requisite quantity of hot water to bring the exiting mixed water temperature back to programmed set point. The technology has advanced to the point that DRVs require such minimal temperature differentials that hot water systems can be designed with improved efficiency and performance.

Using DRV, institutional hot water systems can be designed into multiple zones that require minimal balancing, experience minimal heat loss, deliver temperature consistency across the complete recirculation system, simplify the point of use fixture options, reduce maintenance and provide a simplified protocol for a Standard of Care that endorses thermal disinfection.[3]

Before we can fully develop a zoned system discussion, we must first address centralized (sometimes dubbed Point of Source) versus Point of Use water temperature control.

Observed exclusively from a system performance perspective, small Thermostatic Mixing Valves installed at the point of use are not a technical requirement in a hot water system, which has a consistent recirculating hot water pressure and temperatures. Point of Use TMV are only required when there are inlet supply temperature and pressure inconsistencies or there is potential for a dangerous spike in the centrally supplied hot water deliverable.

ASSE 1070 will likely come to mind for the reader at this point so to acknowledge, ASSE 1070 – 2015 Performance Requirements for Water Temperature Limiting Devices is a standard which is referenced in the current (2015) Uniform Plumbing Code excerpted as follows: Hot water delivered from public-use lavatories shall be limited to 120 F (49 C) by a device that is in accordance with ASSE1070.[4]

The definition of "public use" is sometimes open to interpretation and further discussion on the application of Point of Use Thermostatic control is encouraged, but there is a supportable argument that a TMV installed at a lavatory is redundant with the advent of the DRV.

The concept that to reduce water temperature at a lavatory to either a code required or building management preferred temperature requires a small under sink TMV can be questioned. A TMV at a point of use has two functions: First, to adjust the proportion of incoming hot and cold water to maintain a fixed outlet temperature. And second, to shut off an incoming supply in the event of a failure of the opposing supply.

Regarding the first function, cold water temperatures may change seasonally, but do not spike and drop to a point where a conventional TMV is required. And if a DRV is controlling the inlet hot supply there will not be any temperature changes which have not already been

3 OSHA, NYDOH, CDC & VA 1061 are Standards of Care which include a thermal disinfection directive.
4 For more information, refer to the white paper issued by ASSE International Scald Awareness Task Group "Guidelines for Temperature Control Devices in Domestic Hot Water Systems."

addressed further upstream. For the second function, inlet supplies rarely fail, and even if they do, an outlet temperature rise/fall is required before a TMV can affect a shutdown. With an incoming hot water supply of ≤ 125 F and a Point of Use setting of 110 F-120 F, there is often not enough of an inlet to outlet temperature differential to have anything other than a minimal effect upon fixture flow.

Basic TMV are typically installed at a Point of Use to reduce the temperature at the user access point so that it is lower than the recirculating hot water supply. You don't require a thermostat to do that — it is a function of the adjustable mechanical maximum temperature limit stop* typically located beneath the TMV temperature control handle (Figure 4). The position here is that presuming consistent and nominally equal inlet pressures and ≥ .5 gpm fixture flow, point of use TMV would not be required in a hot water system which has a consistent and dependable recirculating hot water supply. If the proposed 125 F recirculating hot water temperature requires reduction at a draw off point, this can be achieved with a non-thermostatic mechanical valve.[5 6]

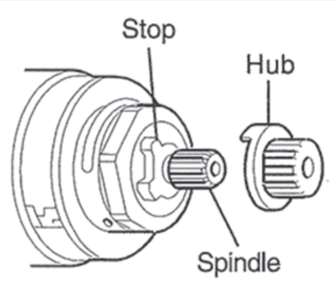

Figure 4

There is a position that Point of Use TMV may create additional issues. They have been identified by Dr. John Lee, a leading global expert as a potential Legionella incubator. That's because they maintain warm water stagnancy points between the TMV and the recirculating hot water supply, the TMV and the fixture and the actual TMV itself presents a warm and comfortable bacterial incubation environment. In addition, Point of Use TMV may exacerbate the system maintenance requirement and without a manual override will prevent thermal disinfection of the pipework leading to them, to the fixture and the fixture itself.

The counsel from many with hot water system operational experience is to "reduce complexity." Large recirculation systems with significant temperature loss inclusive of group and point of use TMV can be difficult to operate and maintain. Loops which run into sub loops and are served by multiple risers and manifold into the return piping system(s) are often tricky to balance which can lead to system temperature inconsistency.

Simplified systems in multiple zones with tight temperature tolerances managed by DRV deliver a wide variety of benefits.

Consider the following design example:

A multi-story/wing building (Figure 5) with a single mechanical room. Mechanical room will feature water heating equipment with a set point of 160 F supplying a DRV set to 140 F (meeting the requirement of ASHRAE Guideline 12-2000 6.1.3). Note — the 160 F water heater set point suggestion is to facilitate thermal disinfection. Instantaneous and semi-instantaneous type water heaters which feature a DRV as the primary control valve could be set to 140 F and the thermal disinfection program within the DRV would adjust to disinfection temperature.

The building has a central pumped 140 F hot water system that serves individual self-contained DRV located in ceiling spaces, pipe chases, etc., which in turn serve multiple separate zones (1-2 floors/wings each).

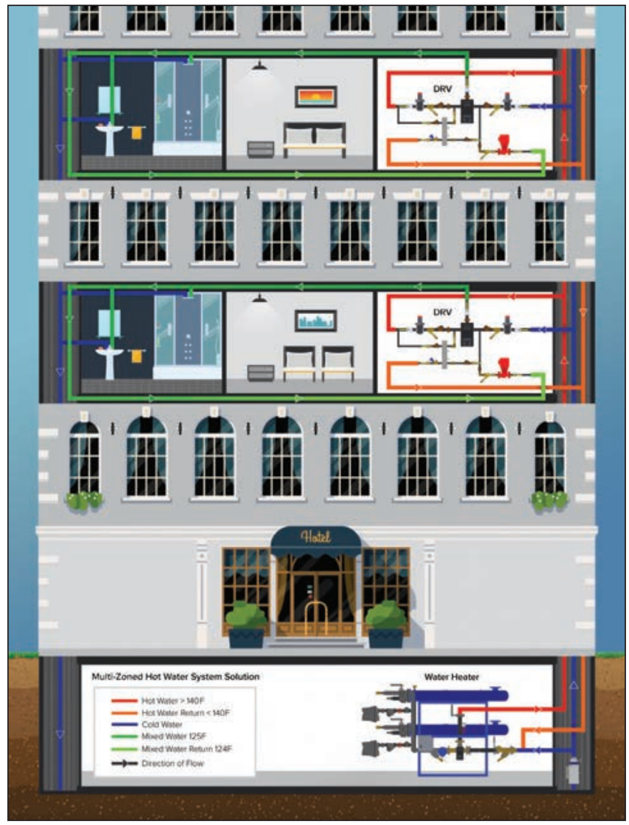

Figure 5 Zoned System Design Graphic

At each zone is a DRV set to 125 F with a small Plate & Frame Heat Exchanger (Figure 6) and a small recirculation pump. The zone is designed to circulate with a 1 F heat loss (return at a minimum of 124 F per ASHRAE Guideline 12-2000 6.1.3).

Each lavatory on the zone is equipped with a sensor faucet, a standard fixture with integral maximum temperature limit stop or the previously noted mechanical under sink mixing valve if the desired access temperature of 125 F – 124 F is deemed too hot by code or preference.

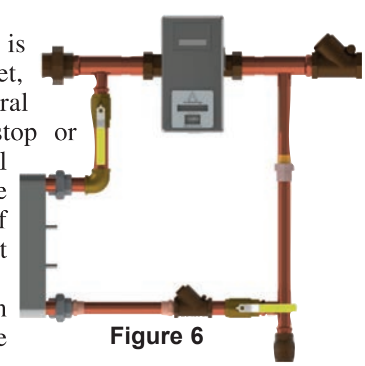
Figure 6

At each shower is an ASSE1016 certified pressure

5 Also known as a "hot stop," the maximum temperature setting or locking feature on a point of use TMV, limits the travel of the internal proportioning mechanism by limiting the rotation of the temperature control handle/lever.

6 For more info, refer to the white paper issued by the ASSE International Scald Awareness Group "Adjustment of Automatic Compensating Valves to Prevent Potential Scald Hazards"

balance valve with the maximum temperature limit stop adjusted to limit the amount of hot water the user can access.

The central 140 F hot water supply circulates to the inlet of the DRV, which supply each zone. The central 140 F hot water supply also passes through the primary side of the small heat exchanger located at the DRV. The return water from the zone passes through the secondary side of the heat exchanger and is reheated and then controlled back to 125 F by the DRV. Each zone remains a continuously circulated closed loop until there is a fixture demand at which time the 140 F hot water enters the DRV and a requisite amount of return water is redirected back to the primary 140 F loop for return to the central mechanical room for re-heating.

The result is a building with hot water zones which offer consistent temperatures, reduce the requirement for system balancing and can be isolated from the rest of the system if thermal disinfection is desired or system component maintenance is required.[7]

DRV offer a programmable Thermal Disinfection option inclusive of recording and documenting the protocol.

Bringing together advanced technology and system design

With self-contained compact DRV available in a variety of sizes with more in the new product development pipeline, the plumbing system designer can now choose between a small centralized or larger zoned hot water system suitable to the building form, function and size to make every hot water system design digital.

System designs that enable the building operator to comply with a Standard of Care is viewed as a positive outcome by Legionella management consultants. Whether operators are charged with managing utilities in a 1,000-room casino hotel, a 20-story hospital, a K-12 school, a college campus with a hundred buildings and everything in between.

Digital water temperature control with matching software operating in concert with, independent from, or placed in buildings that do not deploy building automation, is one of the most significant advancements the plumbing industry has experienced this century.

To learn more about Digital Hot Water generation and control, to discuss zoned system design, request a lunch and learn, society chapter presentation or online webinar go to www.armstronginternational.com/zoned-solution and register. ●

Paul L. Knight holds the position of Director of Global Hot Water Markets for Armstrong International based in Three Rivers Michigan. He has more than 30 years of global experience with the design, application, and marketing of water heating and water temperature controls. He is a 30-year active member of ASPE and ASSE, which includes consecutive terms on the board of the ASPE Northern New Jersey Chapter.