Water Temperature Control and Limitation

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The control and limitation of water temperature supplied to plumbing fixtures is a critical health and safety issue that the Plumbing Manufacturers Institute (PMI) takes very seriously. Over the years, PMI has played a major role in the development and implementation of product standards and plumbing code requirements that provide protection against temperature-related injuries in bathing facilities. Shower safety has been the primary focus of our efforts due to the degree of risk. As a result, hot water supply systems are much safer because the vast majority of plumbing codes throughout the United States and Canada now require thermal shock and scald protection in the shower.

As part of an on-going effort to educate the plumbing industry and prevent potential problems, PMI has prepared the following information to assist code authorities, plumbing engineers, plumbers and consumers. This article identifies various temperature-related tap water hazards, applicable product standards, and the methods of use to provide protection.

With appropriate shower safety measures in place, the industry recently focused its attention on increasing protection of other fixtures. This prompted manufacturers to re-engineer existing temperature control technologies and develop new products. With a variety of new temperature control methods available, new product standards need to be written to identify important features, and establish minimum performance requirements. In response, PMI and its members have been working with the American Society of Sanitary Engineers (ASSE) to identify various applications for tempered water, assess the degree of hazard associated with each application, and develop appropriate American National Standards for these products.

Although work is well underway at ASSE, additional time is needed to complete these new documents. Unfortunately, the availability of these products coupled with the lack of appropriate product standards has caused some confusion over product capabilities and proper utilization. This has led to potentially unsafe installations and the unnecessary prohibition of acceptable devices. This document is intended to provide clarification.

WHAT ARE THE HAZARDS?

Temperature-related tap water injuries can be classified into two types of hazards - **scalding and thermal shock**. Although accidental and intentional scaldings from hot water outlets occur less frequently, many research reports involving the frequency and nature of scalding incidents have concluded that the most serious injuries have involved immersion where a large portion of the body is exposed. The risk and severity of scalding drastically increases with relatively small increases in water temperature. The time to produce first and second degree burns at various water temperatures is illustrated in Table 1. The information in Table 1 is the result of historic research by Drs. Moritz and Henriques at Harvard Medical School in the 1940s.

Thermal shock is a rapid and uncomfortable change in water temperature causing an abrupt physical reaction of a person. Thermal shock is primarily a concern in showers, since the resultant reaction to move away from the flowing water could cause a serious injury from a slip or fall. The temperature change can be either toward colder or hotter water. Rapid temperature changes are caused by simultaneous water usage of other fixtures, such as a toilet, or an appliance, such as a washing machine, that demands a large quantity of water, quickly. This creates a temporary pressure imbalance between the hot and cold water supply. The imbalance changes the ratio of hot and cold water, which leads to a change in outlet temperature.

Table 1 - Water Temperature Effects on Adult Epidermis

Temperature		First Degree	Second Degree
°C	**°F**	**No Reversible Damage**	**Full Thickness Injury**
44°	111°	4.5 hours	5 hours
45°	113°	2.0 hours	3 hours
47°	116.4°	20 minutes	45 minutes
48°	118.4°	15 minutes	20 minutes
49°	120°	8 minutes	10 minutes
51°	124°	2 minutes	4.2 minutes
52°	125.6°	45 seconds	1.5 minutes
53°	127.4°	30 seconds	60 seconds
55°	131°	17 seconds	30 seconds
60°	140°	3 seconds	5 seconds
66°	151°	—	2 seconds
70°	158°	—	1 second

APPLICATIONS, ASSOCIATED HAZARDS AND METHODS OF PROTECTION

- **Individual Showers and Tub/Showers.** Scalding and thermal shock are potential risks in a shower or combination tub and shower. Bathers are particularly vulnerable to thermal shock situations associated with excessive and rapidly changing water temperature because showering occurs in a confined space while standing on a wet floor surface with a large portion of the body in contact with flowing water discharged from a fixed showerhead. In addition to the risk of scalding, an abrupt reaction to move away from the flowing water could cause a serious injury from a slip or fall.

  Virtually all plumbing codes throughout the U.S. require an individual pressure balancing, thermostatic, or combination pressure balancing and thermostatic valve complying with ASSE 1016 to protect against the risk of scalding and thermal shock in individual bath facilities, such as a shower and combination tub/shower. In order to maintain protection against thermal shock, these devices must be installed at the point of use to limit and control water temperature delivered to the fixture. In-line devices that only limit the water temperature to the hot supply to a shower mixing valve, only provide scald protection and do not provide thermal shock protection since additional unprotected cold water is mixed in down stream of the in-line device.

  In existing shower installations without the protection of an ASSE 1016 device, reduced scald risk can be accomplished with the use of a temperature actuated flow reduction (TAFR) valve complying with ASSE 1062, installed before the showerhead on the shower arm. In combination tub and shower installations, the tub spout and the showerhead must both be equipped with a TAFR valve. To reduce the risk of thermal shock, a pressure balancing in-line valve complying with ASSE 1066 can be installed on the hot and cold water supplies to the shower valve. It should be noted that these devices alone, or in combination, do not provide the same level of protection as a device complying with ASSE 1016.

- **Gang Showers.** Gang showers are commonly defined as two or more showerheads intended for two or more bathers. These are installations where all of the showers are being fed with a single pipe supply of tempered water. Currently, there is no standard to specifically cover the thermostatic valve that would supply tempered water to these showers. Historically, a thermostatic mixing valve complying with ASSE 1017 has been used because it comes the closest to meeting the flow and temperature requirements of this type of installation. Many manufacturers of these devices will suggest using a hi-low system (consisting of two or more thermostatic valves working together) when larger flow rates are required. A large capacity valve is needed to feed multiple heads, but may not be sensitive enough during low flow situations to maintain the temperature within 3 degrees F. Large pressure fluctuations represent the area that gives a thermostatic valve the most problems. In these instances, a smaller valve is also installed to temper the water during low flow periods. This scenario occurs in large gang shower applications with on-off controls at each shower station.

  Thermostatic mixing valves complying with ASSE 1017 are designed to control temperature from +/- 3 to 7 degrees F. depending on the size when flowing at the required flow rate. It should be noted that ASSE 1017 has no test for compensation during pressure fluctuation. As such, the mixing valve needs to be located at the hot water source to minimize pressure fluctuations between the hot and cold water lines.

  For large gang shower applications with on-off controls at each shower station, a single thermostatic mixing valve is exposed to a wide range of flow rates. In these instances, it may be necessary to install a hi-low system that incorporates two or more thermostatic mixing valves. A smaller valve is used to compensate and maintain temperature during low flow conditions, and multiple valves work together as the flow rate increases.

- **Tub Fillers.** Scalding is a risk when there is a need to have hot water temperatures sufficiently high to accommodate filling large tubs and still ending up with a water temperature satisfactory to the bather after heat loss due to long fill times. Children, the elderly, or those with disabilities are especially vulnerable to this hazard when using a tub filler with such high temperature water.

  There have been cases of the elderly and children being scalded when immersed in tubs that have been filled with water that has not been checked for suitable temperature.

  If limits are put on the maximum temperature of water allowed from tub fillers, these situations may be alleviated. Some methods of accomplishing temperature control for tub filler applications include:

  - Point of use thermostatic, pressure balancing or combination pressure balancing and thermostatic valve, such as a wall-mounted device in compliance with ASSE 1016 or CSA B125 with high temperature limit stop set at a suitable temperature.
  - In-line thermostatic valves equipped with high limit stops at the point of use or at the hot water source, that provide scald protection to the hot water inlet of the tub filler. The limit stops can be set at a suitable temperature dependent on application.
  - A TAFR valve complying with ASSE 1062 installed in the tub spout, which restricts flow if a specified temperature is exceeded.
  - A thermostatic mixing valve complying with ASSE 1017 at the hot water source supplying the hot side of a single or two-handle faucet.

- **Individual and multiple sinks and lavatories.** Water delivered to sinks and lavatories can present a scalding risk, although in these situation the hands can be pulled away. However, some plumbing codes in the U.S. have imposed temperature limits on the water delivered to accessible lavatories in public restrooms. Like gang shower applications, there is no standard to cover a thermostatic valve that would supply tempered water to these faucets. Where deemed necessary, some methods of limiting temperatures for sink and lavatory applications include:

- Pressure balancing, thermostatic or combination pressure balancing and thermostatic mixing valves can be utilized to supply water to individual or multiple electronic, metering and single-supply faucets and fittings. Lavatory faucets are available with mechanical high limit stops, and could be utilized to provide additional protection.
- In-line thermostatic valves with high temperature limit stops, can provide tempered water to the hot water inlet of individual or groups of sink and lavatory faucets and fittings.
- A TAFR valve complying with ASSE 1062 at the point-of use.

WHY WATER HEATERS CAN'T BE RELIED UPON TO CONTROL AND LIMIT FINAL TEMPERATURE

Although water heater manufacturers are recommending that installers set thermostats at 120 degrees F., the plumbing engineering community continues to recommend hot water systems be designed with higher temperatures to reduce the threat of Legionella. Additionally, water heaters set at lower temperatures reduce the capacity to deliver hot water. As such, water heaters will likely be set at temperatures above 120 degrees F., which means that hot water systems will continue to store and deliver water at potentially scalding temperatures.

Water heater thermostats were never intended to provide precise limits and controls on hot water temperatures. To illustrate this point, the thermostat dial calibration test of ANSI Z21.10.1-1998, which is the applicable standard for gas-fired water heaters, allows the temperature to vary 10 degrees above or below the thermostat setting. Additionally, the maximum temperature limit test of ANSI Z21.10.1 allows the outlet water temperature to rise 30 degrees F. above the thermostat setting. This provision accounts for the phenomenon known as “stacking” or “layering”. Stacking or layering occurs when hot water gathers at the top of the heater due to recurring short duration heating cycles caused by frequent number of small quantity hot water uses. Although the above example addresses gas water heaters, this phenomenon can also occur in other types of storage water heaters.

REVIEW OF TEMPERATURE CONTROL DEVICE STANDARDS

Product standards are an important source of information for manufacturers, code authorities, plumbers, engineers, contractors and consumers. They describe important features of a product, establish minimum performance requirements, and play an essential role in product selection and approval. Where standards are not available, or where existing standards are improperly applied or misunderstood, potentially unsafe installations or the unnecessary prohibition of acceptable devices can result.

The following review of the various standards addressing temperature control devices identifies product features, functions, and requirements in order to gain a better understanding of their proper application and the safety issues surrounding their utilization. It should be noted that work is underway with ASSE working groups to clarify the scope of ASSE 1016 in addition to developing appropriate standards for products used to provide temperature control to fixtures, such as gang showers, tub fillers, sinks and lavatories. The purpose of this effort is to fill the current void that exists for standards covering products exposed to a wide range of flow rates and provide final limitation of mixed water temperatures.

- **ASSE 1016, *Performance Requirements for Individual Thermostatic, Pressure Balancing and Combination Control Valves for Bathing Facilities.*** As the title of the standard indicates, this standard addresses thermostatic, pressure balancing and combination thermostatic and pressure balancing valves. The primary applications for ASSE 1016 devices are showers and combination shower and bathtubs to provide scald and thermal shock protection. This is reinforced by the fact that the standard requires these devices to maintain the set temperature at a flow rate of 2.5 gpm (the maximum flow rate of a showerhead). As such, it is inappropriate to require valves to comply with ASSE 1016 for applications with flow rates less than 2.5 gpm. ASSE 1016 requires these devices to:

- be controlled and adjusted by the bather or bather's attendant
- incorporate an adjustable means to limit the maximum temperature setting
- reduce flow to 0.5 gpm or less when cold water supply failure occurs
- maintain outlet temperature within 3 degrees F of the set position (pressure balancing valves subjected to a 50 percent change in incoming water pressure, thermostatic valves subjected to a 20 percent change in incoming pressure and 25 degree F change in incoming water temperature)

- **ASSE 1017*, Performance Requirements for Thermostatic Control Valves, Self Actuated for Primary Domestic Use.*** This standard addresses thermostatic mixing valves, located at the heat source, used for general reduction of hot water service temperatures delivered to the water distribution system. Final temperature control at fixture outlets must be provided by other suitable individual mixing devices. ASSE 1017 requires these devices to be:

  - installed at the hot water source to minimize fluctuating pressure differentials between the hot and cold water supply
  - maintain a mixed water temperature within a permissible tolerance when subjected to a 10 psi pressure differential between the hot and cold supply (permissible temperature tolerance varies from 3 degrees F to 7 degrees F depending on the flow capacity of the device)

- **ASSE 1062, *Performance Requirements for Temperature Actuated, Flow Reduction (TAFR) Valves for Individual Fixture Fittings.*** This standard applies to valves intended to reduce the risk of scalding by restricting the flow of water when the water temperature exceeds a preset temperature (maximum of 120 degrees F). These devices are limited to point-of-use applications serving a single fixture fitting, and are primarily used with showerheads, tub fillers, and sink and lavatory faucets. These valves can be an add-on device or integral to the fixture fitting. It is important to note that TAFR valves do not provide thermal shock protection since they can not compensate for temperature or pressure fluctuations. ASSE 1062 requires these devices to:

  - automatically reduce flow to 0.25 gpm or less within 5 seconds when outlet temperature exceeds 120 degrees F.
  - located at the point-of-use
  - serve a single fixture fitting only
  - provide a means to reset the device when water temperature returns to safe temperature

- **ASSE 1066, *Performance Requirements for Individual Pressure Balancing In-Line Valves for Individual Fixture Fittings.*** This standard applies to pressure balancing valves used to reduce the risk of thermal shock caused by pressure fluctuations in the hot and cold water supply lines. Products complying with this standard are not designed to limit the maximum outlet temperature at the point-of-use. ASSE 1066 requires these devices to:

  - be used in individual fixture fitting applications only
  - maintain outlet temperature within 3 degrees F of the set position when subjected to a 50 percent change in incoming water pressure
  - reduce flow to 0.5 gpm or less when cold water supply failure occurs

- **CSA B125, *Plumbing Fittings.*** Thermostatic, pressure balancing and combination thermostatic and pressure balancing valves are included within the scope of CSA B125. Like ASSE 1016, the primary applications for these devices are showers and combination shower and bathtubs to provide scald and thermal shock protection. CSA B125 requires these devices to:

- incorporate a handle adjustment stop to limit the maximum temperature setting
- reduce flow to 0.5 gpm or less when cold water supply failure occurs
- maintain outlet temperature within 3.6 degrees F of the set position when subjected to a 50 percent change in incoming water pressure for pressure balancing valves
- Maintain outlet temperature (dependent of the size of the valve) within 3.4 (1/2" valve), 5.6 (3/4" valve), and 7(1" valve) degrees F of the set position when subjected to a 20 percent change in incoming pressure and 4.5 (1/2" valve), 6.5 (3/4" valve), and 8 (1" valve) degrees F for a 27 degree F change in incoming water temperature for thermostatic mixing valves.

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