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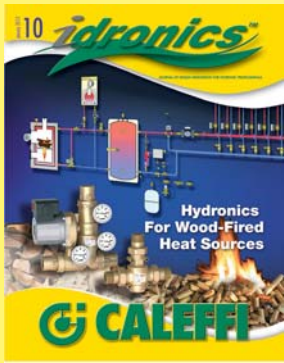
# *idronics*<sup>TM</sup>

JOURNAL OF DESIGN INNOVATION FOR HYDRONIC PROFESSIONALS



## Domestic Water Heating

# **CALEFFI**



A Technical Journal  
from  
Caleffi Hydronic Solutions

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Dear Plumbing and Hydronic Professional,

Welcome to the 11<sup>th</sup> edition of idronics, Caleffi's semi-annual design journal for hydronic and plumbing professionals.

Almost every occupied building requires a source of safe domestic hot water. There are many ways to provide it. This issue of idronics begins with a brief history and overview of the most common methods and hardware for supplying domestic hot water.

Specific sections go on to discuss solar water heating subsystems, heat pump water heaters, indirect water heaters and greywater heat recovery.

Safety issues associated with prevention of scalding and avoidance of Legionella are also covered.

This issue concludes with a discussion of recirculating domestic hot water systems.

Answers are provided to questions such as:

- At what water temperature will Legionella bacteria die?
- Can 125°F water cause skin to burn?
- How should a hot water recirculation system be piped to prevent temperature creep?

We encourage you to send us feedback on this issue of idronics by e-mailing us at [idronics@caleffi.com](mailto:idronics@caleffi.com).

If you are interested in previous editions of idronics, please go to [www.caleffi.us](http://www.caleffi.us) where they can be downloaded free of charge. You can also register online to receive future hard copy issues.

Mark Olson

General Manager & CEO

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# Domestic Water Heating

## 1. INTRODUCTION

A reliable source of clean and safe domestic hot water is now one of the most basic necessities in any building intended for human occupancy. The importance of domestic hot water in providing comfort, convenience and hygiene cannot be overstated. Delivering it remains one of the most important responsibilities of plumbing system designers.

### A BRIEF HISTORY OF WATER HEATING

What most of us now take for granted—clean, hot running water at the turn of a faucet—was not available in much of North America only a couple of generations ago. It still isn't available in many parts of the underdeveloped world.

**Figure 1-1**



Over the centuries, mankind's desire for heated water led to the development of many heating devices and systems that have used a wide range of energy sources.

The ancient Romans adored their baths and designed them with elaborate supply and drainage systems. Roman bathhouses usually included hot pools, cool pools and even a sauna area called the *tepidarium*. In some cases, the water and bathhouse were heated

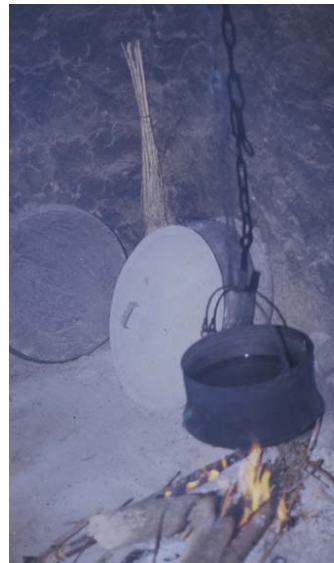
by hypocausts in which hot combustion gases from wood fires were channeled between stone pillars supporting elevated floors and around large water-filled pools. In other locations, the baths were supplied by natural hot springs.

In the centuries that followed, water was usually heated in kettles suspended over a fire within a hearth. Due to the time and effort spent to produce it, the heated water was used judiciously. A weekly bath, rather than a daily shower, was normal.

**Figure 1-2**



**Figure 1-3**



Source: UMass library

Open fireplaces gave way to wood- and coal-fired stoves for heating and cooking. Some of these stoves were available with porcelain or tin-lined reservoirs that would gradually heat water for baths and other uses. The stove shown in Figure 1-4 is equipped with a water-heating compartment on its right side.

As hot water delivery evolved from pots to pipes, stoves that burned either wood or coal were developed with water jackets, as illustrated in Figure 1-5. They were piped to elevated storage tanks called "range boilers" that were made of galvanized steel. Water circulated between the stove's water jacket and the range boiler by natural convection. Pipes carried hot water from the tank to fixtures in the building.

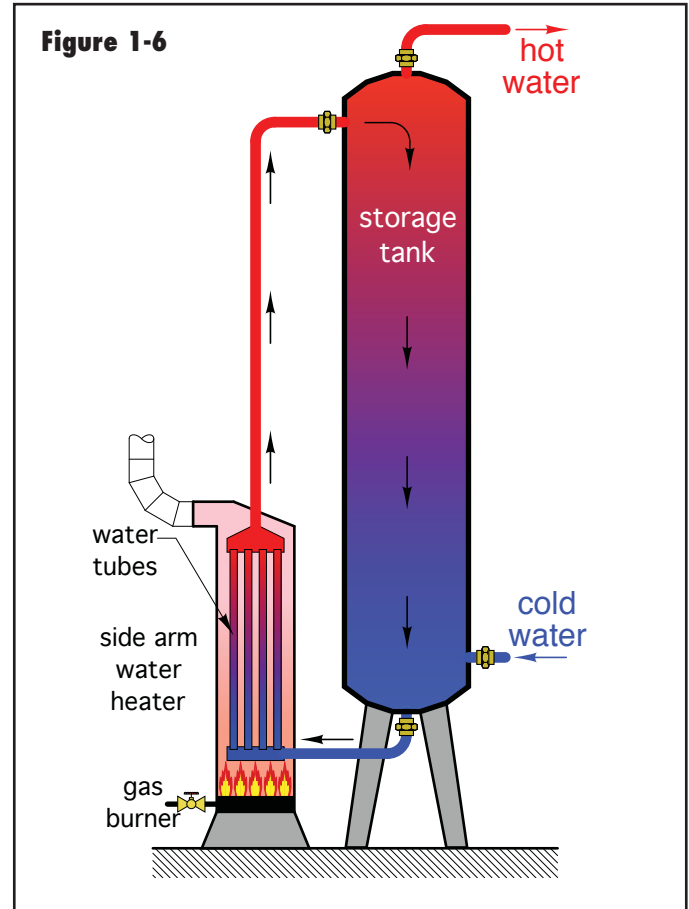
**Figure 1-4**



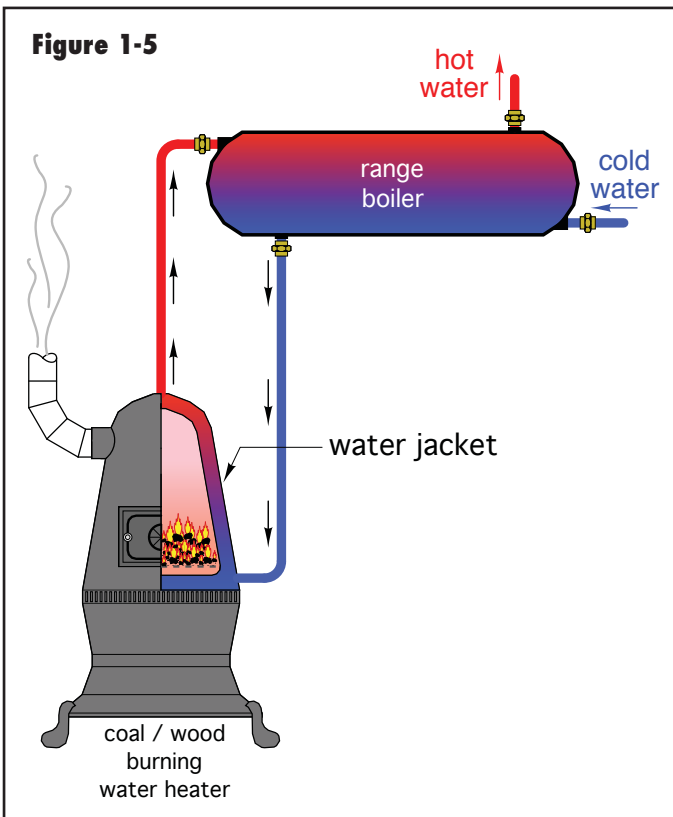
Source: Good Time Stove Company

As gas replaced wood and coal, another type of device appeared called a “side arm water heater.” A gas burner was located under a small copper heat exchanger enclosed in a steel cylinder. It was mounted low and beside a storage tank. As with a range boiler, the heated water flowed upward by natural convection, and thus created circulation between the side arm heater and storage tank, as seen in Figure 1-6.

**Figure 1-6**

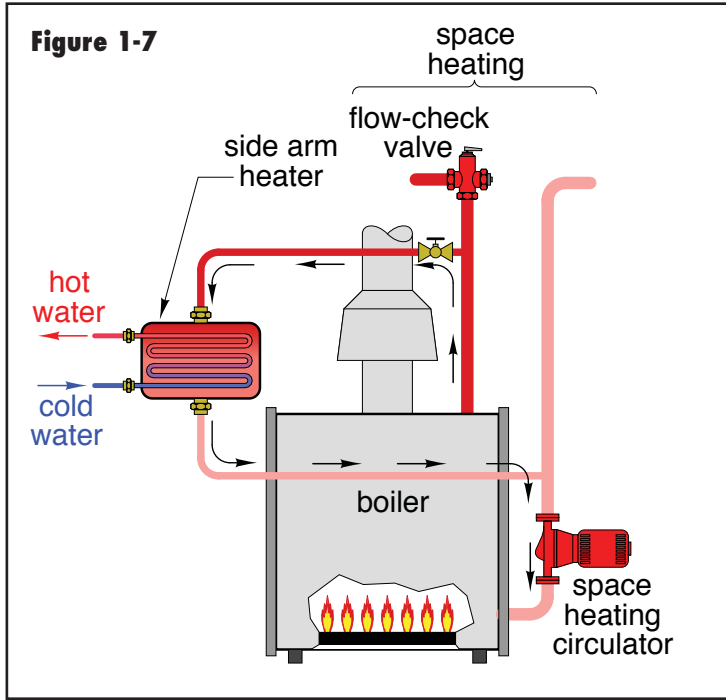


**Figure 1-5**



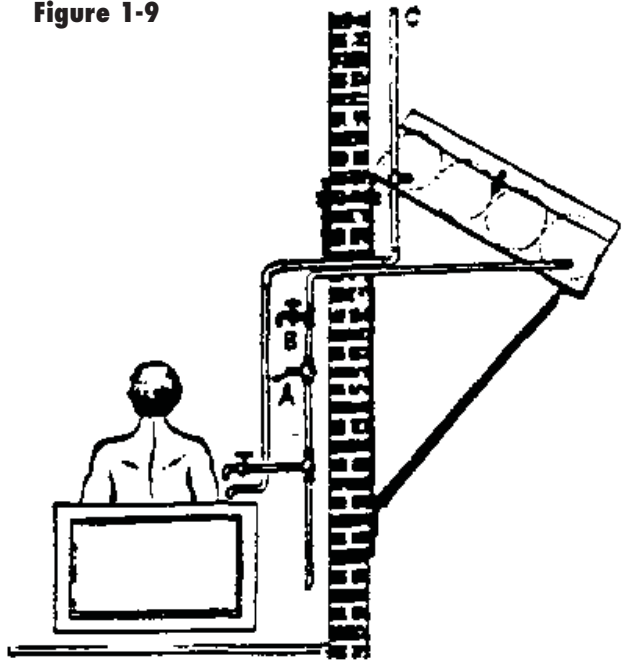
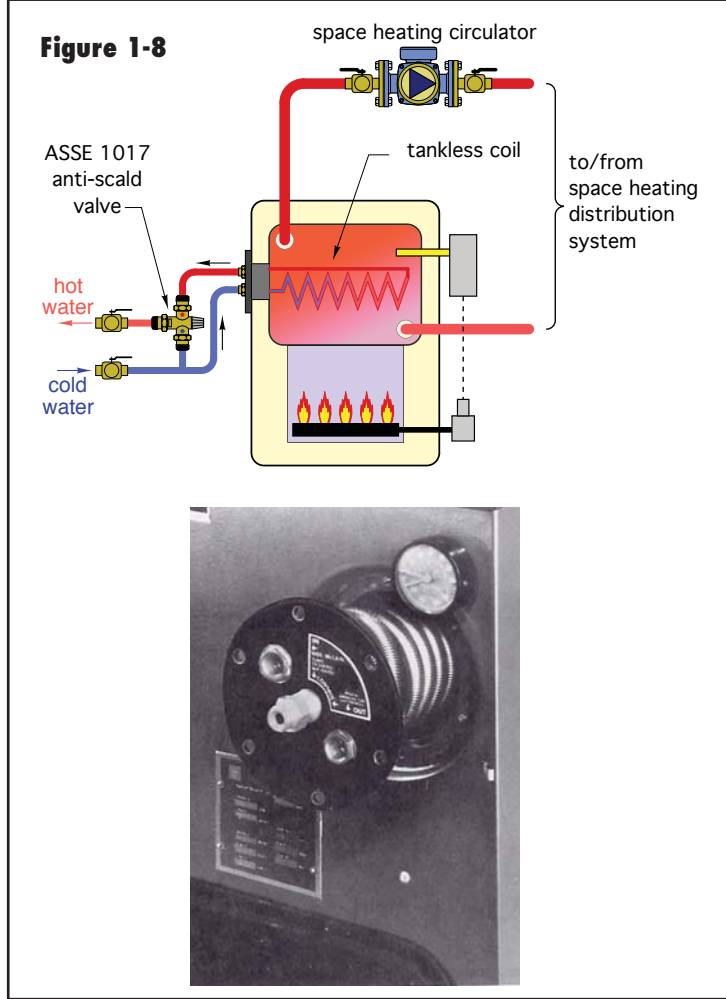
Side arm domestic water heaters were also developed for use with heating boilers, as shown in Figure 1-7. No circulator was needed between the side arm heater and the boiler. The boiler was always maintained at some minimum temperature, and flow between the boiler and the side arm heater occurred by natural convection. Cold domestic water would make a single pass through the copper coil inside the side arm heater and flow onward to the fixtures. Sufficient heat transfer was present because of the relatively high water temperature typically maintained in these older boilers. The overall efficiency of this approach was poor by today’s standards.

Another somewhat dated method for heating domestic water using a space heating boiler is known as a “tankless coil.” This approach, shown in Figure 1-8, uses a tightly



coiled finned copper coil fitted into a cavity within the boiler's heat exchanger. The coil is completely surrounded by hot boiler water at all times. Whenever a hot water faucet is opened, cold water makes a single pass through the coil and emerges fully heated. Thousands of "tankless coil" boilers are still in use. A limited number are still being installed as replacement units. However, the need to maintain the boiler water at a minimum temperature of 140° to 160°F 24/7 significantly lowers the fuel efficiency of this approach relative to more modern methods.

Solar water heating devices started being used in sunny warm climates during the late 1800s. Some were as simple as a barrel painted black and mounted on the roof. These "batch-type" solar water heaters were popular in Florida and Southern California in the early 1900s. Figure 1-9 shows one of the batch-type solar water heaters used over a century ago. Such devices gave way to systems in which the solar collection hardware was separated from the storage hardware to reduce nighttime heat loss.



Source [www.collections.infocollections.org](http://www.collections.infocollections.org)

"On demand" domestic hot water service quickly developed from a luxury to an expectation in 20th century buildings. This spawned what is now a multi-billion-dollar industry supplying a wide range of domestic water heating devices that operate on almost any commonly available energy source.

Domestic water heating has also become one of the largest energy consuming loads in a typical house, second only to space heating and cooling. All current and future methods of heating domestic hot water must address energy efficiency as well as reliability, cleanliness and safety.



## 2. HEALTH AND SAFETY ISSUES

A “safe” source of domestic hot water is considered an absolute necessity by nearly all North Americans. To be safe, heated water must be free of contaminants that could create health risks or cause premature deterioration of components within the plumbing system. The water must also be delivered at a consistent temperature that is adequate for the intended use, but not hot enough to rapidly burn skin. This section discusses the basic health and safety issues associated with providing domestic hot water.

**Figure 2-1**

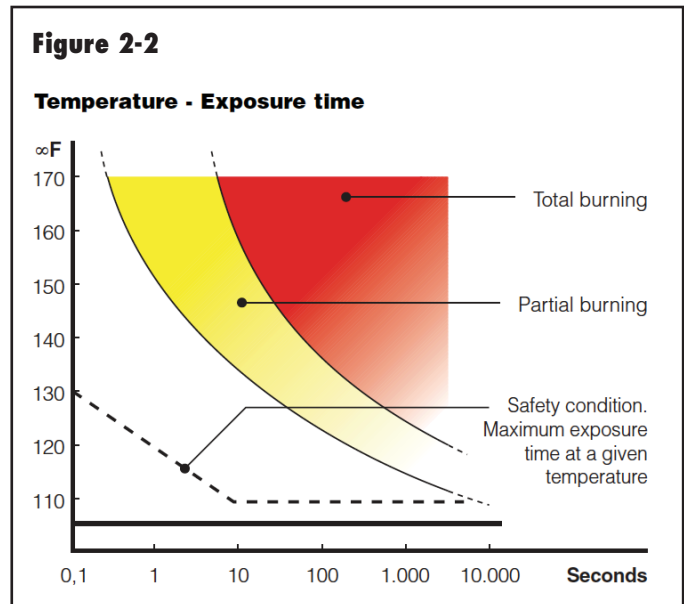


In many regions of North America, the chemical and biologic quality of domestic water is maintained by municipal water utilities. In buildings with private wells, water quality is maintained by on-site equipment that filters out sediments, extracts unwanted chemicals such as sulfur, iron or calcium compounds and kills bacteria. Such treatment can be through filtration, heating, injection of antiseptic chemicals or by exposing water to ultraviolet radiation. In most cases, a water quality specialist designs a treatment program and specifies the necessary equipment based on laboratory analysis of the water available at a specific site.

### BURN PROTECTION

Notwithstanding chemical or biological contaminants, one of the greatest potential hazards associated with domestic water is the risk of moderate to severe burns when skin is exposed to excessively heated water at sinks, showers, bathtubs or other fixtures.

The ability of hot water to burn human skin depends on its temperature and exposure time. The higher the water temperature, the shorter the time required to produce a burn of a given severity. Figure 2-2 shows how burn severity of adult skin is affected by water temperature and exposure time.



In a shower, adult skin can be exposed to water at 110°F indefinitely, without risk of burns. However, at temperatures above 110°F the risk of burns increases rapidly. Water at 130°F will cause first-degree burns to adult skin in about 10 seconds. Continued exposure to 130°F water will eventually cause second- and third-degree burns. Water at 160°F can instantly cause a first-

degree burn. Children can experience similar burns in *half* or less of the time required to burn an adult.

The consequences of serious and possibly irreversible burns caused by overheated domestic water should never be taken lightly. Beyond the potentially life-changing medical issues faced by the victim is the legal liability associated with designing, installing or adjusting the domestic water heating system that caused the burn. It is therefore a highly recommended and often *mandated* practice to equip *all* domestic hot water systems with devices that can reliably protect against such conditions.

Unless otherwise required by local code or regulation, domestic hot water should never be delivered from fixtures at temperatures above 120°F. In most cases, water at a temperature of 110°F is perfectly acceptable for showers, bathtubs and lavatories. This issue of idronics will describe methods and components for providing reliable protection from burns associated with overly heated water.

## LEGIONELLA

One biological impurity that can be present in domestic hot water systems is Legionella bacteria. There are currently over 40 known types of these bacteria. One example is shown, under high magnification, in Figure 2-3.

**Figure 2-3**



Legionella bacteria are naturally present in rivers, lakes, wells or stagnant pools of water. They are also found in municipal water mains and can, to some extent, survive municipal water treatment processes.

Legionella bacteria can multiply in water at temperatures between 68°F and 122°F. Below 68°F, the bacteria are present, but remain dormant. Tempered water between 77°F and 113°F provides an optimum growth environment for Legionella bacteria. Growth is also aided by the presence of biofilms, mineral scale, sediment or other microorganisms within plumbing systems. Dead-leg plumbing systems that harbor stagnant water also provide an enhanced growth environment and should be avoided.

Given the right conditions, Legionella bacteria can cause two diseases in humans:

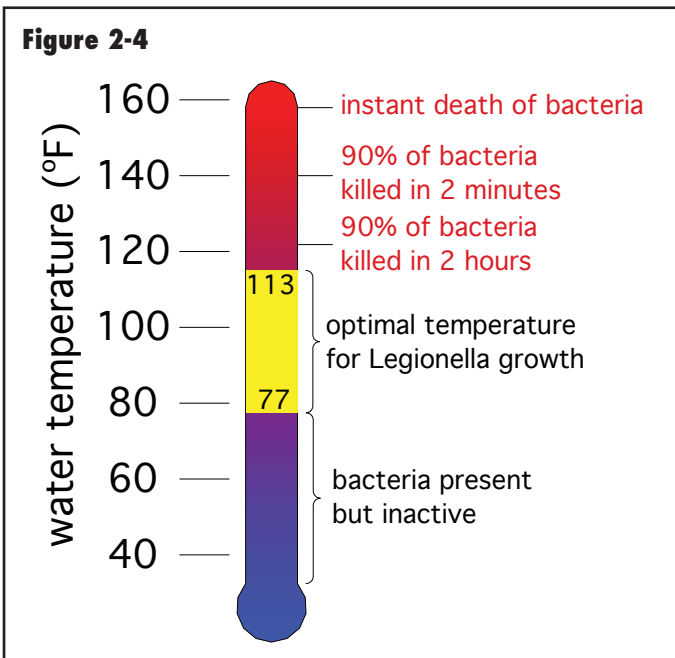
- *Pontiac fever*, which develops after an incubation period of 1 to 2 days. Its symptoms include fever, muscle aches, headache and, in some cases, intestinal complaints. This form of Legionella infection is often mistaken as the common flu and usually runs its course in 2 to 5 days without need of antibiotic treatment.
- *Legionnaire's disease*, which was first identified after a 1976 outbreak of pneumonia at a Philadelphia hotel where an American Legion convention was being held. The outbreak affected 221 people and led to 34 deaths.

Legionnaire's disease develops after an incubation period of 2 to 10 days (5 or 6 days on average). Symptoms may include high fever, muscle aches, diarrhea, headache, chest pain, cough, impaired kidney function, mental confusion, disorientation and lethargy. Legionnaire's disease is difficult to distinguish from pneumonia. Treatment involves a course of antibiotics. Legionnaire's disease can be fatal, especially if diagnosed late or involving patients that are older, weak or have depressed immune systems. Men tend to be two to three times more susceptible than women. It is estimated that 8,000 to 18,000 people are hospitalized with Legionnaire's disease each year in the United States.

Legionnaire's disease is contracted by inhaling a sufficient amount of ultra-fine water droplets, (1 to 5 microns in diameter) that contain Legionella bacteria. Such droplets can be produced by shower heads, faucets, spas, humidifiers, decorative fountains and cooling towers. Legionnaire's disease is *not* passed from person to person, *nor acquired by drinking water* containing Legionella bacteria.

## PROTECTING HOT WATER SYSTEMS FROM LEGIONELLA BACTERIA

Figure 2-4 shows the relationship between the status of Legionella bacteria and the temperature of the water in which they exist. Legionella bacteria can be rapidly killed by maintaining stored hot water at 140°F or higher. While effective biologically, this approach to Legionella control creates a significant scalding hazard if the hot water were to be delivered directly to fixtures.

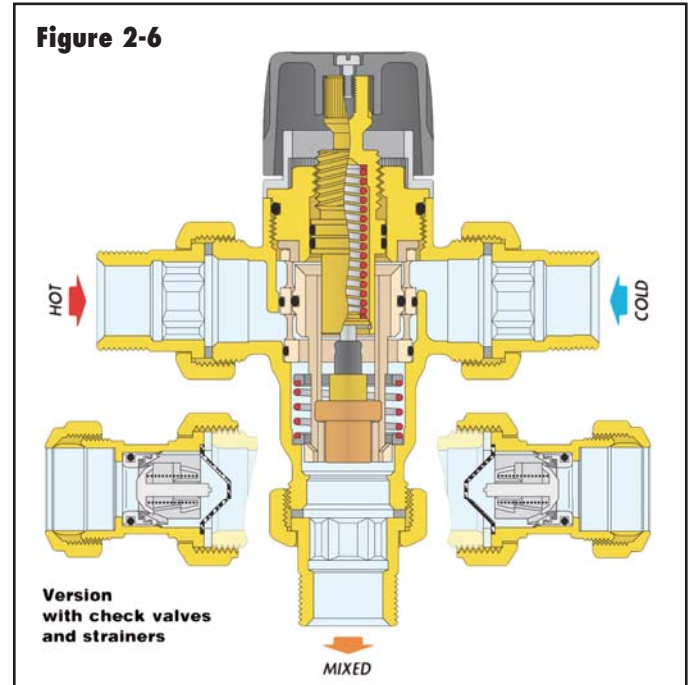


The use of high-quality temperature activated mixing valves, in combination with adequately high source water temperature, provides the solution. It allows hot water to be stored at temperatures high enough to kill Legionella bacteria, but also delivered from fixtures at temperatures that don't cause burns. An example of a temperature activated mixing valve is shown in Figure 2-5.

**Figure 2-5**



Temperature activated mixing valves continuously adjust the proportions of hot water and cold water entering the valve so that the mixed water stream leaving the valve remains at a set (and safe) temperature. This regulation is based on the linear movement of a thermostatic element within the valve, as shown in Figure 2-6.



The thermostatic element contains a specially formulated wax that expands and contracts with temperature changes. This element is fully immersed in the mixed-flow stream leaving the valve, and thus it continually reacts to changing inlet temperatures and flow rates. The thermostatic element moves the shutter, which controls the flow of hot and cold water entering the mixing chamber. As the size of the hot water inlet passage decreases, the size of the cold water inlet passage increases, and vice versa. If the temperature or pressure at either inlet port changes, the valve quickly and automatically compensates to maintain the set outlet temperature.

The American Society of Sanitary Engineers (ASSE) publishes several standards that pertain to temperature activated mixing valves used in domestic hot water systems. These standards are often listed as conformance requirements by plumbing codes. Of these, the ASSE 1017 and ASSE 1070 standards apply to the majority of residential and light commercial systems.

Some temperature activated mixing valves offered by Caleffi are listed to the ASSE 1017 standard. These valves are used to regulate water temperature at the "point-of-distribution" (POD), which refers to the *source* of the hot water. Such valves are installed near a water heater.

Other temperature activated mixing valves offered by Caleffi are listed under the ASSE 1070 standard. These valves are intended for "point-of-use" (POU) applications. Such valves are mounted close to a water fixture, such as a lavatory, shower, tub, bidet or clothes washer.



**Figure 2-7**



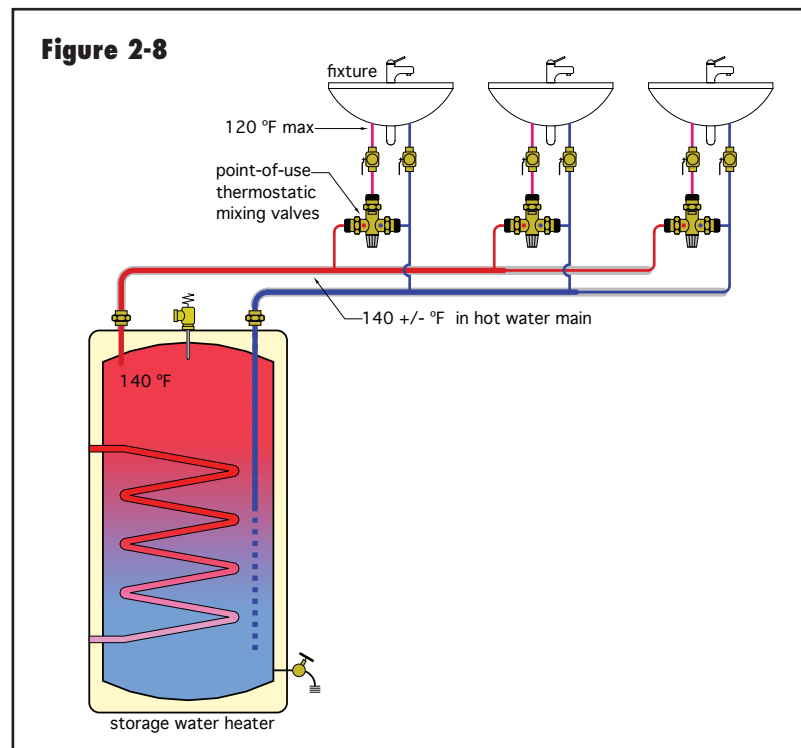
An example of a point-of-use temperature activated mixing valve conforming to the ASSE 1070 standard and installed under a lavatory is shown in Figure 2-7.

Figure 2-8 shows how multiple point-of-use valves can be used, one at each fixture. This approach allows the water in the storage heater to be maintained at a temperature of 140°F or higher to kill Legionella bacteria. This hot water is distributed through insulated piping leading to the hot water inlet of each point-of-use temperature activated mixing valve. Each valve then blends some high-temperature water with an appropriate amount of cold water to create a safe delivery temperature from the fixture. For most bathtubs, showers and lavatories, a hot water delivery temperature no higher than 110°F will be sufficient. No hot water fixture should ever have a delivery temperature above 120°F.

Valves listed under the ASSE 1070 standard are also pressure compensated. If cold water flow to the valve is interrupted, the valve must immediately reduce the flow of hot water leaving the valve to a small percentage of normal flow. The action requires a minimum temperature difference of 18°F between the hot water inlet and mixed water outlet. If the hot water supply to the valve is interrupted, the valve stops mixed water from leaving the valve to prevent the possibility of thermal shock to the plumbing system downstream of the valve. Valves listed to the ASSE 1070 standard must also have internal check valves in both inlet ports.

Later sections will show how to combine temperature activated mixing valves with recirculation hot water delivery systems.

For long, trouble-free operation, all temperature activated mixing valves require reasonable water quality. Caleffi suggests a maximum water hardness of 10 grains for all of its temperature activated mixing valve products. Professional water quality testing is the only way to ensure that the water available at a given site meets this criterion.



## LEAD

Most brass alloys used to construct valves and other piping components worldwide contain a small amount of lead. This lead improves the metallurgical characteristics of the brass, especially when it is machined to produce threads or other precisely dimensioned features.

In recent years, some concern has arisen within the United States about the potential of lead-containing plumbing components to adversely affect the quality of potable water. This concern has convinced some states to enact laws that now require all potable water plumbing components sold in those states to be "lead-free." Specifically, these laws stipulate that the average lead content of the materials forming the wetted surfaces of components cannot exceed 0.25%.

The U.S. Congress recently took action to expand this requirement to all 50 states. In December 2011, Congress passed an

amendment to the existing Safe Drinking Water Act that requires all potable water plumbing components sold in the U.S. to meet the “lead-free” requirement by January 4, 2014. Caleffi North America has been proactive in this transition and currently offers many of its temperature activated mixing valves in “lead-free” alloys that are fully compliant with federal law.



**Figure 2-9**

**Figure 2-10**



Source: Watts

valves can be installed. In general, that piping should be routed with minimal bends and no pipe size reductions or valves to within a few inches above a floor drain.

### THERMAL EXPANSION PROTECTION

When water is heated, its volume increases. This expansion often occurs when there is no simultaneous demand at the fixtures within the building. If a “non-return” device, such as a backflow preventer, pressure reducing valve or check valve, is present in the cold water piping, the pressure in the building’s plumbing system can rise rapidly as the water is heated.

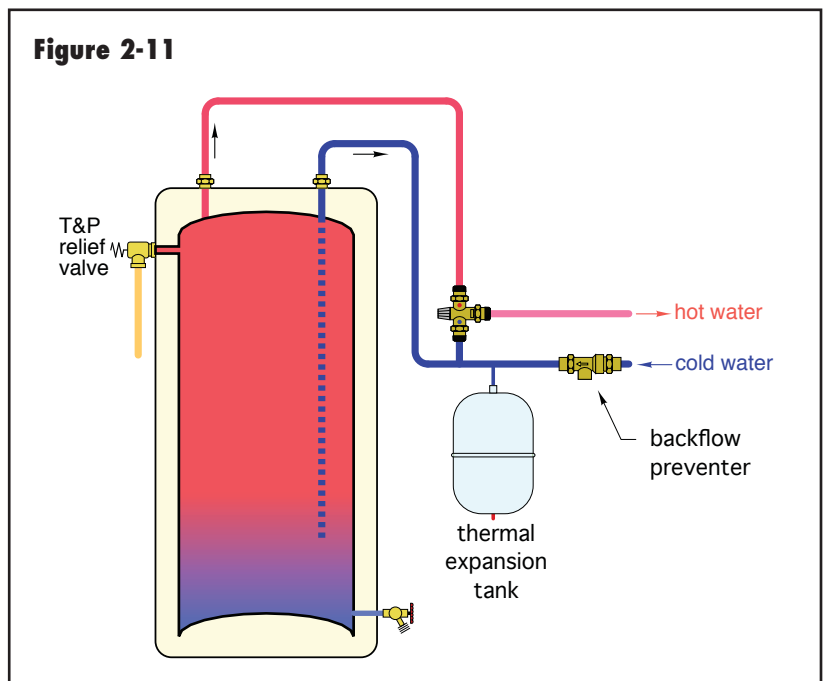
Although T&P relief valves are designed to open if excessively high pressure occurs, it is not desirable for such valves to discharge water during each heating cycle. Allowing water heaters to operate at excessively high pressures can create bursts of water and piping noise when a hot water fixture is first opened. It can also lead to leaks in fittings or valves, or even cause the flue within a gas-fired water heater to collapse, leading to possible spillage of toxic exhaust gases into the building. The life expectancy of glass-lined

### OVERPRESSURE PROTECTION:

All tank-type water heaters are required to have a temperature and pressure (T&P) relief valve. An example of such a valve is shown in Figure 2-10.

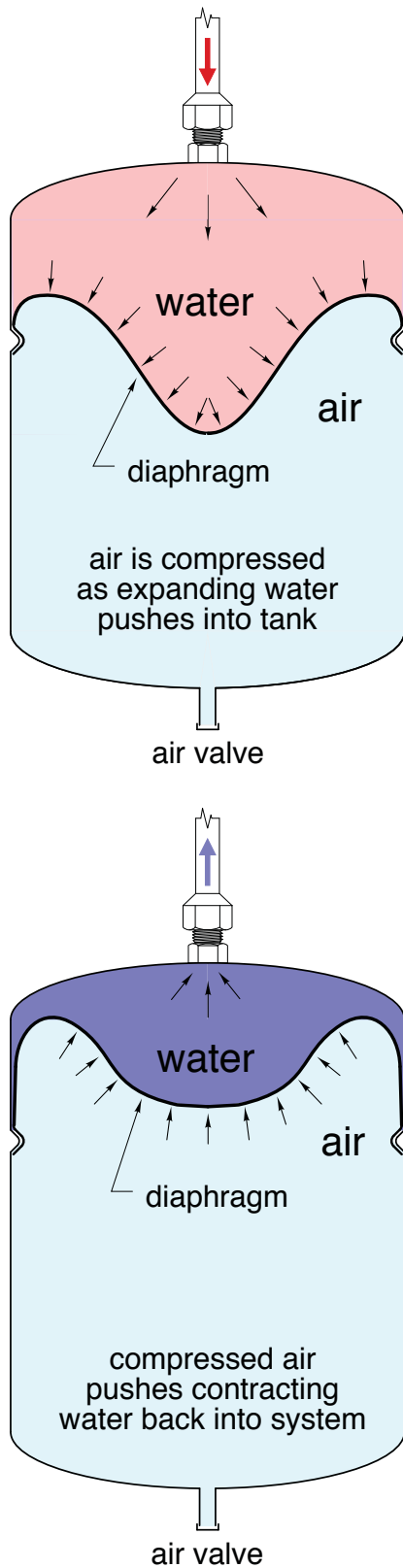
T&P relief valves have a temperature sensing probe extending from their tank connection port. This probe is part of an internal mechanical thermostat that is designed to open the valve if the water temperature reaches approximately 210°F.

T&P relief valves also contain an internal spring-loaded valve assembly designed to open when the valve’s rated pressure is reached. T&P relief valves are available with pressure ratings ranging from 75 to 150 psi. The pressure rating required may be dictated by local plumbing codes or the tank manufacturer. Plumbing codes also specify how the discharge piping from T&P relief



**Figure 2-11**

**Figure 2-12**



water heaters can also be reduced by high pressure that causes flexing of the tank walls.

Fortunately, it is easy to limit the pressure increase in domestic water heating systems using a thermal expansion tank placed as shown in Figure 2-11. Such tanks are required by some plumbing codes. Even when not required, they are recommended to limit water pressure variations.

A thermal expansion tank should always be placed in the *cold* water piping supplying the water heater, and always downstream of any “non-return” valve or device. This placement ensures that the tank will always “feel” the pressure in the water heating device. It also minimizes any change in temperature of the tank’s shell.

Thermal expansion tanks for domestic water heating systems are similar to expansion tanks used in closed hydronic systems. They have a steel shell and flexible butyl diaphragm. The diaphragm separates a sealed chamber of air in the lower portion of the tank from the water contained in the upper portion of the tank. Thermal expansion tanks for domestic water systems also include a non-corrosive polypropylene liner that separates the steel shell from fresh water in the upper portion of the tank, thus preventing corrosion.

As water expands, the increased volume is forced into the tank, compressing the air under the flexible diaphragm, as illustrated in Figure 2-12. In a system with a properly sized tank, the increase in air pressure is such that the T&P relief valve does not open during each normal heating cycle.

*During installation, the air side of the thermal expansion tank must always be pressurized to match the line water pressure at the water heater.* This ensures that the diaphragm in the tank is fully expanded against the tank’s shell before the water in the system expands. If the tank is underpressurized, a portion of its water side volume will fill with water *before* the water starts to expand. This needlessly wastes tank volume and reduces the tanks ability to moderate pressure fluctuations. The air pressure within the tank is adjusted by adding or removing air through the schrader valve on the tank.

Appendix C provides a sizing procedure for thermal expansion tanks in domestic hot water systems.

### 3. COMMON APPROACHES TO DOMESTIC WATER HEATING

Many devices have been developed for heating domestic water using every commonly available source of energy. Some simply convert electrical energy into heat using resistance heating elements. Others use combustion to convert the chemical energy in a hydrocarbon fuel into heat. Still others operate as heat pumps, gathering low temperature heat from air or soil and transferring it to water. This section will briefly discuss several common types of water heating devices.

#### TANK-TYPE ELECTRIC WATER HEATERS

One of the most common devices used in residential and light commercial buildings is a tank-type electric water heater. An example of such a unit is shown in Figure 3-1.

For residential and light commercial building applications, most electric water heaters come with volumes ranging from 1 to 119 gallons. Small tanks with volumes from 1 to 10 gallons are commonly used to provide a limited supply of hot water to a single fixture. Tanks from 30 to 119 gallons are typically used to supply an entire house. Tanks larger than 119 gallons require ASME certified welding. Such tanks are available, but are significantly more expensive and usually only used in commercial applications.

Most tank-type electric water heaters have a welded steel pressure vessel surrounded by an insulated jacket. The space between the pressure vessel and jacket is filled with fiberglass or foam insulation. The higher the R-value of this insulation, the lower the standby heat loss from the tank. Figure 3-2 shows the typical internal construction and external piping used with a tank-type electric water heater.

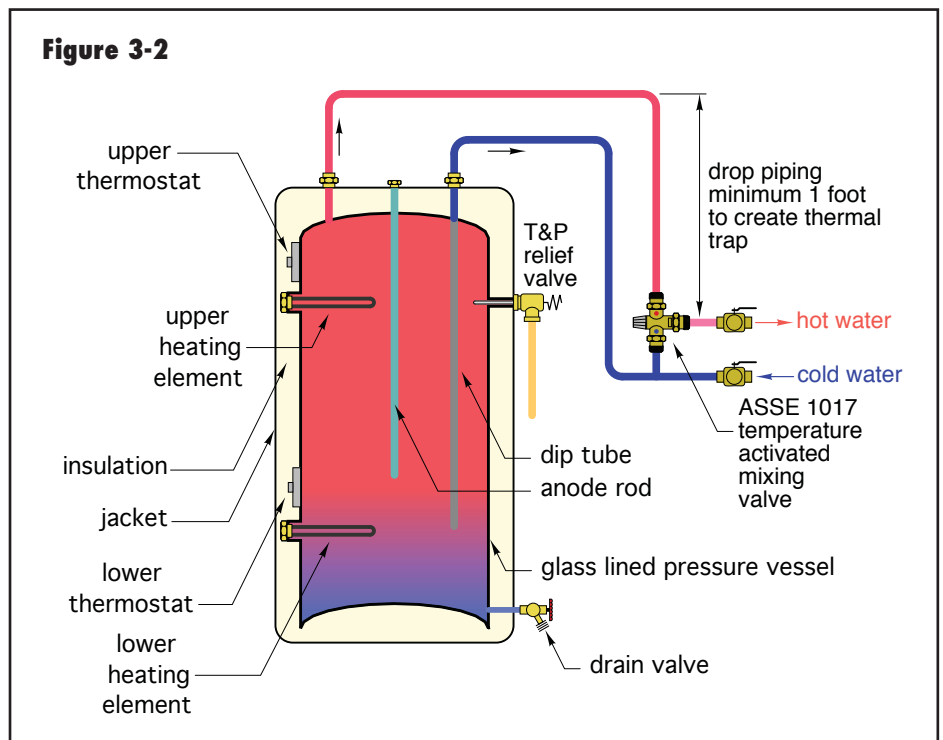
The inner surfaces of the steel pressure vessel are coated with a heat-fused vitreous material often referred to as “glass lining.” Its purpose is to isolate the steel tank surfaces from the corrosive effects of water.

Although this glass lining covers the majority of the inner tank surfaces, there are small areas that may not be coated. To protect these exposed steel areas against corrosion, most tank-type water heaters are supplied with one or more anode rods, which are screwed into ports at the top of the tank. Anode rods are made of either aluminum or magnesium. These metals are less “noble” on the galvanic scale compared to steel. As such, they serve as the preferred corrosion surface (rather than the exposed steel within the tank). Over time, anode rods are consumed or “sacrificed” by this corrosion process and need to be replaced to extend the life of the water heater. Figure 3-3 shows a comparison between a new anode rod and one that has effectively reached the end of its life.

**Figure 3-1**



**Figure 3-2**



**Figure 3-3**



Courtesy of [www.waterheaterrescue.com](http://www.waterheaterrescue.com).

Tank type water heaters also contain a “dip tube.” Its purpose is to deliver cold water near the bottom of the tank, thus preserving temperature stratification within the tank (e.g., hottest water at the top and coldest water at the bottom).

An electric tank-type water heater that is sized to cover all the water heating needs of an average single family home will usually range in size from 30 to 119 gallons. It will have two electric heating elements: One in the lower portion of the tank and the other near the top of the tank. In residential applications, these elements are powered by a 240 VAC circuit and have heating outputs ranging from 3.8 to 6.0 kW (approximately 13,000 to 20,500 Btu/hr).

Under normal operating conditions, the *lower* element provides the heating. It is turned on and off by a line voltage thermostat built into the tank. During periods of high demand, the water temperature near the top of the tank may drop several degrees. When this occurs, the lower heating element is turned off and the upper element is turned on. This concentrates heat input where water is leaving the tank. The objective is to sustain acceptable water temperature to the fixtures during high demand. When demand lessens and the upper tank thermostat is satisfied, the lower element resumes heating under the control of the lower tank thermostat.

Unless the plumbing system is otherwise protected, all tank-type electric water heaters should also be equipped with an ASSE 1017 listed temperature activated mixing valve, as described in Section 2. Such valves contain a thermostatic element that can mix cold water and hot water to prevent the temperature delivered to the hot water distribution piping from exceeding a set limit. For residential applications, the setting on this valve should never exceed 120°F.

In theory, electric water heating is 100% efficient. One kilowatt-hour of electrical energy supplied to a resistance heating element will yield exactly one kilowatt-hour (3413 Btus) of water heating. While this remains true at the element, there are heat losses from any tank-type water heater due to heat transfer through the insulated jacket and attached piping. These losses reduce the “net” efficiency of a tank-type water heater.

**Figure 3-4**



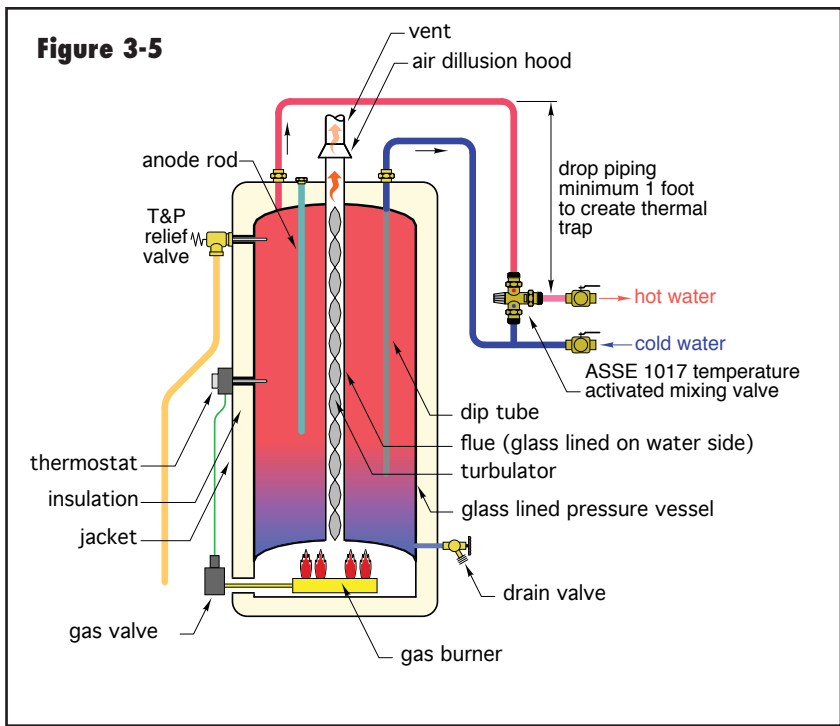
The U.S. Department of Energy (DOE) currently uses a standard for assessing the net efficiency of tank-type electric water heaters with volumes between 20 and 120 gallons. That standard uses the term “energy factor” (abbreviated as EF). EF is the amount of energy delivered from the tank as heated water during a day, divided by the total daily energy consumption of the water heater. Under the current standard, the minimum EF of a tank-type electric water heater is based on its rated volume. A 52-gallon tank would require a minimum EF of 0.94. This means that 94% of the electrical energy used by the element is transferred to the water leaving the heater, and the other 6% is lost through heat transfer from the tank’s jacket. As of this writing, new, more stringent DOE efficiency standards for water heaters are scheduled to take effect in 2015.

### **GAS-FIRED TANK-TYPE WATER HEATERS**

Another very common water heater is a gas-fired tank type unit fueled by either natural gas or propane. The construction of such a unit is shown in Figure 3-5.

Most “atmospheric” water heaters of this type use a glass-lined welded steel pressure vessel with a vertical flue passage between the combustion chamber at the bottom and the vent connector at the top. Air from the surrounding room enters the combustion chamber at the base of the water heater. It mixes with gas supplied to the burner through a gas valve. Ignition is usually provided by a standing pilot light flame.

Hot combustion gases flow upward through the flue by their own buoyancy. A twisted steel strip called a “turbulator” located inside the flue spins these hot gases as they rise. This increases heat transfer through the wall of the flue into the water. At the top of the flue is an air dilution hood that allows air from the surrounding room to mix in with exhaust gases. This helps stabilize combustion against variable draft in the vent. It also reduces the temperature and relative humidity of the exhaust gases before they pass into the vent.



with gas input ratings of 75,000 Btu/hr or less. Due to incomplete combustion and heat loss up the flue, standard gas-fired tank-type water heaters have lower energy factors (EF) compared to electric water heaters. Typical values range from 0.6 to 0.7, depending on insulation and internal design.

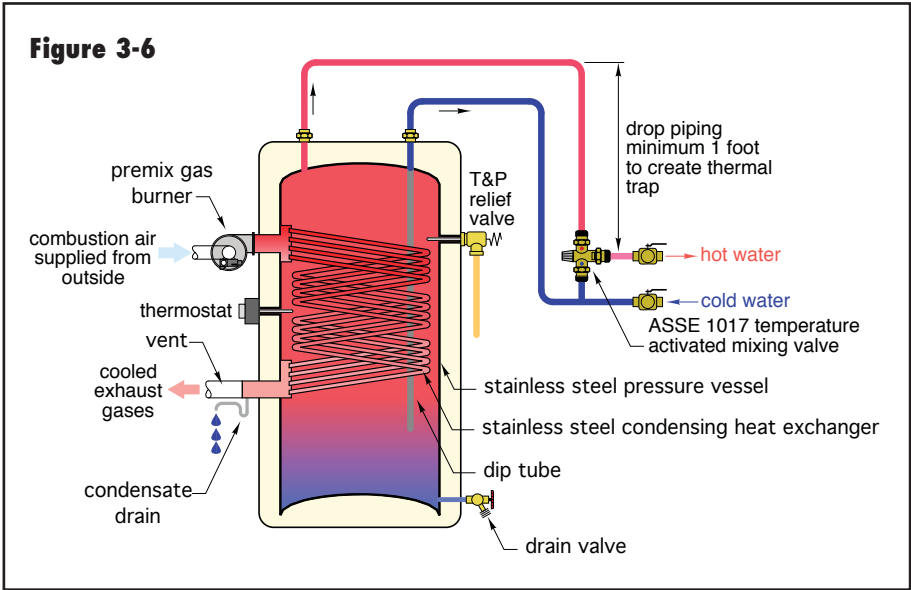
Some gas-fired tank-type water heaters are now available with direct vented/condensing combustions systems, as shown in Figure 3-6. These systems use a sealed combustion system. All air for combustion is drawn to the unit through a PVC tube terminating outside the building. This air is mixed with gas and forced into the combustion chamber by a blower. Combustion is initiated by an electronic ignition system. The hot combustion gases travel through a long, coiled stainless steel heat exchanger suspended within the stainless steel pressure vessel. These gases are eventually cooled below their dewpoint,

Most water heaters of this type use a non-electric thermostat that constantly measures tank temperature and turns the gas valve on and off. These water heaters also have redundant safety devices that can close the gas valve upon a failure of the pilot light or detection of an abnormally high water temperature.

As with electric tank-type units, gas-fired tank-type water heaters are often equipped with sacrificial anode rods to reduce internal corrosion. They also must be equipped with temperature and pressure (T&P) relief valves.

Unless the plumbing system is otherwise protected, all tank-type gas-fired water heaters should also be equipped with an ASSE 1017 listed temperature activated mixing valve, as described in Section 2. This valve contains a thermostatic element that can mix cold water and hot water to prevent the temperature delivered to the hot water distribution piping from exceeding a set limit. For residential applications, the setting on this valve should never exceed 120°F.

Energy factor ratings apply to gas-fired tank-type water heaters with volumes between 20 and 100 gallons, and



and thus liquid condensate is produced. This condensate must be properly drained away from the unit. The relatively cool exhaust stream leaving the unit is routed outside the building through PVC, CPVC, polypropylene or stainless steel vent piping, as required by the tank manufacturer or local codes.

Sealed combustion/condensing water heaters can achieve significantly higher efficiencies in comparison to standard atmospheric gas-fired water heaters. Energy factors of 0.80 to 0.90 are typical. However, these higher

**Figure 3-7**



Source: Bock Water Heaters

efficiency water heaters are also significantly more expensive than standard gas-fired tank-type water heaters.

Oil-fired tank-type water heaters are also available, as seen in Figure 3-7. These water heaters are similar in design to atmospheric gas-fired units, but with larger combustion chambers at the base of the tank. The energy factor of a typical oil-fired water heater is approximately 0.55.

**SIZING TANK-TYPE WATER HEATERS**

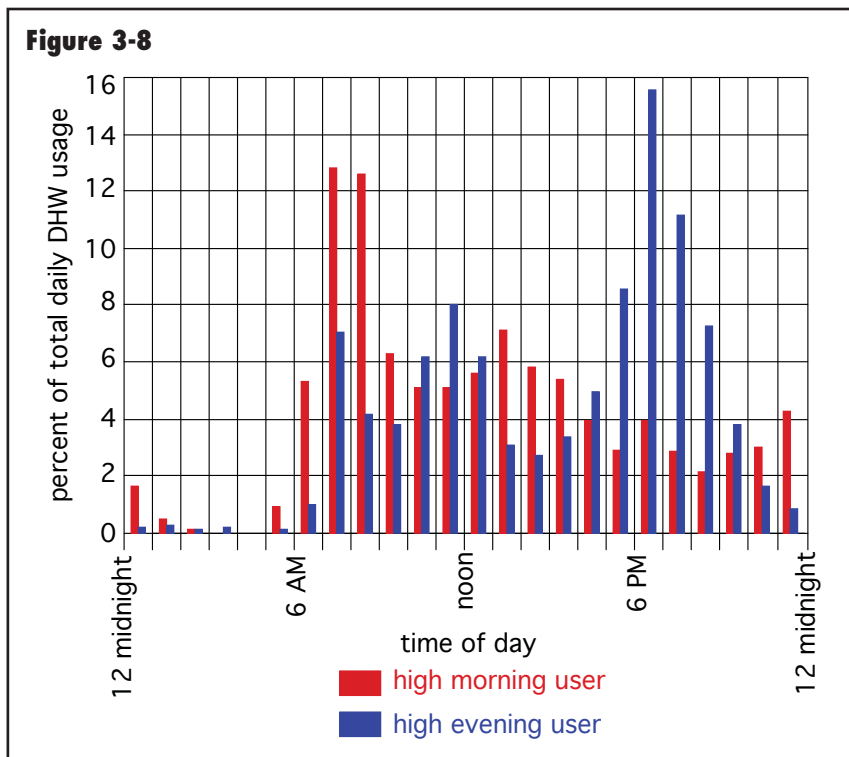
Domestic hot water usage patterns vary greatly from one building to the next. Residential water use patterns are generally characterized by occupants taking baths or showers in combination with typical work or school schedules. Some homes will have peak domestic hot water demand in morning as occupants rise and take showers before departing for the day. Other homes will have higher domestic hot water demands in evenings, especially if luxury tubs

**Figure 3-9a**

USE	AVERAGE GALLON OF HOT WATER PER USE	TIME USED DURING FIRST HOUR	GALLONS USED IN FIRST HOUR
Shower	12	x	=
Bath	9	x	=
Shaving	2	x	=
Hands and face washing	4	x	=
Hair shampoo	4	x	=
Hand dishwashing	4	x	=
Automatic dishwashing	14	x	=
Food preparation	5	x	=
Automatic clothes washer	32	x	=
		TOTAL PEAK HOUR DEMAND	=

are present. Figure 3-8 shows the percentage of total daily domestic hot water demand created in residential buildings for both “high morning users” and “high evening users.”

**Figure 3-8**



Another important rating for storage water heaters is their “first hour rating.” This is the number of gallons of heated water the water heater can supply over one hour, starting from a normal heated standby condition. The rating includes the contribution of storage volume as well as the heating capacity of the burner or element. The gallons of hot water supplied by the burner or heating element is based on a 90°F rise between the cold water inlet temperature and the hot water delivery temperature.

All modern storage-type water heaters with storage volumes over 20 gallons (other than heat pump water heaters) are required to carry a yellow “EnergyGuide” label. This label lists the first hour rating of the water heater.

**Figure 3-9b**

EXAMPLE					
3 showers	12	x	3	=	36
1 shave	2	x	1	=	2
1 shampoo	4	x	1	=	4
1 hand dishwashing	4	x	1	=	4
Peak hour demand				=	46

The first hour rating of the water heater selected for a specific application should equal or slightly exceed the greatest one-hour hot water demand of that application.

This can be estimated by first identifying the hour of probable highest demand for hot water based on expected usage habits. Then use the table in Figure 3-9a to estimate the number of gallons of hot water required during that hour. This table is based on statistics of typical usage as published by the U.S. Department of Energy. If the building has water-conserving shower heads and faucets, usage may be less. Likewise, if the building has high-flow fixtures, usage could be higher. Designers need to evaluate the likely usage of each building based on described usage patterns and owner preferences.

### TANKLESS WATER HEATERS

Most North Americans associate domestic water heating with tank-type appliances that hold heated water that is ready for use. However, there are many water heating devices now available in North America and other parts of the world that do not require storage tanks. Instead, they heat water “instantaneously” as it flows through them and onward to fixtures. Such devices are called by different names, including “tankless water heaters,” “on-demand water heaters” and “instantaneous water heaters.” They are available in both electric and gas-fired models in a wide range of capacities for both residential and commercial applications.

### GAS-FIRED TANKLESS WATER HEATERS

Figure 3-10 shows an example of a gas-fired tankless water heater. Figure 3-11 is a simplified illustration of the internal components in a typical gas-fired tankless water heater.

**Figure 3-10**

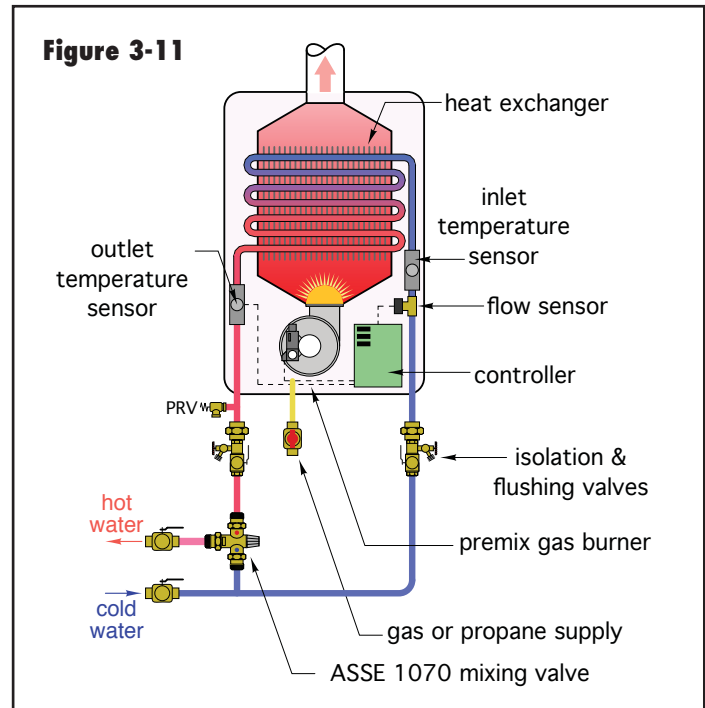


Source: Rinnai

A tankless water heater turns on whenever it detects a preset minimum water flow rate. Most gas-fired tankless water heaters start their burner at flow rates of 0.5 gallons per minute or higher. At that point, a blower forces a mixture of gas and air into the combustion chamber and an electronic ignition system initiates combustion. The combustion chamber and heat exchanger in a tankless water heater contain minimal amounts of metal and water, and thus have very low thermal mass.

Given the relatively high rate of heat generation, the heat exchanger warms quickly. It can usually warm to the point of producing an acceptable domestic hot water delivery temperature within 15 to 30 seconds after turning on.

**Figure 3-11**



The water temperature leaving the heat exchanger is monitored by a sensor. The controller within the water heater uses this temperature information to control the rate of combustion. The faster the water passes through the water heater, the higher the rate of combustion must be to produce the necessary temperature rise.



As is true with tank-type water heaters, all tankless water heaters should be equipped with a temperature activated mixing valve. Its purpose is to protect against scalding water temperatures in the unlikely but possible event of a failure of the temperature controller in the water heater.

All tankless water heaters must be equipped with a pressure relief valve (PRV) in accordance with ANSI or CSA standards. Some plumbing codes may instead require a combination temperature and pressure (T&P) relief valve. Its pressure rating cannot be higher than 150 psi, and its thermal rating must equal or exceed the maximum heat production rating of the water heater. The discharge port of the PRV should be routed as directly as possible to within 6 inches of the floor, preferably over a drain. There can be no valves in the discharge pipe or between the PRV and the water heater. The PRV should be manually operated at least once each year to ensure that it hasn't seized.

The maximum flow rate at which any gas-fired tankless water heater can supply hot water depends on its maximum rate of combustion, the efficiency of that combustion process, and the required temperature rise between the entering water temperature and set leaving water temperature.

Formula 2-1 can be used to estimate the maximum flow rate supplied by a gas-fired tankless water heater based on these conditions.

Formula 3-1

$$f = \frac{Q \times n}{500 \times (\Delta T)}$$

Where:

f = maximum hot water flow rate (gpm)

Q = gas input rate to water heater (Btu/hr)

n = combustion efficiency of water heater (decimal %)

ΔT = temperature rise of water through water heater (°F)

For example: Determine the maximum hot water flow rate that can be supplied from a gas-fired tankless water heater having a gas input rate of 150,000 Btu/hr, a combustion efficiency of 90%, while heating water from 45°F to 120°F.

Solution:

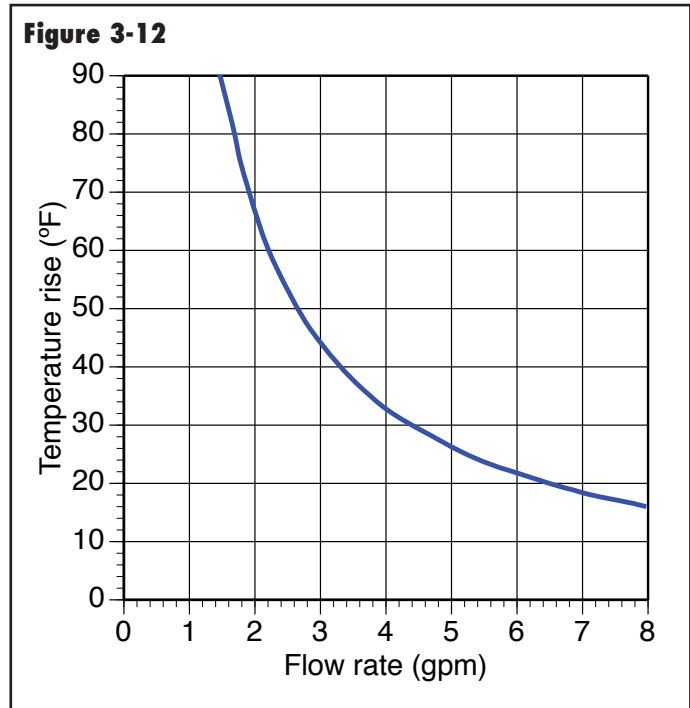
$$f = \frac{Q \times n}{500 \times (\Delta T)} = \frac{150,000 \times 0.9}{500 \times (120 - 45)} = 3.6 \text{ gpm}$$

Keep in mind that this is the *maximum* flow rate under the specified conditions. If the required temperature rise is less, the maximum flow rate increases, and vice versa.

If the flow rate through the heater is less, the burner will reduce the rate of combustion in an attempt to keep the

leaving water temperature at, or close to, the setpoint temperature. Many current generation gas-fired tankless water heaters can reduce heat output to 10% to 20% of their maximum rated output.

Manufacturers typically provide graphs showing the relationship between flow rate and required temperature rise. Figure 3-12 is a representative example for a heater with a gas input rating of 150,000 Btu/hr.



### TANKLESS HEATERS AND PREHEATED WATER

One increasingly common application for tankless water heaters is as an “auxiliary” heater for a solar water heating system. When necessary, the tankless heater is intended to boost the temperature of water that has been preheated by a solar heating system.

One issue that arises in this situation is the ability of the tankless heater to work with water that is already preheated to a temperature close to the setpoint delivery temperature. An example would be 115°F water being delivered to a tankless heater that is set to deliver 120°F water.

The controls in some tankless heaters constantly monitor the flow rate and inlet water temperature, and then use this information along with the unit’s setpoint temperature to determine the thermal load on the heater, and compare it to the heater’s minimum heat transfer rate. If the thermal load is less than the minimum heat transfer rate, the burner will not fire.

Formula 3-2a can be used to determine the thermal load on the unit. Formula 3-2b determines the minimum heat transfer rate of the burner/heat exchanger in the tankless heater.

Formula 3-2a:

$$Q_{thermal} = 500 \times f \times (T_{setpoint} - T_{in})$$

Formula 3-2b:

$$Q_{HT\ min} = Q_{gas} \times n$$

Where:

$Q_{thermal}$  = current thermal load on heater (Btu/hr)

$f$  = flow rate through heater (gpm)

$T_{setpoint}$  = desired water outlet temperature leaving heater (°F)

$T_{in}$  = water inlet temperature to heater (°F)

$Q_{HT\ min}$  = minimum rate of heat transfer to water (Btu/hr)

$Q_{gas}$  = minimum gas input rate to burner (Btu/hr)

$n$  = combustion efficiency of burner/heat exchanger (decimal %)

Once the thermal load is determined, the controller in the tankless water heater uses the following logic:

IF  $Q_{thermal} < Q_{HT\ min}$  THEN burner doesn't fire

For example: Assume the minimum gas input to a tankless heater is 10,000 Btu/hr, and the combustion efficiency is 90%. Solar preheated water enters the unit at 110°F and 0.8 gpm. The setpoint of the heater is 120°F. If the controller in the unit operates as described above, will the burner fire under the stated conditions?

To answer this, it's necessary to determine the thermal load on the unit using Formula 3-2a and 3-2b.

Formula 3-2a

$$Q_{thermal} = 500 \times 0.8 \times (120 - 110) = 4000 \text{ Btu / hr}$$

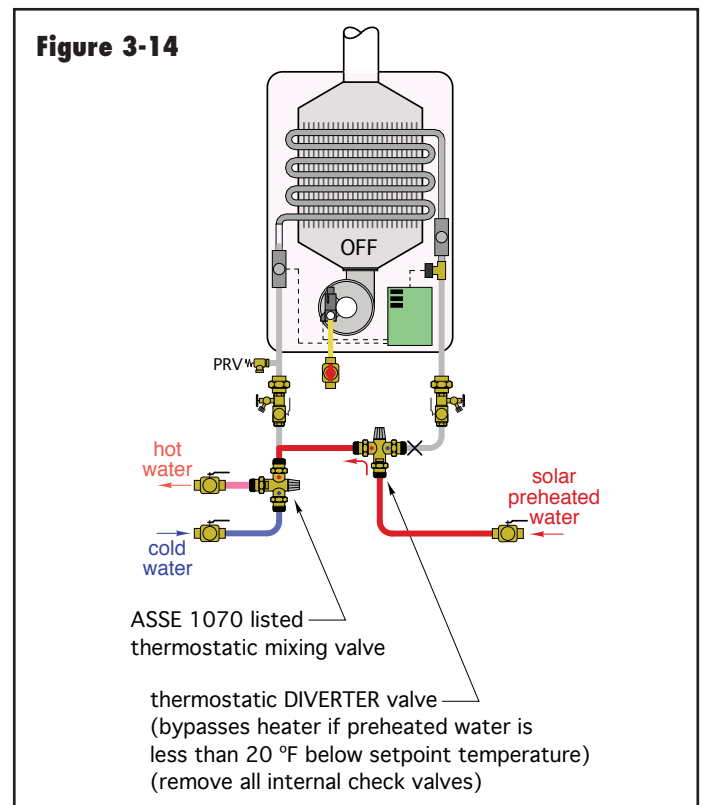
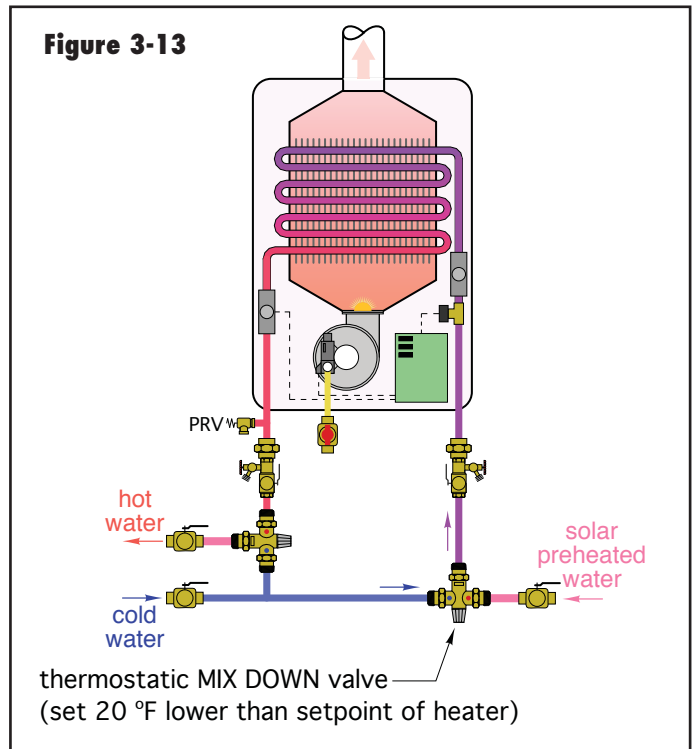
Formula 3-2b:

$$Q_{HT\ min} = 10,000 \times 0.90 = 9,000 \text{ Btu / hr}$$

Because the current thermal load on the heater ( $Q_{thermal}$ ) is well below the unit's minimum rate of heat transfer ( $Q_{HT\ min}$ ), the controller will not fire the burner.

One remedy for the above situation is to blend cold water into the preheated water so that the temperature of the water entering the tankless heater is low enough

to allow proper operation. This is called "mix down" and is illustrated in Figure 3-13. A common suggestion is to have the maximum entering water temperature at least 20°F lower than the heater's setpoint temperature.

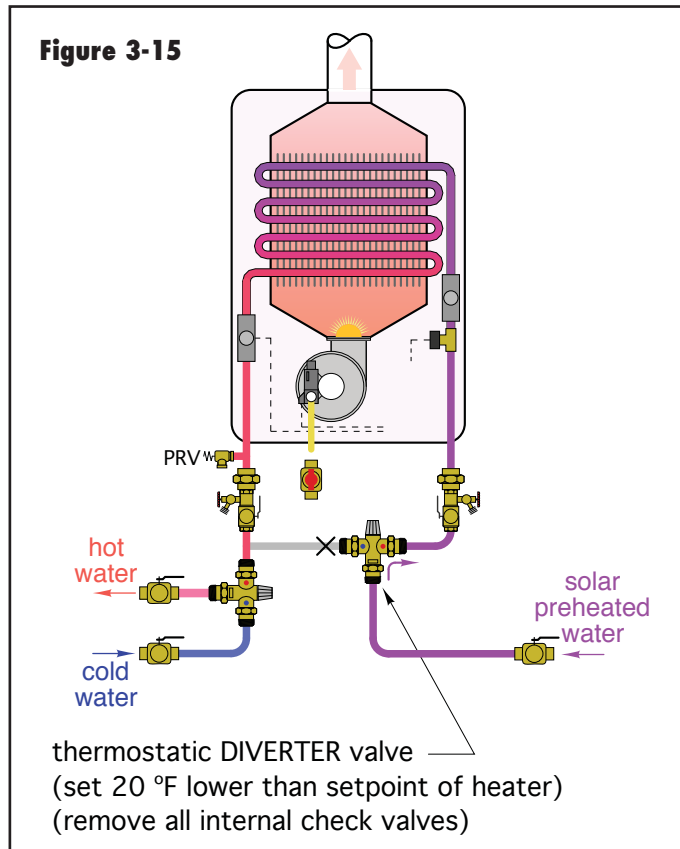


Although mix down stabilizes operation of the gas-fired tankless heater, it also creates the *undesirable* condition of lowering the “net” preheating effect supplied by the solar subsystem. For example: Assume the setpoint of the tankless heater is 120°F. Solar preheated water arriving at the tankless heater at 110°F would have to be mixed down to 100°F before entering the heater. Assuming a desired delivery temperature of 120°F and a cold water temperature of 50°F, this 10°F mix down decreases the solar supplied portion of the water heating load from 86% to 71%.

Another option is to *divert* preheated water around the water heater if its temperature is less the 20°F below the heater’s setpoint. This also requires a second temperature activated mixing valve, but that valve is now set up to *divert* rather than *mix*. The placement of this diverting valve is shown in Figure 3-14.

Figure 3-14 shows the valve diverting hot solar heated water around the tankless water heater. After passing through the diverter valve, the high-temperature water enters the hot port of the temperature activated mixing valve, where it is blended with cold water to achieve a safe delivery temperature to the fixtures.

Figure 3-15 shows a situation where the temperature of the preheated water is 20°F or more *lower* than the



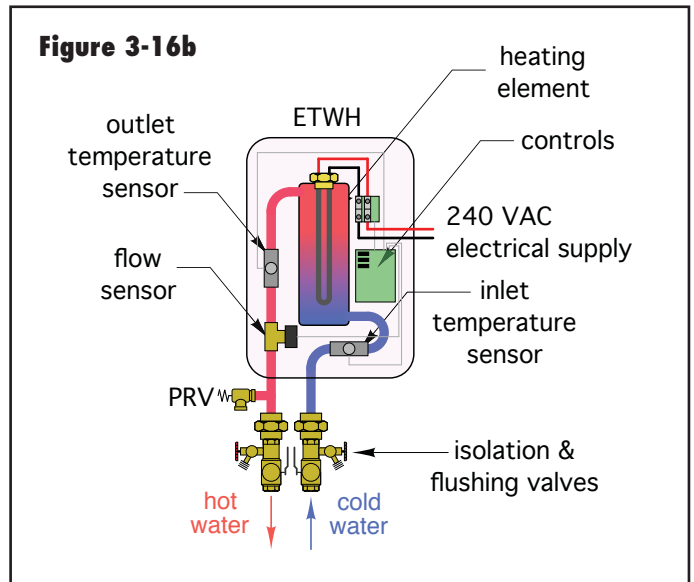
**Figure 3-16a**



Photo courtesy of Eemax

setpoint of the tankless heater. Under this condition, the preheated water is diverted through the tankless heater. Upon leaving the heater, the hot water also passes through the temperature activated mixing valve, which ensures a safe delivery temperature to the fixtures.

To ensure that delivery temperature is acceptable during the bypass mode, the diverter valve temperature should be set equal to the desired delivery temperature, and the setpoint of the tankless heater should be set at least 20°F *higher* than the desired delivery temperature.



It is also possible to use a motorized diverter valve and associated electronic temperature control to operate the system as described. Be sure that any valve used for this application is rated for use with domestic water and has the appropriate listings required by local codes.

### ELECTRIC TANKLESS WATER HEATERS

The versatility of electric heating has been applied to tankless water heaters, which have been available in North America for several decades. Electric tankless water heaters are available as both *centralized* water heaters to serve an entire building and as “point-of-use”

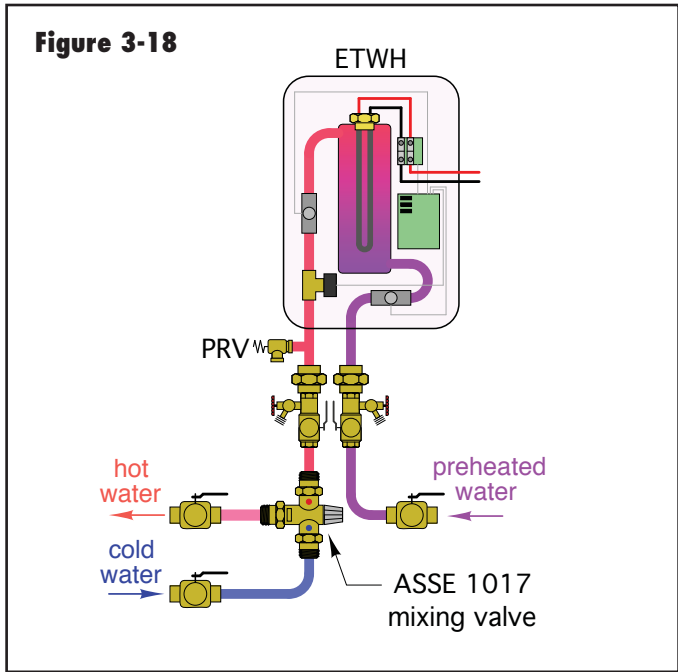
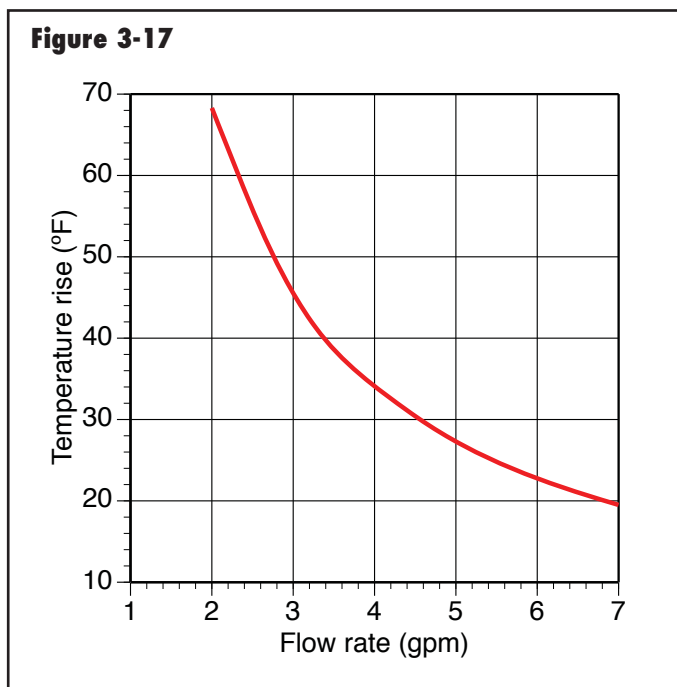
heaters to serve a single fixture. An example of the latter is shown in Figures 3-16a and 3-16b.

An electric tankless water heater has one or more resistance heating elements housed in a pressure-tight chamber through which water flows. Like a gas-fired tankless heater, heating is initiated by detecting flow. Minimum flow rates of 0.4 to 0.5 gpm are typical.

Some electric tankless water heaters are “on/off” devices. They only monitor flow rate, and they turn on all of their heating capacity whenever the flow rate exceeds a preset threshold. Other electric tankless water heaters are thermostatically controlled, with delivered water temperature accuracies of +/-1°F. Thermostatically controlled units monitor flow rate, incoming temperature and leaving water temperature. They use this information to vary the input power to the heating elements. Thus, as flow through the unit increases, so does power input in an attempt to keep the outlet temperature very close to the setpoint. Thermostatically controlled electric tankless water heaters are preferred in any situation where the incoming water temperature varies, such as in a solar preheating application.

Figure 3-17 shows a typical relationship between maximum temperature rise versus flow rate for an electric tankless water heater with a maximum rated input of 20 kW (68,260 Btu).

Notice how the maximum temperature rise decreases as flow through the heater increases. Thus, at a flow rate of



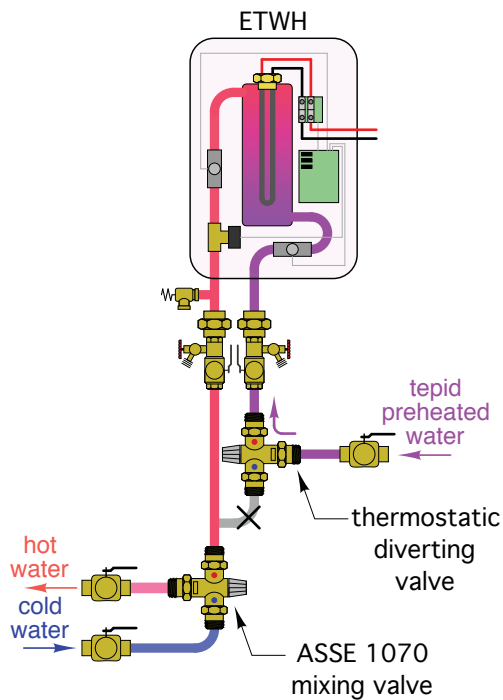
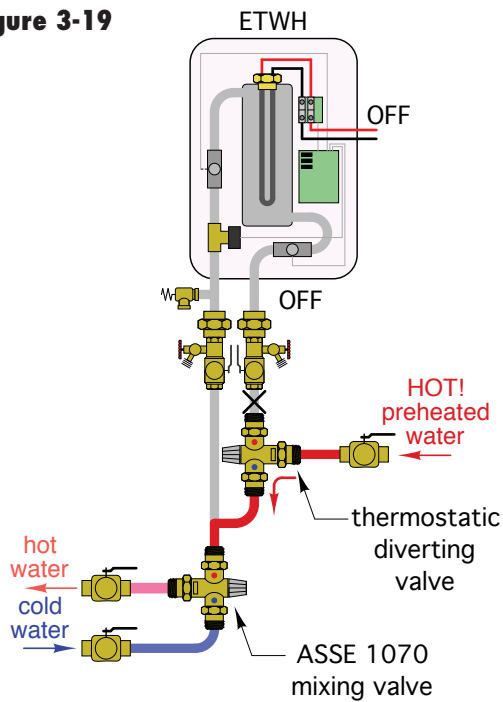
2 gpm, this unit can warm 50°F incoming water to about  $(50 + 68) = 118°F$ . This temperature rise would require full 20 kW input power. If the unit had a setpoint of 120°F, the water would not quite make it to setpoint. However, if the setpoint was 110°F, the unit would reduce its power input slightly and still be able to achieve this setpoint. At a flow rate of 4 gpm and full input power, this unit could raise 50°F inlet water to  $(50 + 34) = 84°F$ . Although this might be acceptable for hand washing, it would not be acceptable for showers or baths. In this case, a unit with a higher wattage rating would be required to achieve the desired setpoint temperatures at a flow rate of 4 gpm.

One beneficial characteristic of *thermostatically controlled* electric tankless water heaters is their ability to accept preheated water without temperature limitations. This is due to the ability to reduce electrical input power essentially down to zero as conditions warrant. Thus, a heater with a setpoint of 120°F could accept preheated water at 119°F and add a very small heat input to boost the outlet temperature to 120°F.

If preheated water enters at temperatures above the setpoint, the heat element in a thermostatically controlled electric tankless water heater does not turn on, and the water simply passes through the unit and on to the fixtures.

If preheated water at temperatures above the setpoint are expected, such as from solar or wood-fired subsystems, the outlet of the electric tankless water heater should be protected with an ASSE 1070 listed temperature activated mixing valve, as shown in Figure 3-18.

**Figure 3-19**

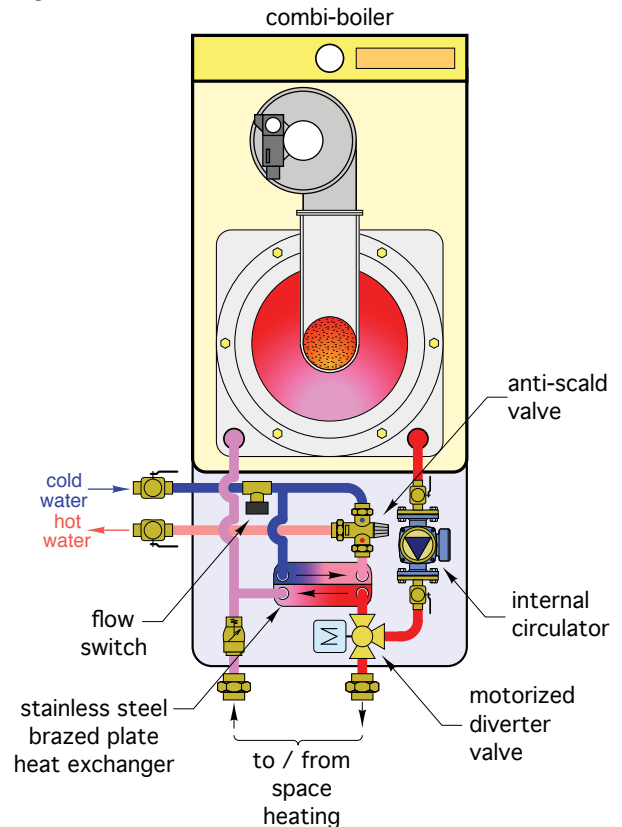


Another option in situations where preheated water is supplied to the electric tankless water heater is to install a second temperature activated mixing valve as a *diverter* valve. This option is illustrated in Figure 3-19.

This approach is appropriate for non-thermostatically controlled tankless heaters.

When planning for an electric tankless water heater, it's crucial to verify that the building's electrical service entrance has sufficient capacity to handle the load. Smaller point-of-use (POU) electric tankless water heaters typically have input power requirements of 8 to 12 kW and a 240 VAC voltage requirement. These units require double-pole circuit breakers with ampacities of 40 to 60 amps. Larger (centralized) electric tankless water heaters can have input power requirements up to 36 kW. Such units can require up to *three* separate 60 amp/240 VAC circuits. Be sure the amperage rating of the service entrance and breaker panel can accommodate the necessary circuit breakers and amperage requirements based on the National Electrical Code. Some electric tankless water heaters are now available with load shedding logic that can intelligently and temporarily turn off other high demand electrical loads during times when there is a sustained demand for hot water. This allows the tankless heaters to be used in situations that otherwise would require an upgraded electrical service entrance.

**Figure 3-20**



## COMBI-BOILERS

Several manufacturers have developed products that combine the functionality of a space heating boiler and an instantaneous domestic water heater. One common approach is to add a stainless steel heat exchanger, along with a motorized diverter valve and flow switch, to a modulating/condensing boiler. This concept is illustrated in Figure 3-20.

When the flow switch detects a demand for domestic hot water, the boiler fires, the internal circulator turns on and the motorized diverter valve directs flow from the boiler's main heat exchanger through the primary side of the brazed plate heat exchanger. Depending on the recent operating history of the boiler, it may take up to 30 seconds for the combustion chamber and the water between the two heat exchangers to warm to the point of supplying the desired hot water temperature.

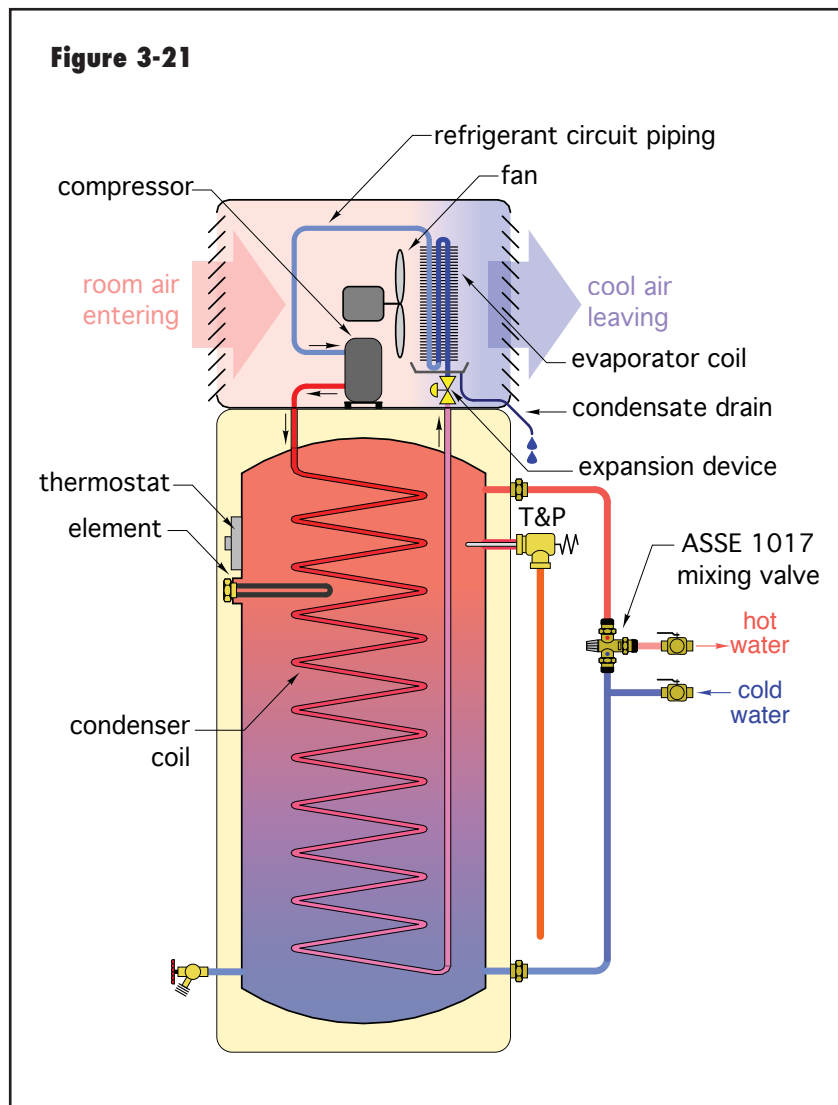
All flow to space heating is suspended while the combi-boiler produces domestic hot water. This allows the full output of the burner to be used for maximum domestic water heating capacity.

## HEAT PUMP WATER HEATERS

Domestic water can also be heated using a dedicated heat pump. All heat pumps are devices for gathering "free" heat from lower temperature sources such as air, ground water or soil, and raising the temperature of that heat to useful levels. Most heat pumps used for domestic water heating are electrically driven. They use a standard refrigeration cycle.

## UNITARY HEAT PUMP WATER HEATERS

One of the newest devices for residential and light commercial water heating is a "heat pump water heater." It consists of a small refrigeration system integrated with an insulated domestic water storage tank, as illustrated in Figure 3-21.



Like any heat pump, this unit uses the four essential components of a refrigeration cycle: The evaporator, compressor, condenser and expansion device. Low-temperature heat is absorbed from room air being circulated through the upper portion of the unit by a fan. The air stream moves across an air-to-refrigerant heat exchanger coil that functions as the evaporator. Low temperature liquid refrigerant within the evaporator absorbs heat from the passing air, which causes the refrigerant to evaporate. The cooled air then exits back to the room at a lower temperature, and often at a reduced humidity.

The refrigerant gas containing the absorbed heat passes to the compressor, where its temperature and pressure are significantly increased. The hot refrigerant gas then passes into a coil of copper tubing suspended within the storage tank. This coil serves as the condenser, rejecting heat from the refrigerant into the domestic water. As the refrigerant cools, it condenses back into a liquid.

Finally, the lower temperature liquid refrigerant passes through a thermal expansion device, where its pressure and temperature are lowered back to the conditions at which we began describing this cycle. The refrigerant now enters the evaporator to repeat the cycle.

Some heat pump water heaters also have an electric heating element that can either supplement heat input to the water during periods of high demand, or operate in place of the refrigerant cycle if that portion of the appliance is not operating properly.

Many modern heat pump water heaters have electronic controls that can be used to create setback periods, temperature boosting periods, supplemental heat input conditions and other operating modes.

Heat pump water heaters operate on significantly lower input power relative to standard electric resistance water heaters. Their Energy Factor (EF) rating is typically around 2.5, whereas a typical electric resistance water heater has an EF rating of 0.9 to 0.95. Heat pump water heaters also have first hour ratings that can be compared to other types of water heaters.

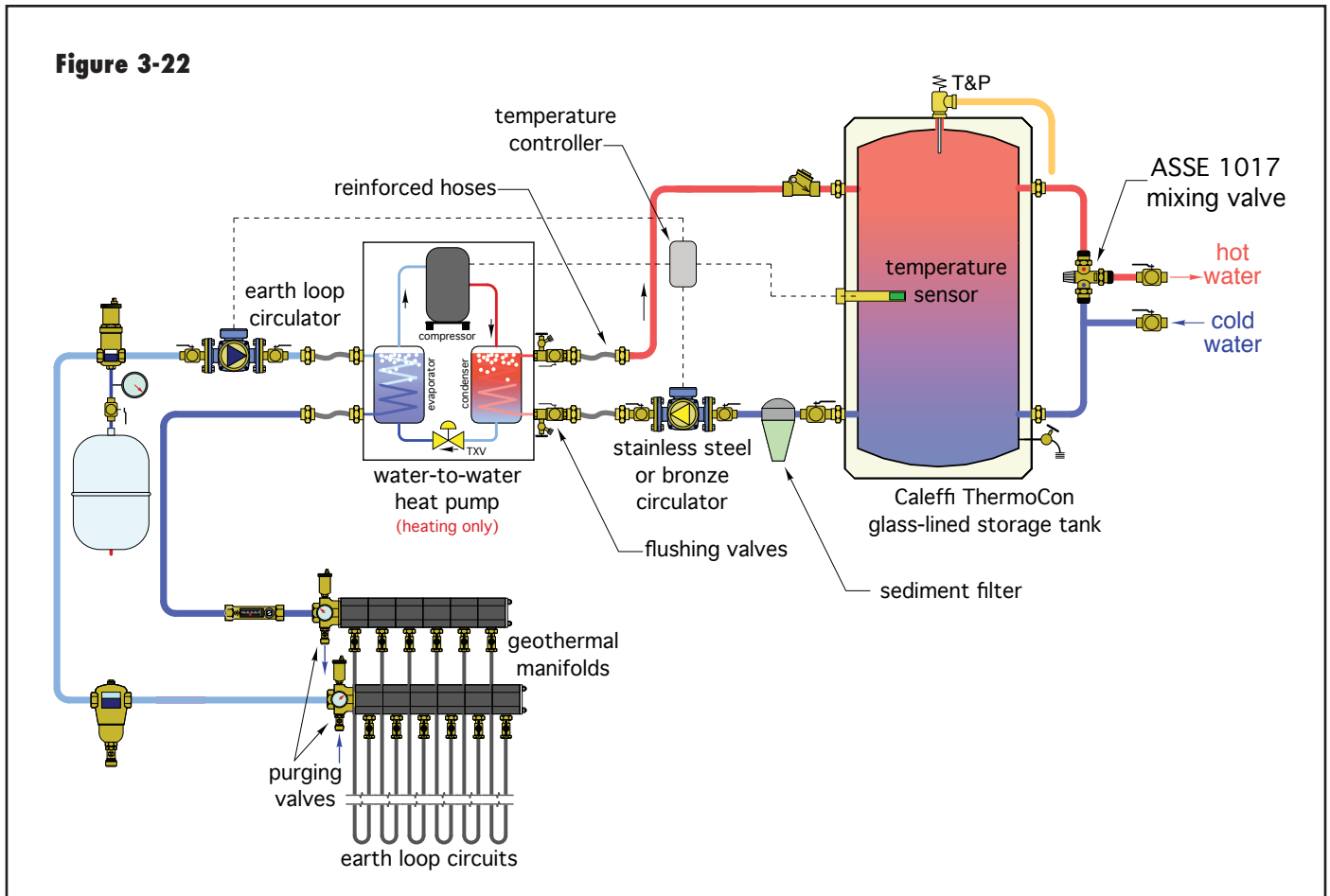
It's important to understand that this type of heat pump water heater decreases the air temperature and humidity of the space where it's located. This can be either beneficial or undesirable. If the heat pump is in a space

that is frequently too warm for normal comfort, such as a garage in a southern home, its operation will create more favorable conditions in that space. However, if the heat pump water heater is in a room such as a basement recreation room or workshop, its operation may cause the air temperature to be too low for human comfort.

Heat pump water heaters also cause moisture in the air to condense on the evaporator coil. Under certain conditions, this condensate will drip off the evaporator coil and collect in a drip pan beneath it. A drainage tube must be installed to route this condensate to a suitable drain or condensate pump station.

### GROUND SOURCE HEAT PUMPS DEDICATED TO DHW PRODUCTION

In some cases, the required domestic water heating capacity exceeds that available from unitary heat pump water heaters. One available option is use of a "heating only" water-to-water heat pump, supplied from an earth loop and connected to a storage tank, as shown in Figure 3-22.



The configuration requires a heat pump that is rated to operate with potable water within its condenser. Not all water-to-water heat pumps, even those with copper condensers, have the necessary agency listings for this application. The condenser in such a heat pump will generally be constructed of copper, cupronickel or stainless steel. The storage tank and circulator between this tank and the heat pump must also be rated for direct contact with domestic water.

It is good practice to equip the condenser connections on the heat pump with flushing/isolation valves that can be used to flush the water side of the heat pump's condenser, if and when necessary. A sediment filter on the lower piping leading from the storage tank to the heat pump is also good practice to minimize deposits within either the circulator or the condenser.

Most currently available heat pumps used for dedicated domestic water heating will have an upper temperature limit of 120° to 130°F.

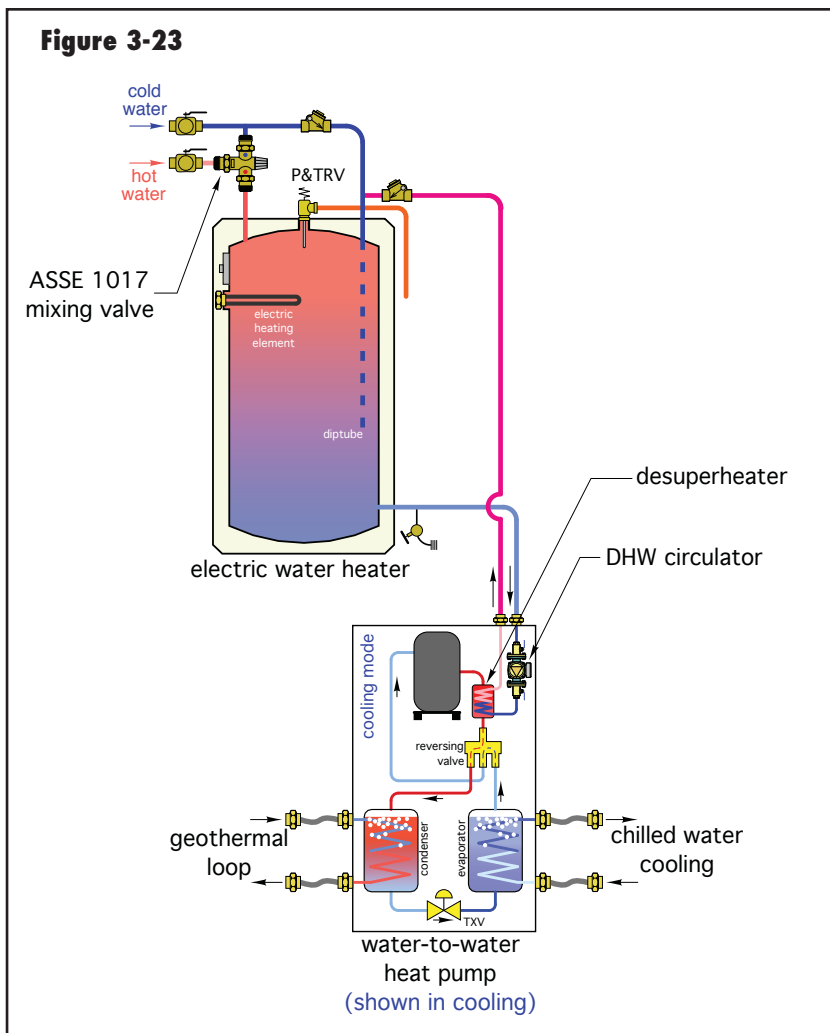
## DESUPERHEATERS

Some water-to-water and water-to-air heat pumps used in geothermal heating/cooling systems are equipped with desuperheaters. A desuperheater is a refrigerant-to-water heat exchanger that receives the highest temperature refrigerant gas directly from the compressor. Some of the heat in this hot refrigerant is transferred to a stream of domestic water circulated through the other side of the heat exchanger, as shown in Figure 3-23.

Heat pumps equipped with desuperheaters allow a portion of the heating output to be used for domestic water preheating, rather than space heating. This is beneficial because domestic water preheating is achieved at the higher coefficient of performance of the heat pump, compared to a COP of 1.0 when using an electric heating element.

When the heat pump is operating in the cooling mode, *all* heat extracted by the desuperheaters would otherwise be dissipated as “waste heat” to the earth loop. Thus, any domestic water preheating effect achieved through the desuperheater in this mode is truly “free heat.”

For more detailed information on geothermal heat pump systems, see *idronics* 9.

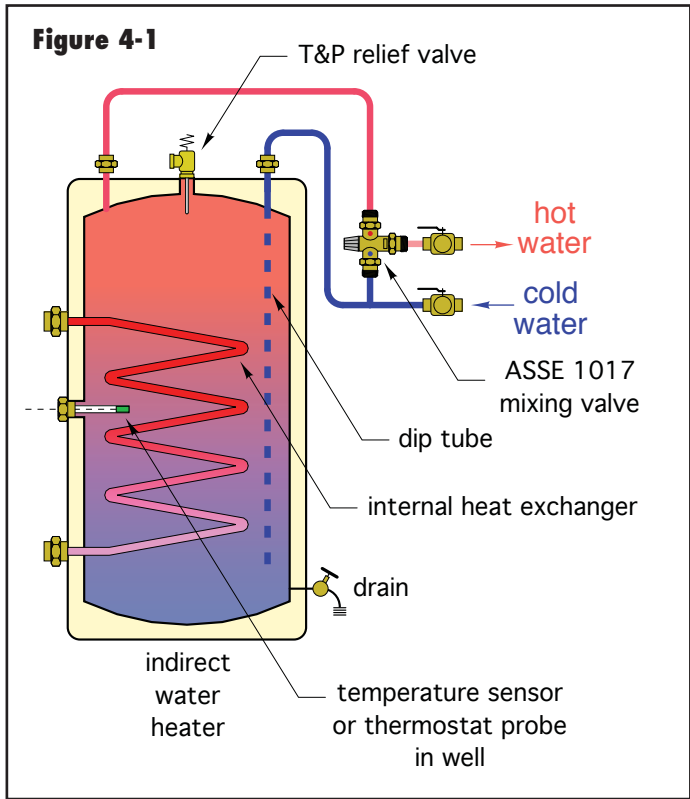


## 4. HYDRONIC-BASED INDIRECT WATER HEATERS

Hydronic heating systems are often configured so that the heat source that provides space heating also provides heat for domestic hot water. There are several ways to do this, depending on the nature of the domestic water heating load and the heat source supplying it.

One of the most common modern approaches uses an indirectly fired storage water heater. Such a unit consists of an insulated storage tank equipped with an internal heat exchanger to transfer heat from a stream of hot water into domestic water. In most indirect water heaters, hot water from the heat source flows through the heat exchanger, while the potable water is held within the tank, as shown in Figure 4-1. In some units, the inner walls of the

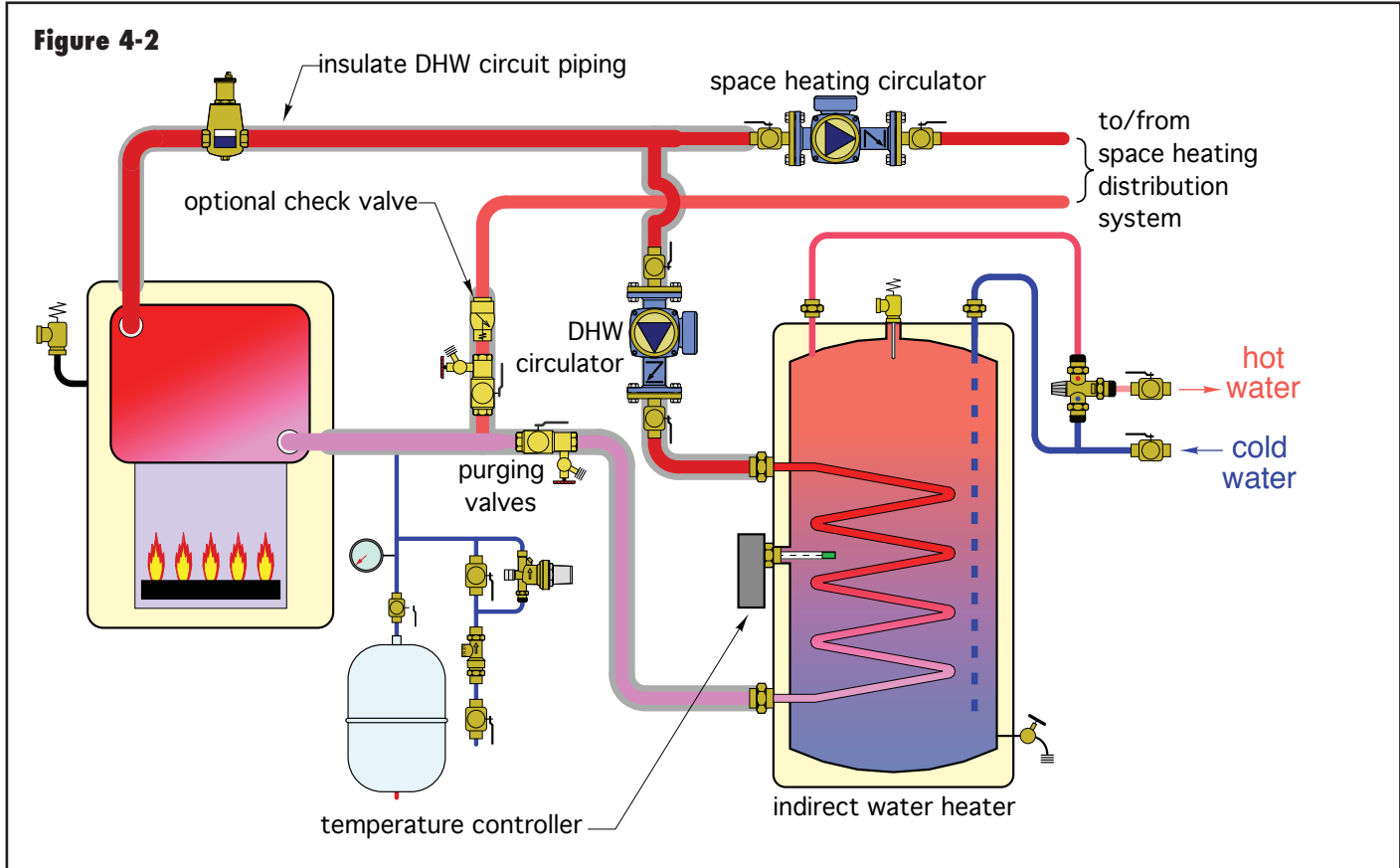




tank are glass-lined. In others, the tank is made of stainless steel. Multiple connections are provided for piping to the heat exchanger, domestic water piping, a T&P relief valve, temperature sensor well, drain valve, and in some tanks, an anode rod.

Figure 4-2 shows a common way to pipe an indirect water heater to a conventional boiler.

In this system, flow through the heat exchanger of the indirect water heater is controlled by a separate circulator. This circulator and the boiler are turned on when the controller monitoring the tank's water temperature calls for heat. Hot water from the boiler enters the top connection of the internal heat exchanger, passes through it and returns to the boiler, giving up heat in the process. The flow direction through the coil is important. A downward flow through the coil is opposite from the upward internal flow of domestic water near the coil. The latter flow is the result of natural convection heat transfer from the coil surface to the domestic water. Opposite flow directions create "counterflow" heat exchange, which increases the rate of heat transfer relative to situations where both flows are in the same direction.



Both circulators in Figure 4-2 are equipped with internal check valves to prevent reverse flow through inactive portions of the system. The check valve in the tank circulator also helps prevent thermosyphoning between the tank and cooler external piping. A third spring-loaded check valve is shown on the return piping from the space heating subsystem, before it joins the return header. This check valve reduces undesirable heat migration to the space heating piping during times when no space heating is needed, but water heating is active.

When piping an indirect water heater, the objective is always to get heat from the boiler(s) into the water heater with minimal losses in between. Whenever possible, an indirect water heater should be *located close to the boiler* to minimize heat loss through interconnecting piping. The piping between the boiler and tank should also be insulated. Remember, hot water will likely be flowing through this piping on the hottest days of summer. The heat loss from uninsulated piping only adds to the building's cooling load.

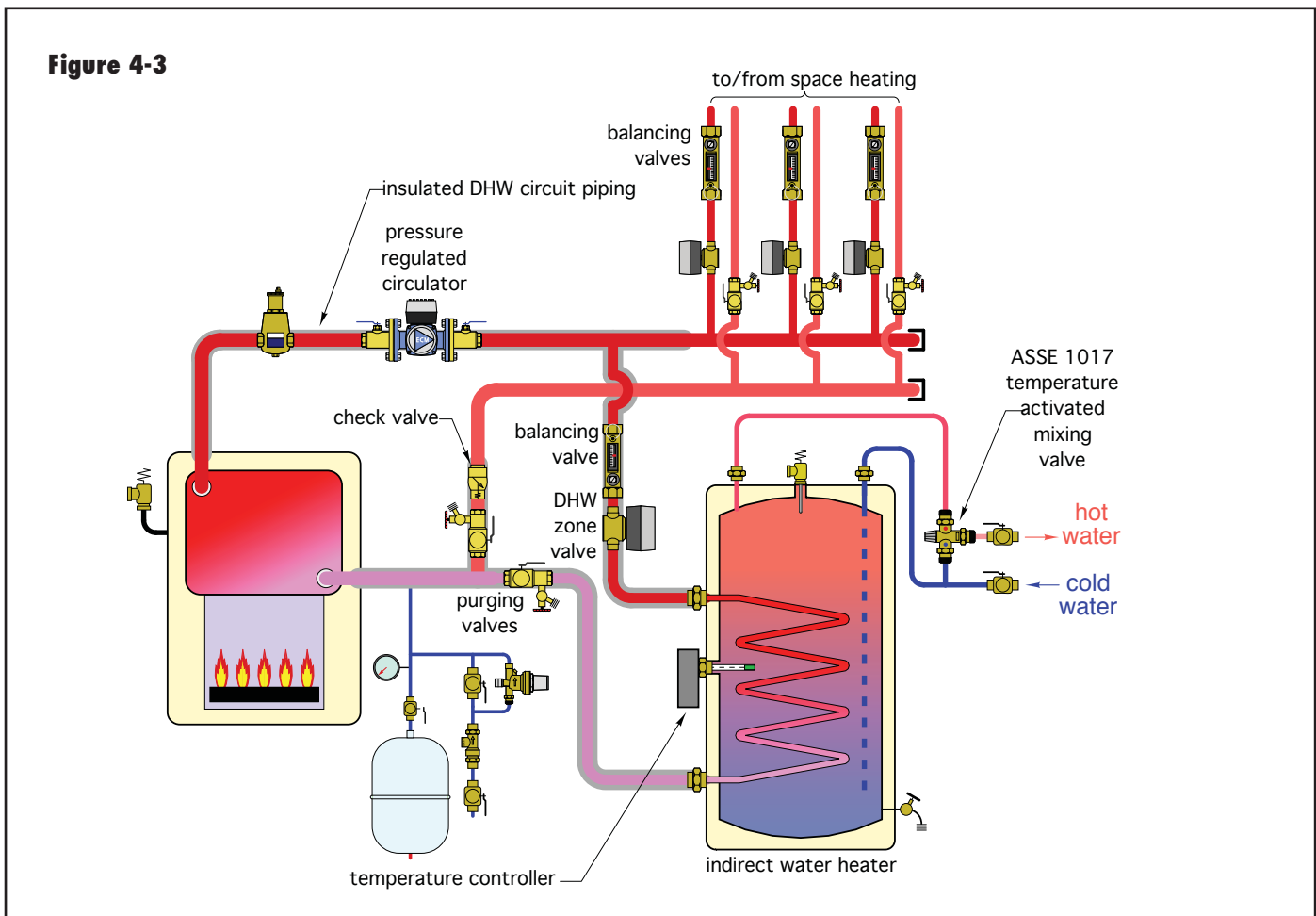
The flow resistance of the "common piping," which

includes the boiler and headers, should be kept as low as possible. This provides hydraulic separation between the two circulators, which minimizes interference and variations in circuit flow.

The domestic water piping of the indirect tank is very similar to the previously discussed direct-fired storage water heaters. Unless point-of-use mixing valves are used, an ASSE 1017 temperature activated mixing valve should always be provided adjacent to the tank to protect against potentially overheated water delivery to fixtures. A temperature and pressure relief valve is also required on all indirect water heaters.

It is also possible to control flow through the heat exchanger of an indirect water heater using a zone valve, as shown in Figure 4-3.

This system uses a pressure regulated circulator to maintain a constant differential pressure across the supply and return headers, regardless of which zone valves are open. A combination balancing/isolation valve is installed in the circuit supplying the indirect



heater. It is used to set the desired flow rate through this circuit. Balancing valves are also installed in each of the space heating zone circuits. Note: The flow resistance of the “common piping,” which includes the boiler and headers, should be kept as low as possible to minimize flow rate variations as different zone circuits turn on and off.

### OTHER CONFIGURATIONS FOR INDIRECT WATER HEATERS

Another type of indirect water heater uses a “tank-

within-a-tank” configuration, as seen in Figure 4-4. The inner stainless steel tank contains domestic water and is suspended within the outer carbon steel tank. Hot water circulated through the space between these tanks heats the domestic water. This “system water” can be heated with a boiler or other heat source, such as solar collectors, a heat pump or a wood-fired boiler. Some tanks of this type are provided with extra connections that allow the tank to serve as a buffering thermal mass for a highly zoned space heating system.

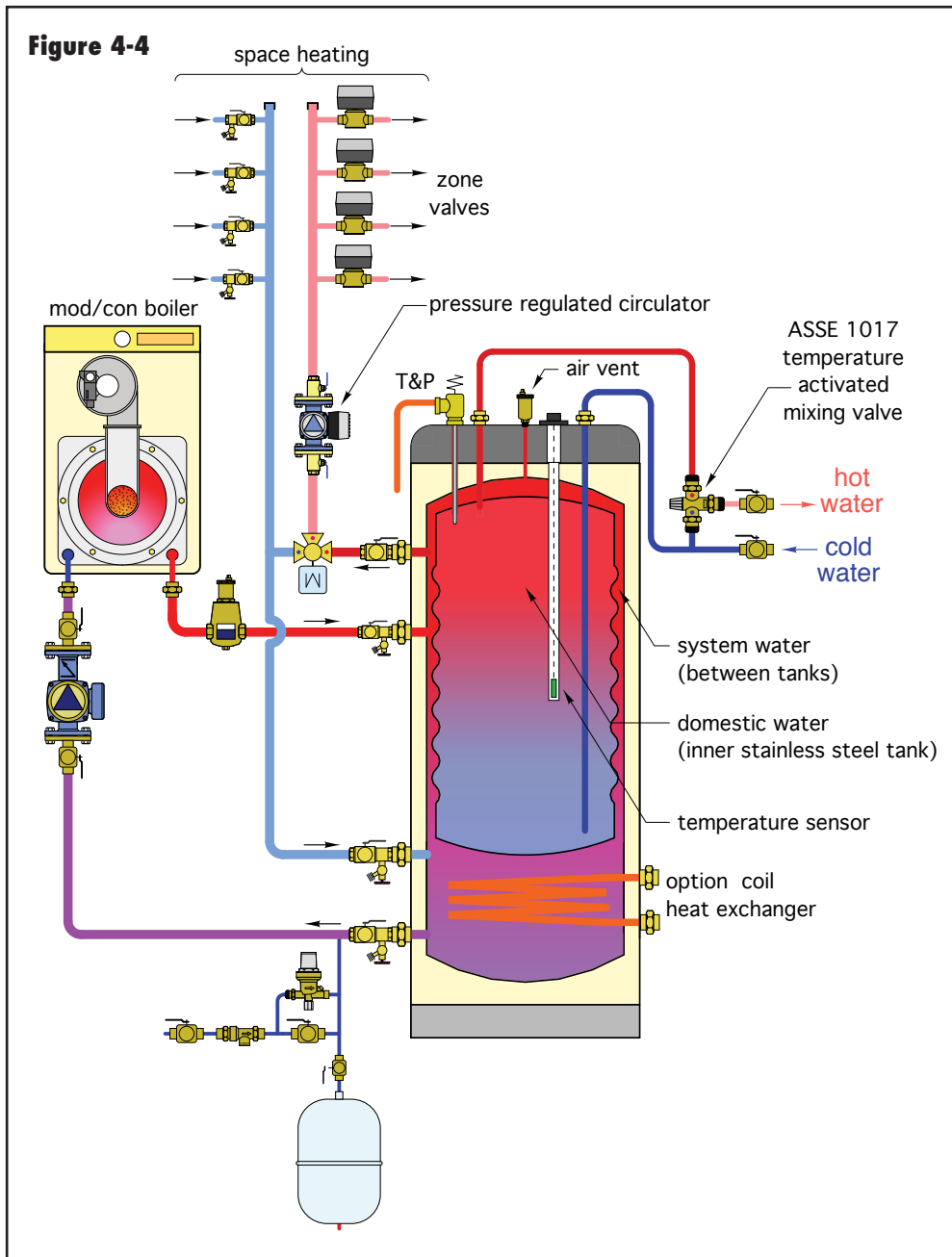
The low internal flow velocity in the space between the inner and outer tanks provides hydraulic separation between circulators in piping circuits connected to this tank.

Another variation on indirect water heaters is known as a “reverse” indirect tank. The pressure vessel is constructed of carbon steel and contains “system water” as part of a closed-loop heating circuit. Domestic water is contained in multiple copper coils that are suspended within the pressure vessel. Cold domestic water enters near the bottom of the tank and is divided among the internal coils by a header. As the water passes upward through the copper coils, it absorbs heat from the system water. The heated domestic water is then collected by an upper header and flows on to the fixtures.

### PERFORMANCE OF INDIRECT WATER HEATERS

Most indirect water heaters sold in North America have first hour ratings based on specific heat input capacities, heat exchanger supply temperatures, heat exchanger flow rate and rate of heat input from the heat source.

It is common to see first hour ratings for heat exchanger inlet temperatures of both 180°F



and 200°F. These are also paired with leaving domestic hot water temperatures of 115°F and 140°F. For example: One 80-gallon indirect water heater has the following first hour ratings in gallons per hour (gph):

- 180°F coil inlet/12 gpm coil flow/115°F domestic outlet: 1<sup>st</sup> hr rating =440 gph
- 180°F coil inlet/12 gpm coil flow/140°F domestic outlet: 1<sup>st</sup> hr rating =330 gph
- 200°F coil inlet/12 gpm coil flow/115°F domestic outlet: 1<sup>st</sup> hr rating =503 gph
- 200°F coil inlet/12 gpm coil flow/140°F domestic outlet: 1<sup>st</sup> hr rating =370 gph

These ratings will also be associated with a stated heat input rate from the heat source.

Continuous domestic water delivery capacity can be estimated by taking the first hour rating (at a specified coil supply temperature, coil flow rate and domestic hot water delivery temperature), and subtracting 75% of the tank volume. Mathematically, this is represented as Formula 4-1.

Formula 4-1:

$$D_c = FHR - (0.75 \times V_t)$$

Where:

- $D_c$  = continuous delivery capacity (gallons/hour)
- FHR = first hour rating (gallons/hour)
- $V_t$  = volume of tank (gallons)

Thus an 80-gallon indirect with a FHR of 440 gallons per hour ( at coil inlet of 180°F, coil flow of 12 gpm, and domestic hot water delivery temperature of 115°F) should have a continuous hot water delivery of approximately:

$$D_c = 440 - (0.75 \times 80) = 380 \text{ gph}$$

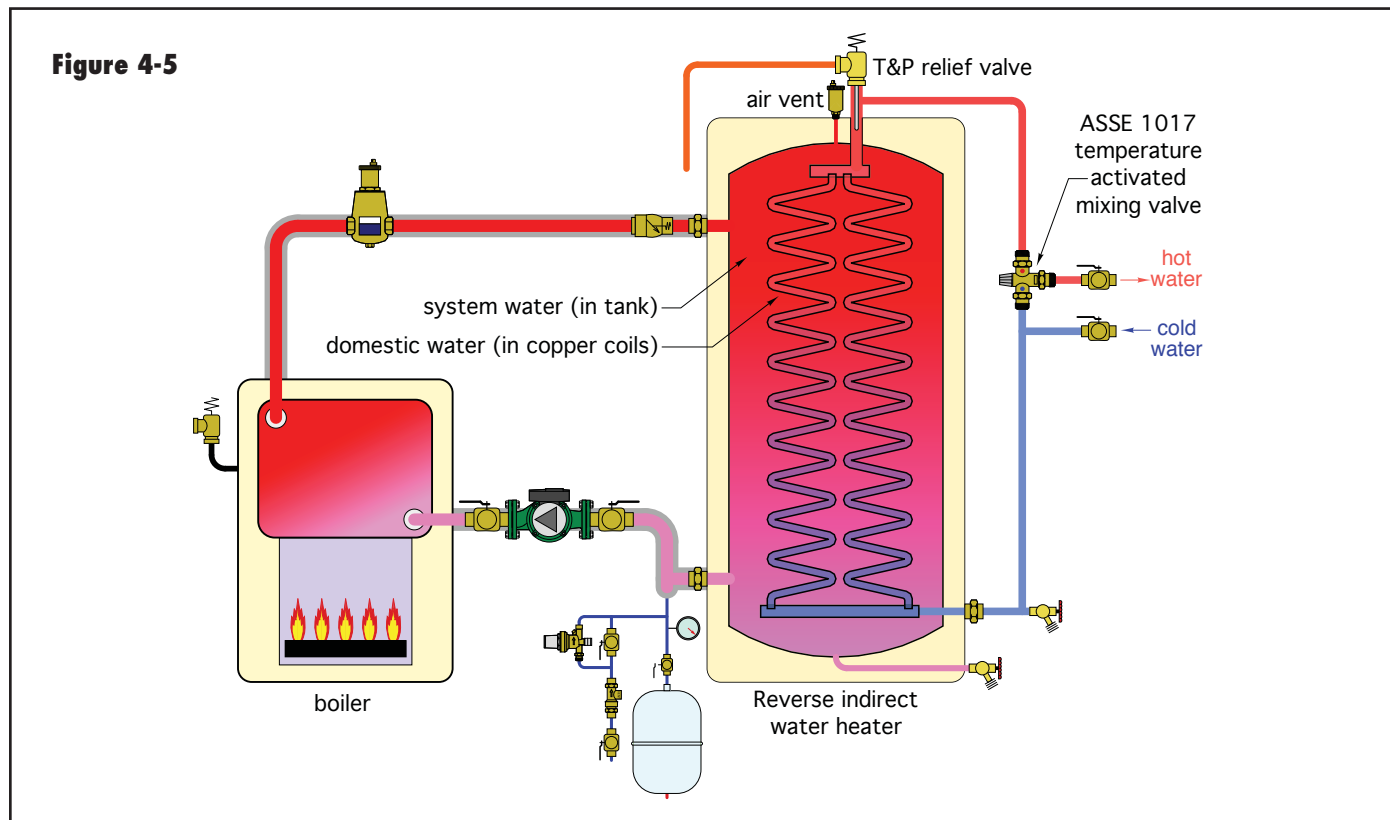
It is very important to assess the heat exchanger flow rate and minimum heating capacity of the boiler for a given rate of hot water production. The latter can be estimated using Formula 4-2:

Formula 4-2:

$$Q_i = 8.33 \times D_c \times (T_h - T_c)$$

Where:

- $Q_i$  = minimum heat input rate to tank (Btu/hr)
- $D_c$  = continuous delivery capacity (gallons/hour)
- $T_c$  = cold domestic water temperature (°F)
- $T_h$  = hot water outlet temperature (°F)



For example, to produce 380 gallons per hour of water heated from 50° to 115°F would require a minimum heat source input of:

$$Q_i = 8.33 \times 380 \times (115 - 50) = 206,000 \text{ Btu / hr}$$

This is a relatively high rate of heat transfer for a typical residential boiler, especially if that boiler were sized for the design heat loss of an average new home. In some systems, high rates of heat production are produced using a multiple boiler system. This and other options for high-capacity domestic water heating are discussed in Section 5.

### FLOW AND HEAD LOSS CONSIDERATIONS

Other important considerations when designing a water heating system using an indirect tank are:

- a. The pipe size between the heat source and tank heat exchanger
- b. The circulator between the heat source and tank heat exchanger.

If the piping or circulator is undersized, the tank will not be able to deliver its rated performance. Thus, in a properly designed system, there can be no flow “bottlenecks.”

Most manufacturers provide recommended heat exchanger flow rates and the associated head loss data for their indirect water heaters. This is usually stated as a single flow rate and head loss. Formula 4-3 can be used to extrapolate the relationship between flow rate and head loss to operating condition above and below the stated condition.

Formula 4-3:

$$H_L = H_0 \left( \frac{f}{f_0} \right)^2$$

Where:

$H_L$  = head loss at a flow rate (f) (feet of head)

$H_0$  = head loss at stated flow rate ( $f_0$ ) (feet of head)

f = flow rate (gpm)

$f_0$  = flow rate at which stated head loss was determined (gpm)

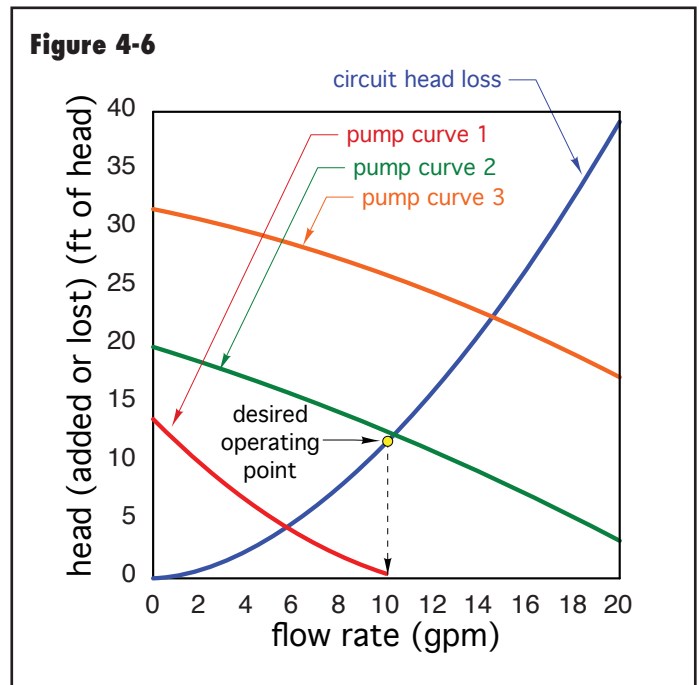
For example: Assume the head loss of the heat exchanger in an 80-gallon indirect water heater is stated as 13.6 ft. at a flow rate of 10 gpm. Determine the head loss of the coil if operated at 12 gpm.

Solution:

$$H_L = 13.6 \left( \frac{12}{10} \right)^2 = 19.6 \text{ ft.}$$

Formula 4-3 can be used, along with head loss data for the piping, components and heat source that make up the indirect water heater circuit, to create a circuit head loss curve. This curve can be plotted along with the pump curve of candidate circulators to determine which circulator(s) would provide the required flow as recommended by the manufacturer. Such a plot is shown in Figure 4-6.

The circuit head loss curve for a typical 80-gallon indirect with 1.25” copper piping and a low-flow-resistance boiler is shown in blue. The desired flow rate in this circuit is assumed to be 10 gpm (shown as “desired operating point”). The pump curves of three “candidate” circulators are also plotted. The intersection of these pump curves with the circuit head loss curve determines the flow rate in the circuit *if that particular circulator is used*.



Pump 1 (red curve) would only produce a flow of about 6 gpm in this circuit. This is well below the target operating flow rate of 10 gpm and is likely to produce unacceptable heat transfer into the indirect tank. Pump curve 3 (orange curve) produces a flow rate slightly over 14 gpm. Although the 1.25” piping and heat exchanger could operate at this flow rate, this circulator likely requires significantly more electrical power relative to a circulator that produces a flow closer to the desired operating point. Pump curve 2 (green curve) passes almost directly through the desired operating point, and thus is an appropriate selection that avoids both underflow and overflow through the tank’s heat exchanger.

## PRIORITY DOMESTIC WATER HEATING

Sometimes, the total load connected to a hydronic system exceeds the output of the heat source. This is often the case when there is a peak demand for domestic hot water at the same time that space heating zones are active. One way to manage this situation without increasing the size of the heat source is by “prioritizing” the domestic water heating load. When water heating is required, all space heating and other loads are temporarily turned off. This allows the full heat output of the heat source to be used for domestic water heating.

A slight modification of this priority control strategy is now common. It’s called “priority override.” This strategy allows the indirect tank to be the priority load *for a preset time* of say 30 minutes. If this allowed time elapses and the thermostat of the indirect tank is still calling for heat, the controller allows it to continue, but also re-enables the space heating loads that were turned off when the priority time period began. This strategy protects against the possibility of a space heating lockout due to a malfunction in the water heating subsystem. Examples of such malfunctions include defective thermostats or sensors, or a leak in the hot water system that creates a perpetual load. Without priority override, such conditions could eventually cause a freeze up in the space heating piping, since these circuits would not be allowed to operate.

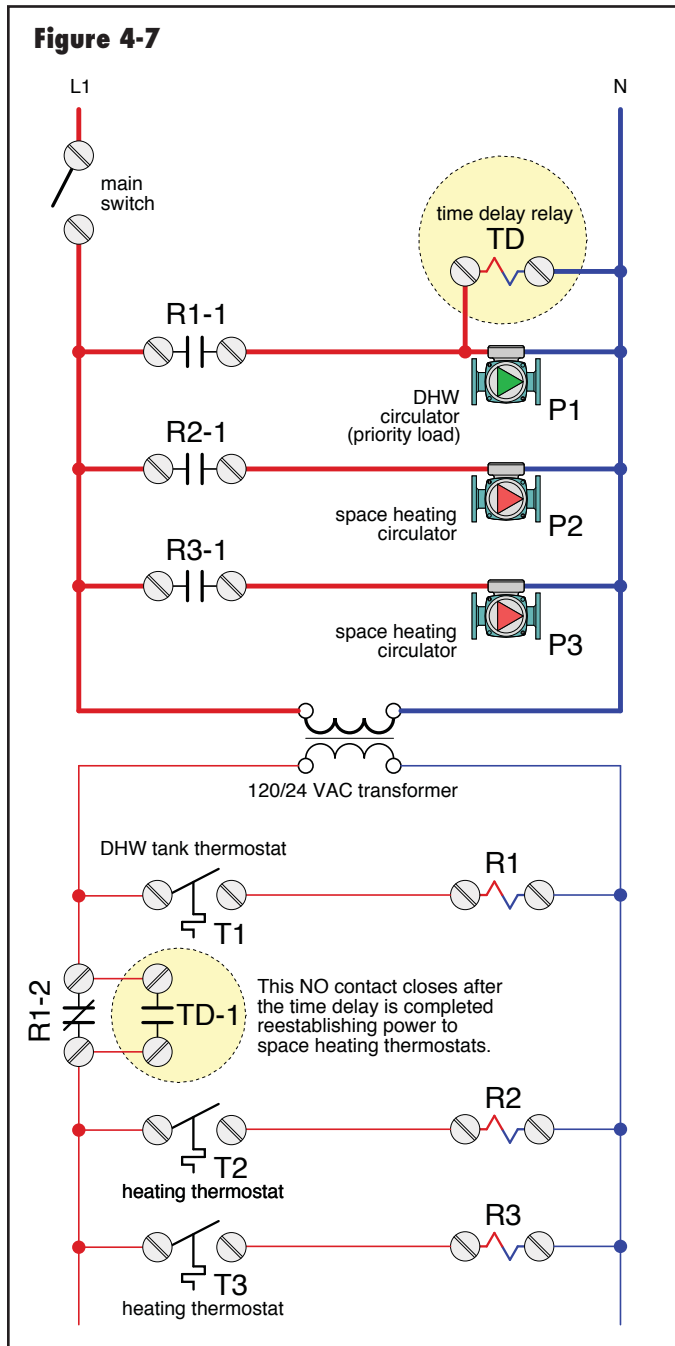
Priority override control can be accomplished using “hard-wired” relay logic or with a prebuilt multi-zone relay center that has this logic built into its circuitry. The latter is the fastest and easiest way to implement priority control. A ladder diagram showing the relay logic used by either approach is shown in Figure 4-7.

This ladder diagram is for a system with two space heating zones, supplied by circulators (P2) and (P3). The indirect water heater is set with its own circulator (P1).

Upon a call for heat from the tank thermostat (T1), the coil of relay (R1) is powered on by the 24 VAC circuit. Relay contact (R1-1) closes to supply line voltage to the tank circulator. This contact also supplies 120 VAC to power-on a time delay relay (TD-1). This time delay relay uses a “delay-on-make” configuration. As such, its normally open contacts will only close *after a preset time has elapsed*. For priority DHW control, this time is typically set for 30 minutes.

Another electrical contact associated with relay (R1) is located in the low voltage portion of the ladder diagram. The contacts (R1-2) are normally closed. As such, they open when relay (R1) is powered on. This interrupts 24 VAC to all space heating thermostats, which turns off any active space heating zones.

At this point, the domestic water heating load is active, all space heating zones are off and the timer in relay (TD-1) is counting towards 30 minutes. If the domestic water thermostat is satisfied within 30 minutes, relay (R1) is turned off, and 24 VAC is resupplied to the space heating thermostats. If the domestic water thermostat is *not* satisfied within 30 minutes, the normally open contact (TD-1), wired in parallel with contact (R1-2), closes. This re-establishes 24 VAC to the space heating thermostats *and* allows the domestic water heater to continue.



## 5. OTHER HYDRONIC-BASED APPROACHES TO DOMESTIC WATER HEATING

This section explores other hydronic-based methods for heating domestic water. It covers situations where the DHW load is high, as well as methods of extracting heat from large storage tanks associated with renewable energy heat sources. It also looks at opportunities for applying heat recovery to domestic water heating.

### HIGH-CAPACITY DHW LOADS

An increasing trend in custom residential construction is increased interest in luxury bathrooms. The North American plumbing industry has done a great job of promoting such bathrooms. The essence of such promotions is surrounding oneself with lavish amounts of warm water, be it in a deep whirlpool tub or a simulated tropical downpour showering experience. An example of such a bathroom is shown in Figure 5-1.



For decades, the ability to produce domestic hot water using a hydronic heating system has been viewed as ancillary to space heating. The traditional thinking was as follows: Since the customer has decided to use hydronic space heating, and therefore needs a boiler, why not “upgrade” the system with an indirect water heater?

This reasoning was sound when the average house didn’t consume the copious quantities of domestic hot water that many new luxury homes now require. Given the increased number of such homes, hydronic heating professionals are now presented with unique opportunities: Providing high-capacity domestic water heating from the same hydronic system that heats the house, and perhaps services other loads as well.

One hardware configuration that is ideal for serving high-demand domestic water heating loads is a multiple boiler system supplying a high-capacity indirect water heater, as shown in Figure 5-2.

In this system, domestic water heating is treated as a priority load. When there is a demand for water heating from the tank’s thermostat, the multiple boiler controller receives a setpoint demand. This controller targets a high temperature (typically 180° to 200°F) at the supply temperature sensor located downstream of the hydraulic separator. The controller fires and modulates the boilers as required to achieve this high supply water temperature. If necessary, all boilers eventually turn on and operate at full output. Any other loads served by the boiler system are temporarily turned off so that the full heat production of the boiler system is directed to the water heater.

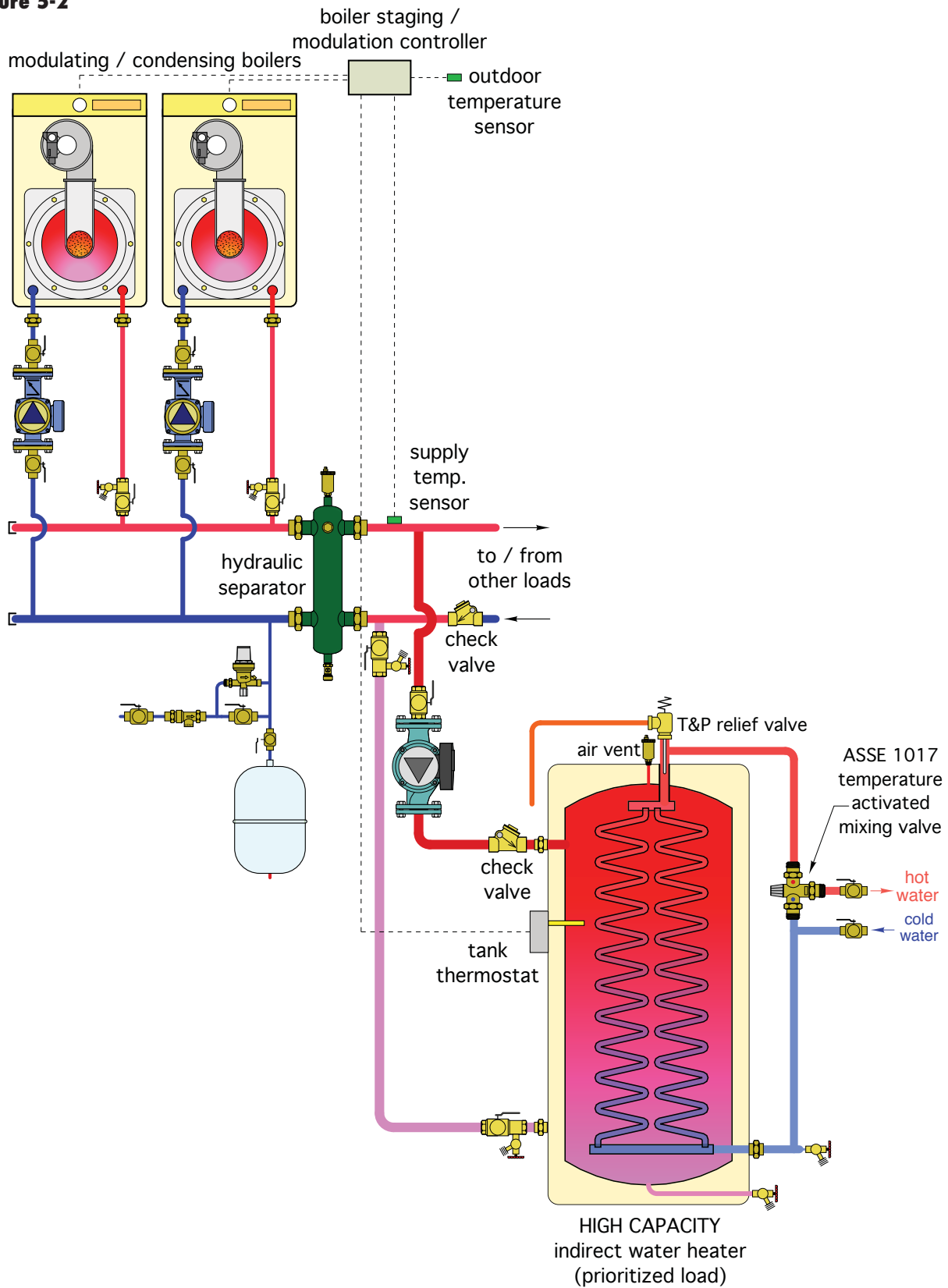
*It is vitally important that the heat exchanger within the water heater can transfer heat to the domestic water at a rate as high as the full heat production rate of the boiler system. Failure to provide sufficient heat exchanger will limit the rate of hot water production. It is also vitally important that the piping and circulator supplying the high-capacity indirect water heater can transfer the full heat production rate of the boiler system. It may be necessary to use 1.5” or 2” piping for the circuit supplying the tank’s heat exchanger. Flow rates of 25 gpm or higher may be required.*

If a suitable indirect water heater cannot be found, an external brazed plate heat exchanger in combination with an insulated storage tank could be used, as shown in Figure 5-3. Again, the heat exchanger, piping and circulators must all be sized to transfer the full heating output of the boiler system to the domestic water.

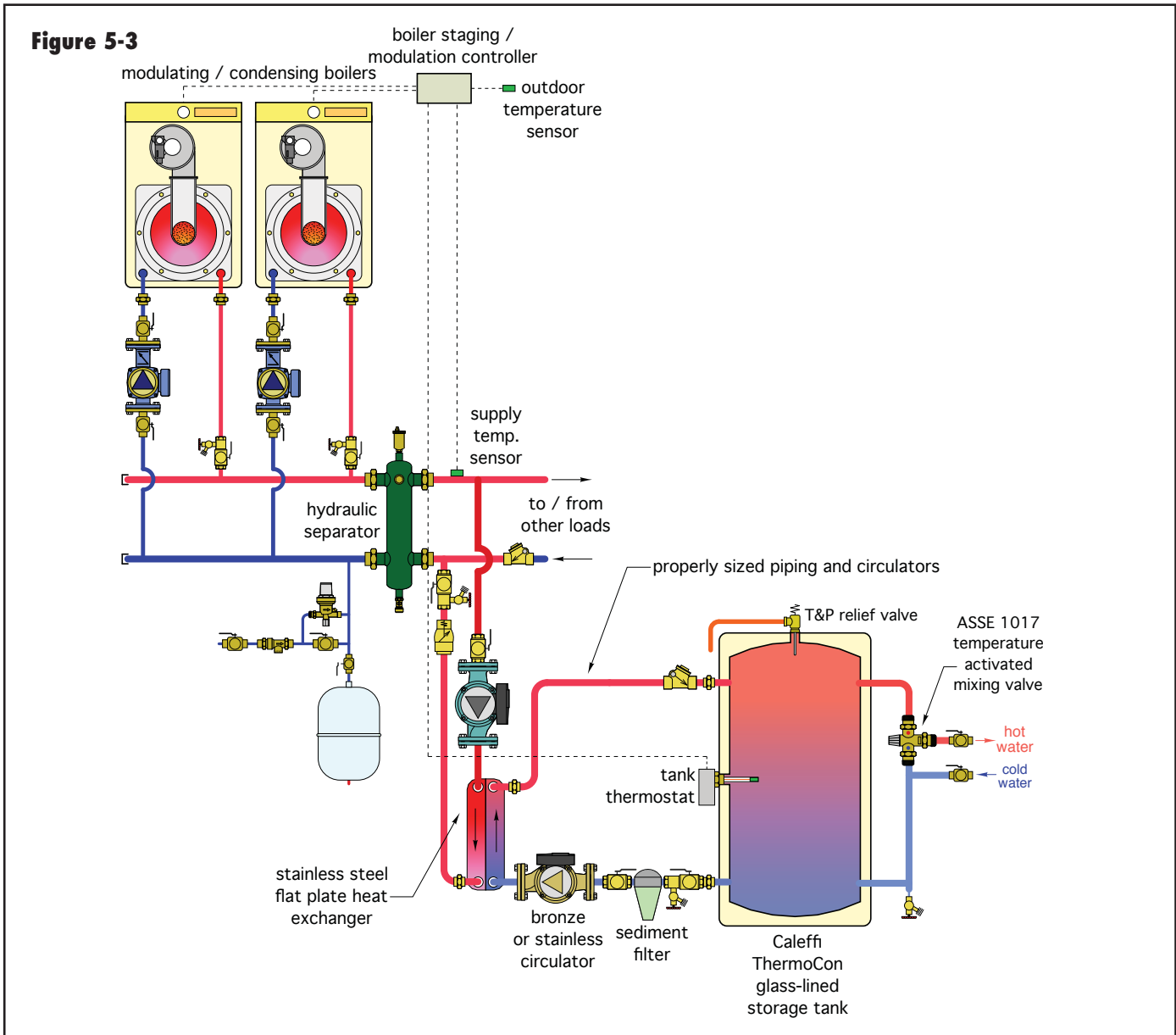
This approach to high-capacity domestic water heating offers several benefits relative to other options:

- It requires less space in a mechanical room compared to multiple storage-type water heaters that would be required for equivalent capacity.
- Standby heat loss from a single high-capacity indirect water heater is lower than that from several storage tanks.
- Multiple direct-fired storage water heaters are only useful for domestic water heating. A multiple boiler system can supply heat for domestic hot water as well as a wide range of other heating loads, such as space heating, pool heating or snowmelting, which can be controlled as lower priority loads.

**Figure 5-2**







**Figure 5-4**



- A multiple modulating/condensing boiler system has a high system turn-down ratio and can maintain high seasonal efficiency under partial load conditions that are prevalent much of the time.

- This approach offers a good combination of “instantaneous” water heating capability when needed for high demands, as well as a modest, but necessary amount of storage to handle small DHW draws without firing a combustion system.

## HEAT EXTRACTION FROM LARGE STORAGE TANKS

Many renewable energy heating systems that use solar collectors, wood-fired boilers or heat pumps also have a large thermal storage tank. At times, this tank could be at elevated temperatures of perhaps 180° or even 200°F. At other times, the heat input from the renewable heat source may have dwindled, and the tank may cool down to less than 100°F, sometimes even approaching room temperature.

Such tanks provide very high thermal mass and temperatures that are usually higher than the entering cold domestic water temperature. As such, they provide an excellent source for preheating, or in some cases, fully heating domestic water.

One method leverages the thermal mass of the storage tank in combination with the rapid thermal response of a stainless steel brazed plate heat exchanger. An example of such a heat exchanger is shown in Figure 5-5.

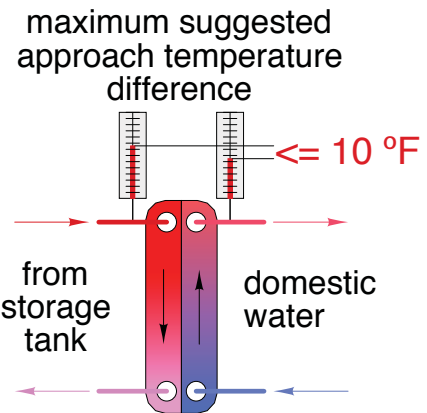
One method of piping such a heat exchanger to a large thermal storage tank is shown in Figure 5-6.

**Figure 5-5**

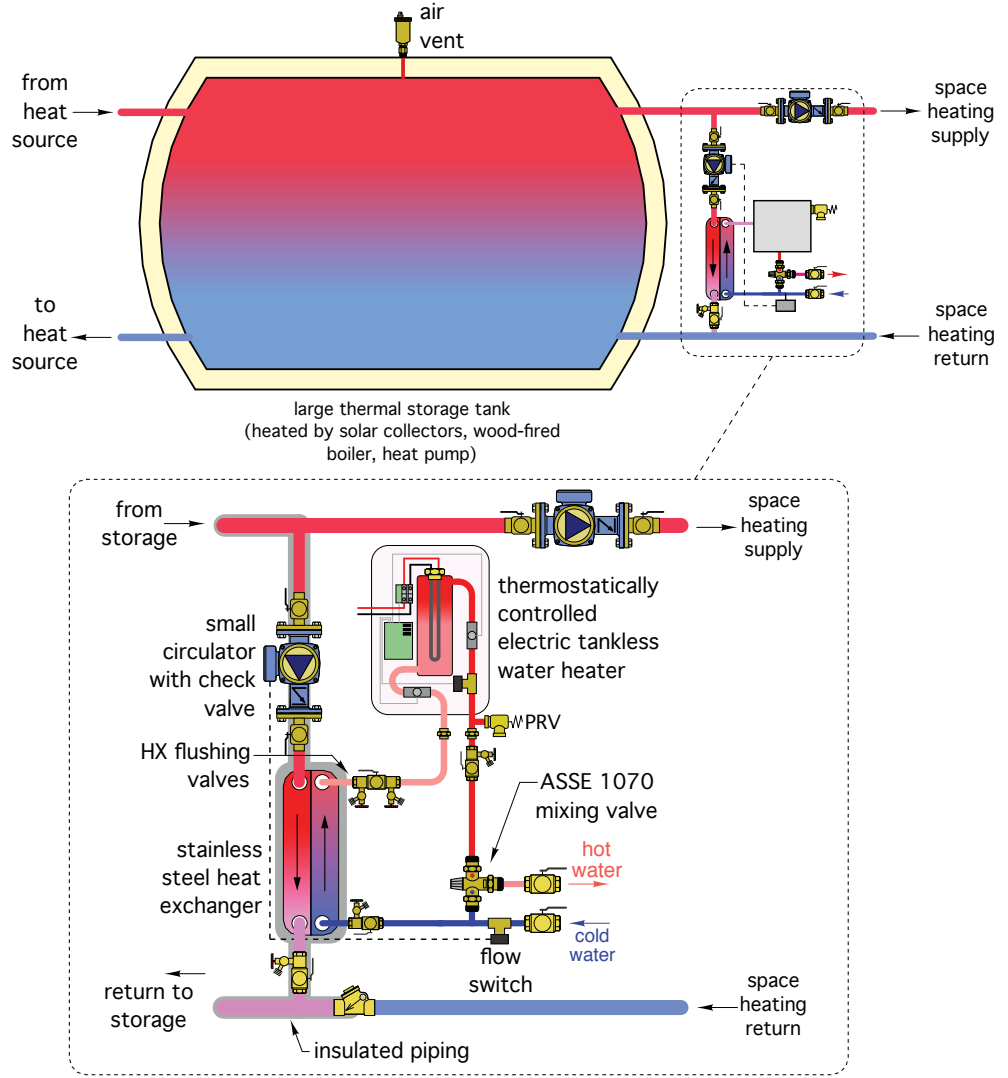


Courtesy of GEA FlatPlate

**Figure 5-7**



**Figure 5-6**



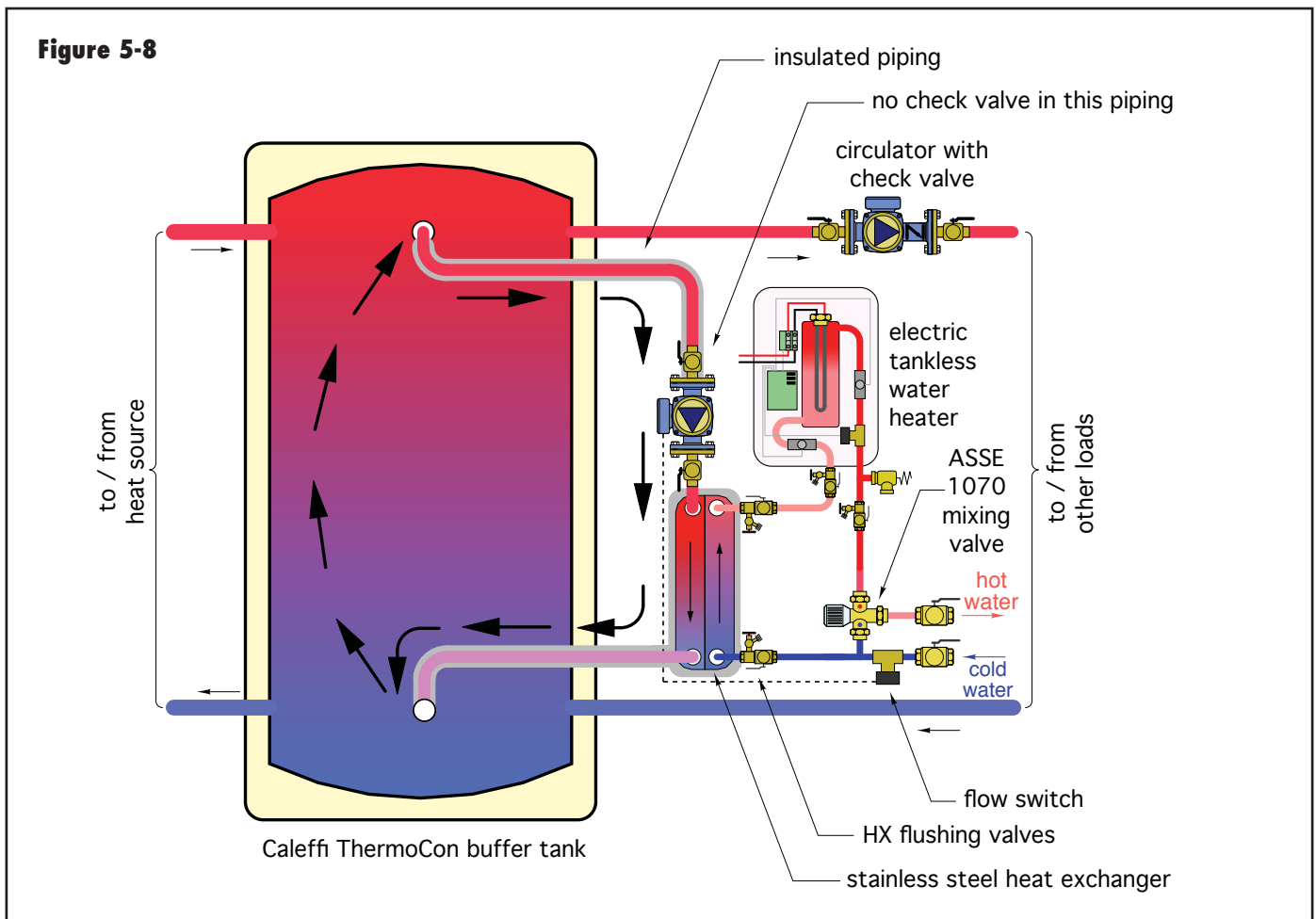
Domestic water is heated instantaneously as it is needed. A flow switch detects whenever domestic water is required at a flow rate at or above 0.5 gpm. Under this condition, it turns on a small circulator that moves heated water from the thermal storage tank through the primary side of a stainless steel heat exchanger. Cold water is instantaneously preheated (or fully heated, depending on the tank temperature) as it passes through the other side of the heat exchanger. A thermostatically controlled electric tankless water heater provides any necessary boost in domestic hot water delivery temperature. If the water entering the tankless water heater is already at or above the heater's setpoint, the electric heating element remains off. An ASSE 1070 listed temperature activated mixing valve protects against high domestic water temperatures when the storage tank is at an elevated temperature. For the fastest possible response, the piping between the thermal storage tank and heat exchanger should be short and fully insulated. A combination isolation/flushing valve should be installed on the domestic water inlet and outlet of the heat exchanger, as well as the inlet and outlet of the tankless heater. These valves allow for flushing if ever required to remove scale.

It is suggested that the stainless steel heat exchanger should be sized for an *approach* temperature difference of not more than 10°F. The approach temperature difference is the temperature difference between the water entering the primary side of the heat exchanger and the water leaving the secondary side of the heat exchanger, as shown in Figure 5-7.

Thus, if the desired domestic hot water supply temperature is 120°F, the incoming hot water from the storage tank should not be assumed higher than 130°F when the heat exchanger is being sized. Closer approach temperature differences are possible, but will increase the required size of the heat exchanger.

As an example, a flat plate heat exchanger was sized for the following “design” conditions:

- Incoming water temperature from storage = 130°F
- Hot water delivery temperature = 120°F
- Incoming cold domestic water temperature = 50°F
- Required domestic hot water delivery rate = 5 gpm



The required heat exchanger is 5 inches wide, 12 inches tall and contains 30 plates.

Assuming the tank was at 100°F, this heat exchanger could supply an outlet temperature (going to the electric tankless water heater) of 86°F at the same 5 gpm flow rate. The temperature rise of the domestic water from 50° to 86°F represents 51% of the total temperature rise. Thus, the relatively low temperature storage tank (100°F) is still supplying about 51% of the current domestic hot water load.

The benefits of this approach include:

- No need for a separate domestic hot water storage tank. This results in a smaller mechanical room footprint.
- The full thermal mass of the storage tank is available to stabilize domestic hot water delivery temperature during lengthy demand periods.
- The standby heat loss associated with a domestic hot water storage tank is eliminated.

- The stainless steel heat exchanger can be easily inspected, cleaned and replaced as necessary.

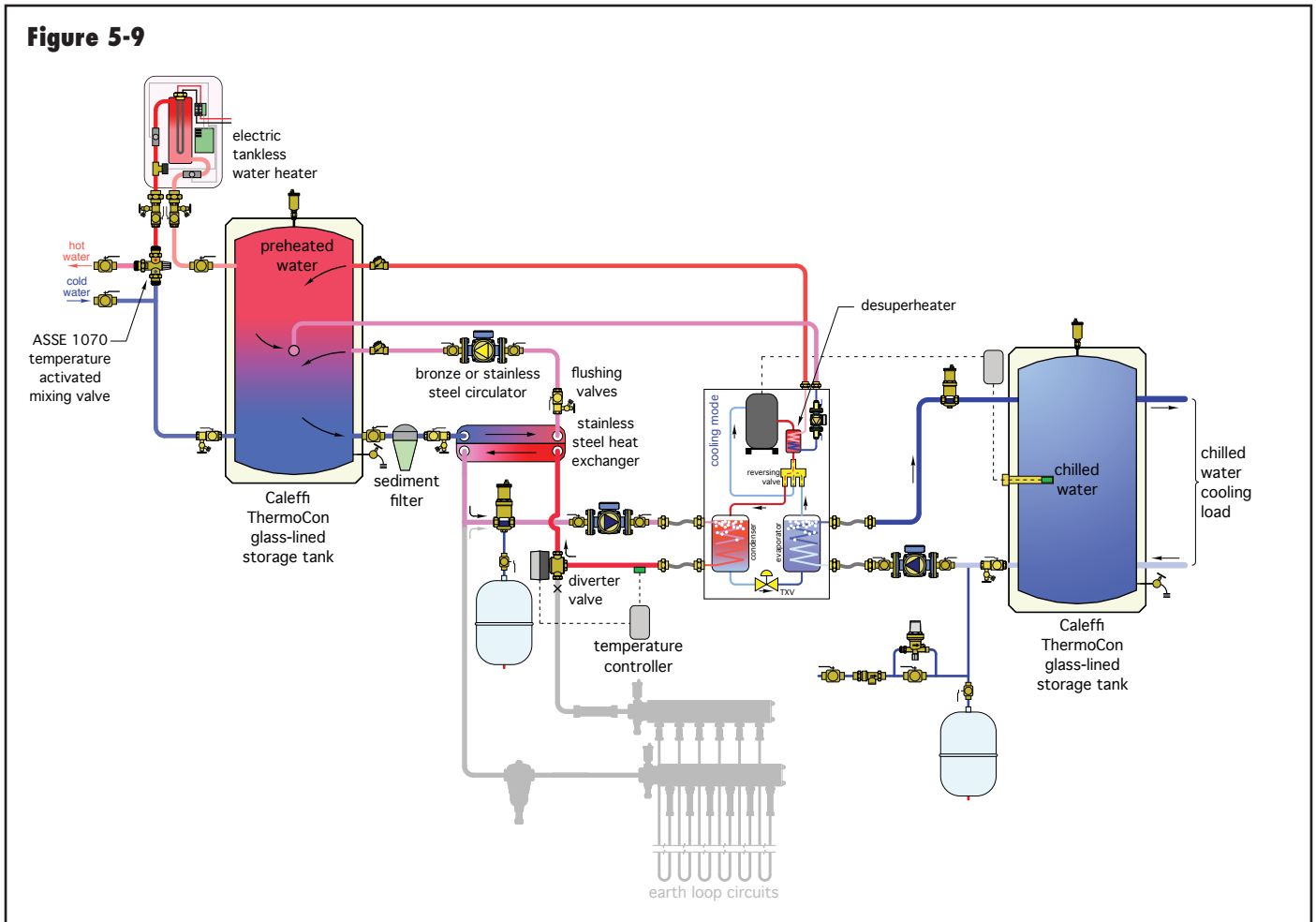
- The “warm up” time of this assembly is shorter than that of a gas-fired tankless water heater because there is no need to initiate combustion.

- The possibility of Legionella is reduced, since very little domestic hot water is “stored” in this assembly.

- There is no need to add “auxiliary energy” to the storage tank. This allows the lowest available water temperature to be supplied to the renewable energy heat source, which boosts its efficiency. It also minimizes standby heat loss from the storage tank.

A modified version of this instantaneous domestic water heating subassembly is shown in Figure 5-8.

This configuration uses a Caleffi ThermoCon tank, which has several piping connections near its top and bottom. These connections allow the heat exchanger subassembly to be separated from the piping that supplies



other loads such as space heating. This arrangement provides hydraulic separation between the two circuits, making it possible to omit the check valve in the piping supplying the primary side of the DHW heat exchanger. A thermosyphon flow can now establish itself through the insulated piping supplying the primary side of the heat exchanger. This keeps the heat exchanger warm, and further reduces the response time for hot water delivery.

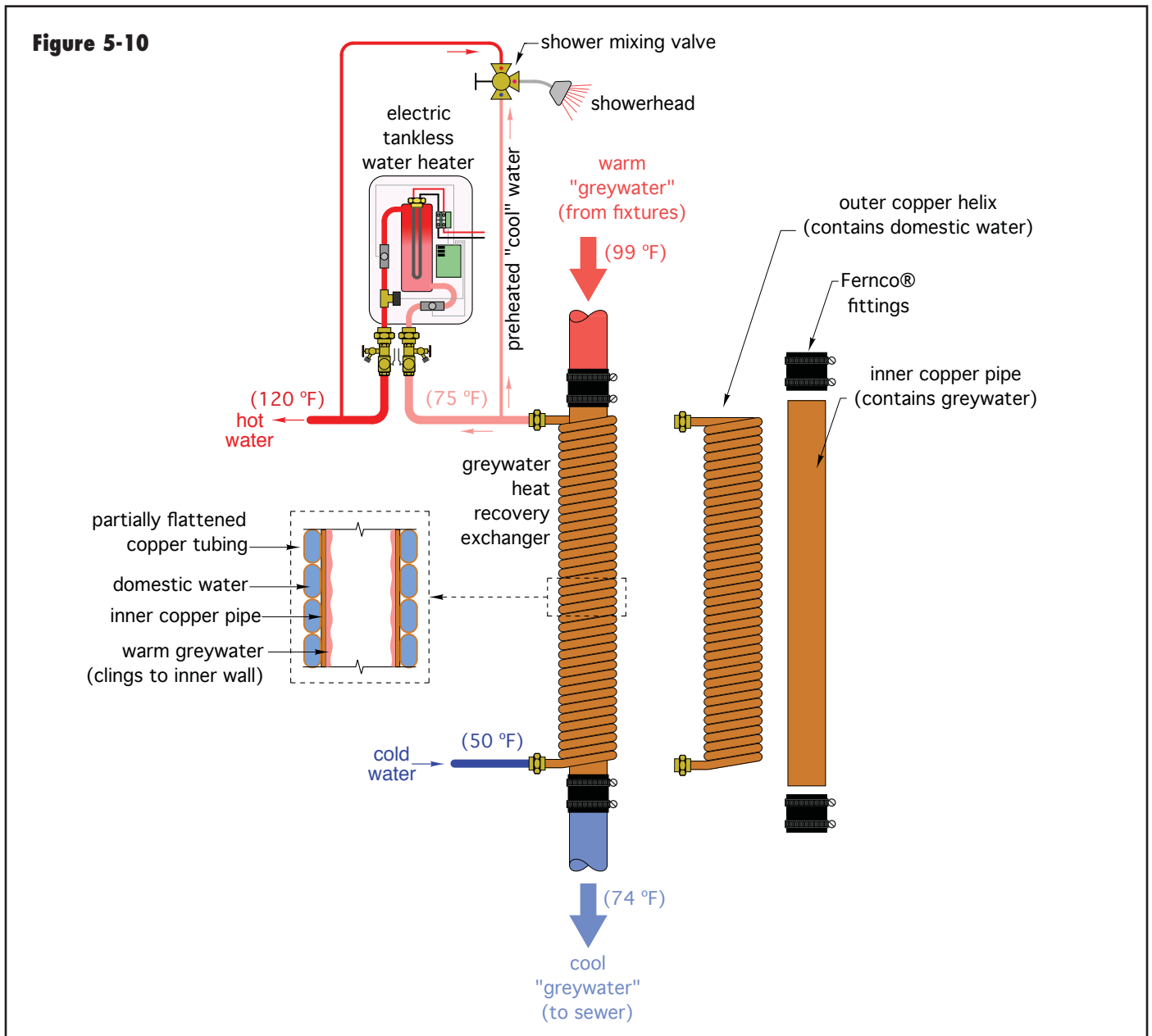
One example is when a water-to-water heat pump is being used for chilled water cooling, as shown in Figure 5-9.

The use of a desuperheater heat exchanger within a water-to-water or water-to-air heat pump was discussed in Section 2. The desuperheater extracts heat from the hot refrigerant gas exiting the heat pump's compressor and transfers this heat to domestic water.

### DOMESTIC WATER HEATING USING HEAT RECOVERY

There are situations in which heat that needs to be removed to provide cooling can be redirected to provide domestic water heating.

The heat pump shown in Figure 5-9 uses a desuperheater to transfer heat to the warmer water in the upper portion of the storage tank. Under the right conditions, cooler water near the bottom of this tank can be routed through a stainless steel heat exchanger that provides



an alternate heat sink option to the earth loop. This routing is controlled by a diverter valve that responds to the temperature of the preheated water. When the water temperature leaving the heat pump is below a set value, the diverter valve routes it through the stainless steel heat exchanger rather than into the earth loop. Another stainless steel or bronze circulator provides domestic water flow through the other side of the heat exchanger. Once the temperature leaving the heat pump's condenser reaches a value where cooling performance declines below acceptable minimums, the diverter valve activates to direct heat to the earth loop. Note that the diverter valve must be sized to handle the full earth loop flow.

### GREYWATER HEAT RECOVERY

Much of the heat in hot water used for washing remains in that water as it goes down the drain. In most buildings, this heat is simply carried into the sewer. However, "greywater" heat exchangers are now available that can recover up to 40% of this otherwise wasted heat and use it to preheat water that eventually becomes fully heated domestic hot water.

**Figure 5-11**



Courtesy of GFX Technology

A greywater heat exchanger is relatively simple. It consists of an inner copper pipe that's fitted inline with the main vertical greywater drainage pipe. This inner copper pipe is wrapped with one or more coils of tightly fitting, partially flattened copper tubing that is bonded to the outer surface of the inner pipe.

The construction and installation concept of a greywater heat exchanger is shown in Figure 5-10. Figure 5-11 shows the installation of a longer length greywater heat exchanger. The greywater drainage pipe joins the main building drain downstream of the heat exchanger.

Greywater heat exchangers take advantage of frequent simultaneous flows of cold water and hot water as the latter is being used in fixtures such as lavatories and showers. As hot water is being used, cold water enters the bottom connection of the coiled tubing and passes upward in a counterflow direction to the greywater. Heat from the greywater transfers through the copper tube walls and preheats cold water.

Under typical operating conditions, the domestic water will be warmed 20° to 25°F before it exits at the top of the coil. Thus, cold water entering the building at 50°F, would enter the final water heating device at 70° to 75°F. Under such conditions, greywater heat recovery is reducing the water heating load by 29% to 36%, assuming a final desired delivery temperature of 120°F. This is a significant contribution for a simple, unpowered and relatively inexpensive device. Greywater heat recovery also increases effective rate at which domestic hot water can be supplied by the auxiliary heating device(s).

Greywater heat exchangers should only be installed in vertical drainage pipes. They rely on the "film effect" of greywater passing through a *vertical* drainage pipe. Most of this water clings to the pipe wall, rather than falling through the air space inside the pipe. This is ideal from the standpoint of extracting heat from the inner copper pipe.

In this type of heat exchanger, the two streams of water are always separated by *two* copper tube walls. A potential leak in either the inner pipe or outer coil would not cause contamination of domestic water by greywater.

Always verify any provisions imposed by local plumbing codes regarding installation of greywater heat exchangers and plan drainage systems accordingly.

## 6. SOLAR WATER HEATING

Domestic water heating has long been considered one of the best applications for solar thermal collectors. Because most domestic water heating loads are present year round, such systems take advantage of the higher solar availability of summer, as well as the more limited solar energy available in winter.

There are many types of solar domestic water heating systems. They include systems with different types of:

- Solar collectors (flat plate collectors, evacuated tube collectors)
- Storage devices (pressurized and unpressurized tanks)
- Freeze protection methods (closed-loop antifreeze-based systems, drainback systems)
- Control methods (passive systems, on/off and variable speed differential temperature controllers)
- Circulation systems (passive circulator, AC circulators, DC circulators).

This section covers the more common approaches used in residential solar water heating systems. A more thorough discussion of solar availability, solar collectors and systems can be found in *idronics 3* and *idronics 6*.

### PASSIVE SOLAR WATER HEATING SYSTEMS

One of the simplest modern approaches to solar water heating locates the solar collector and hot water storage tank on the roof of a building. Heat passes from the collector to the elevated storage tank without need of any circulator or any other electrical power. Such systems are called “passive” because they do not require any electrical power to move heat between the collector and storage tank. On a worldwide basis, passive solar water heating is more common than “active” systems that require electrical power to move heat from collectors to storage.

**Figure 6-1**

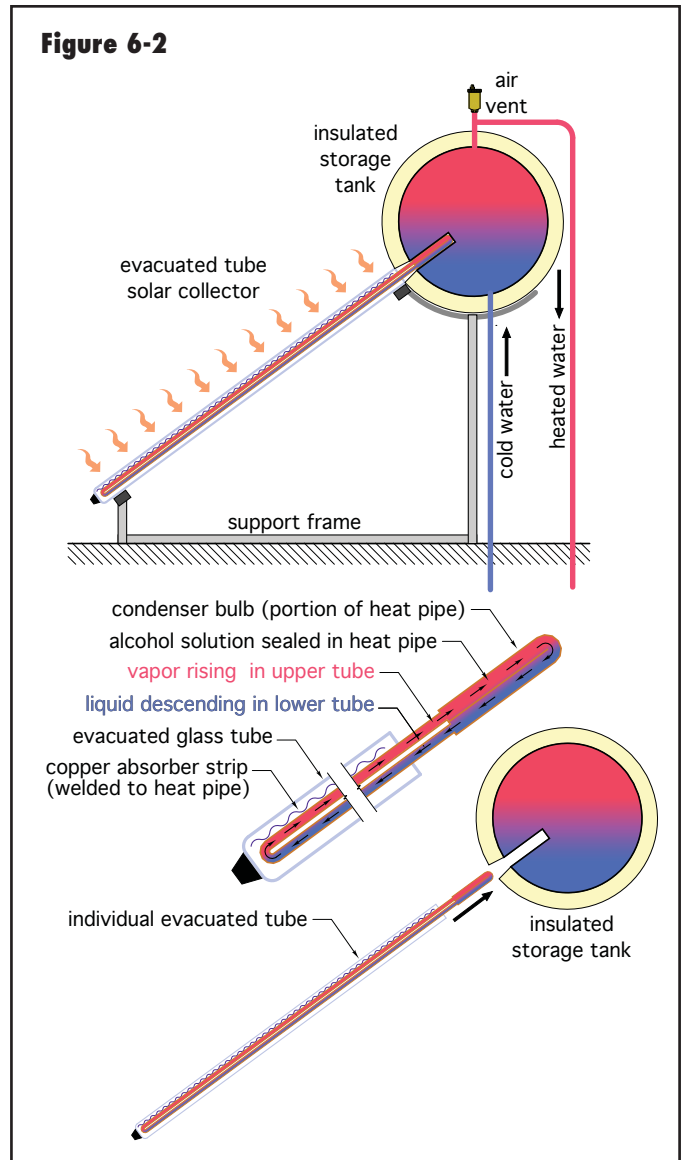


Figure 6-1 shows a passive solar water heater using evacuated tubes for the collector. Figure 6-2 illustrates the basic principle of operation.

Each evacuated tube contains a mixture of ultra pure water and alcohol within a sealed “heat pipe.” A thin strip of highly conductive copper with a special surface coating is welded to the top of this heat pipe. When warmed by the sun, the absorber strip transfers heat to the fluid within the heat pipe, causing it to vaporize and rise to the condenser bulb at the top of the evacuated tube. The condenser bulb fits tightly into a special socket in the insulated storage tank and transfers heat from the vaporized fluid to the water in the tank. The fluid within the heat pipe condenses back to a liquid as it gives up heat. This liquid then runs back down the heat pipe ready to repeat the cycle.

These “batch-type” passive solar water heaters with exterior storage tanks are only suitable for warm climates. They are extensively used in tropical locations. In the U.S., they are typically only used in southern states with minimal sub-freezing temperatures.

The temperature achieved by the water in the tank depends on the available sunlight, the surrounding air temperature and the amount of water passing through the tank during the day. During warm weather in sunny climates, the water temperature in the tank may be very high by the end of a sunny day. Under such conditions, it is imperative to have an ASSE 1017 rated, temperature activated mixing valve installed, as shown in Figure 6-3.

On cloudy days, cool days or during periods of high demand, the water leaving the storage tank may require additional heating to reach the desired delivery temperature. Figure

6-3 shows a thermostatically controlled electric tankless water heater serving as the auxiliary heating device. Any of the water heater devices discussed in previous sections could provide this temperature boost.

When sub-freezing conditions are imminent, the storage tank and exterior piping can be isolated from the remainder of the system and drained using the valves shown in Figure 6-3. During this time, cold water passes through the bypass ball valve, and the electric tankless water heater provides all heating.

**ACTIVE SOLAR WATER HEATING SYSTEMS**

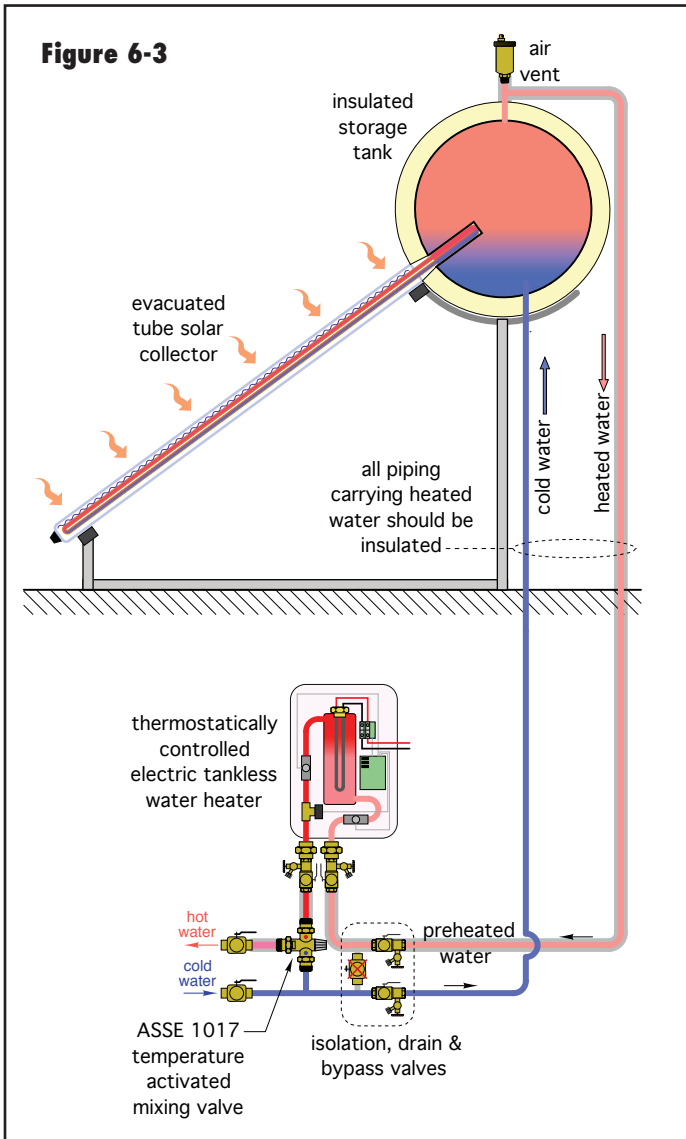
With few exceptions, the possibility of sub-freezing air temperatures mandates that solar water heating systems used in North America be *automatically* protected against freezing. Many types of systems have been developed to provide automatic freeze protection. Most of them have the following characteristics:

- The water storage tank is located inside a heated building
- A circulator is used to move fluid between the storage tank and solar collectors.

The first characteristic decreases heat loss from the storage tank relative to systems with outdoor storage tanks. Water-filled piping between the storage tank and the remainder of the plumbing system is also protected from freezing when located within heated space.

The second characteristic establishes the systems as “active” in comparison to the “passive” systems just described.

Active solar water heating systems can be designed around evacuated tube collectors or flat plate collectors. Of these, flat plate collectors are more common. When properly installed, they provide reliable service for decades. Figure 6-4 shows a typical array of flat plate collectors used for a domestic water heating system.



**Figure 6-4**





Active solar water heating systems can be further characterized based on the two commonly used methods of *automatic* freeze protection:

- Closed-loop/antifreeze systems
- Drainback systems

Of these, closed-loop/antifreeze systems are the most common. They use a closed piping circuit between the solar collectors and a storage tank heat exchanger. That

heat exchanger may be located either outside or inside the storage tank. The latter is more common.

When the system is commissioned, the closed circuit is filled with an antifreeze solution. The most common antifreeze solution is a 30% to 50% solution of inhibited propylene glycol. This solution circulates between the collectors and storage heat exchanger whenever the system's circulator is operating. While circulating, the fluid absorbs heat from the collectors and transfers that heat to water in the storage tank.

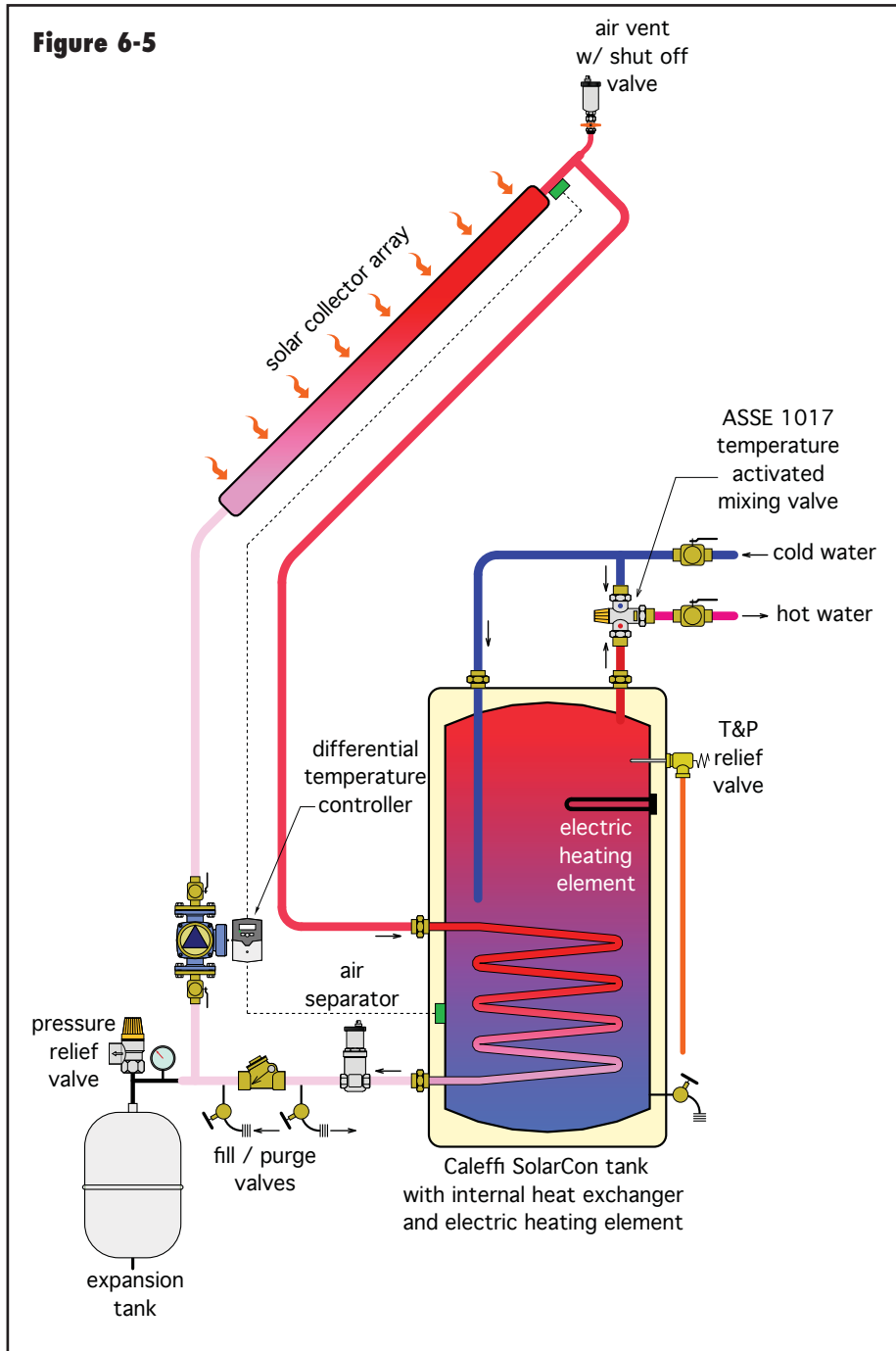


Figure 6-5 shows a typical solar water heating system using a storage tank equipped with an internal heat exchanger.

Besides the solar collectors and storage tank, the collector circuit contains several other components needed for proper operation. The following is a brief description of each component's function in the system:

- *Collector circulator*: Provides circulation of the antifreeze solution through the collector circuit when solar energy is available.
- *Collector temperature sensor*: Provides the current temperature of the collector's absorber plate to the differential temperature controller.
- *Storage temperature sensor*: Provides the current temperature of the water near the bottom of the storage tank to the differential temperature controller.
- *Differential temperature controller*: Compares the collector temperature to the storage temperature. Turns on the collector circulator when the collector is a set number of degrees warmer than storage (typically 5° to 10°F). Turns off the collector circulator when this difference drops to 2° or 3°F. Some controllers can also operate the collector circulator at variable speeds, depending on the temperature difference between the collector and storage.

- **Pressure relief valve:** Opens, if necessary, to relieve excessively high pressure within the collector circuit.
- **Check valve:** Prevents the fluid within the collector circuit from flowing backward when the collector temperature is lower than the storage tank temperature.
- **Fill and purge valves:** Allows the collector circuit to be filled with antifreeze solution and purged of bulk air.
- **Expansion tank:** Provides space to accommodate the thermal expansion of the collector circuit fluid as it is heated.

- **Pressure gauge:** Indicates the current pressure in the collector circuit.
- **Air separator:** Gathers and removes air that was initially dissolved within the collector circuit fluid.
- **High-point air vent and isolation valve:** Allows air bubbles that migrate to the top of the collector circuit to be vented out of the system.

Since these components are used in nearly all solar water heating systems of this type, manufacturers, including Caleffi, offer “solar circulation stations” that combine the

functionality of all these components into a preassembled module, as shown in Figure 6-6.

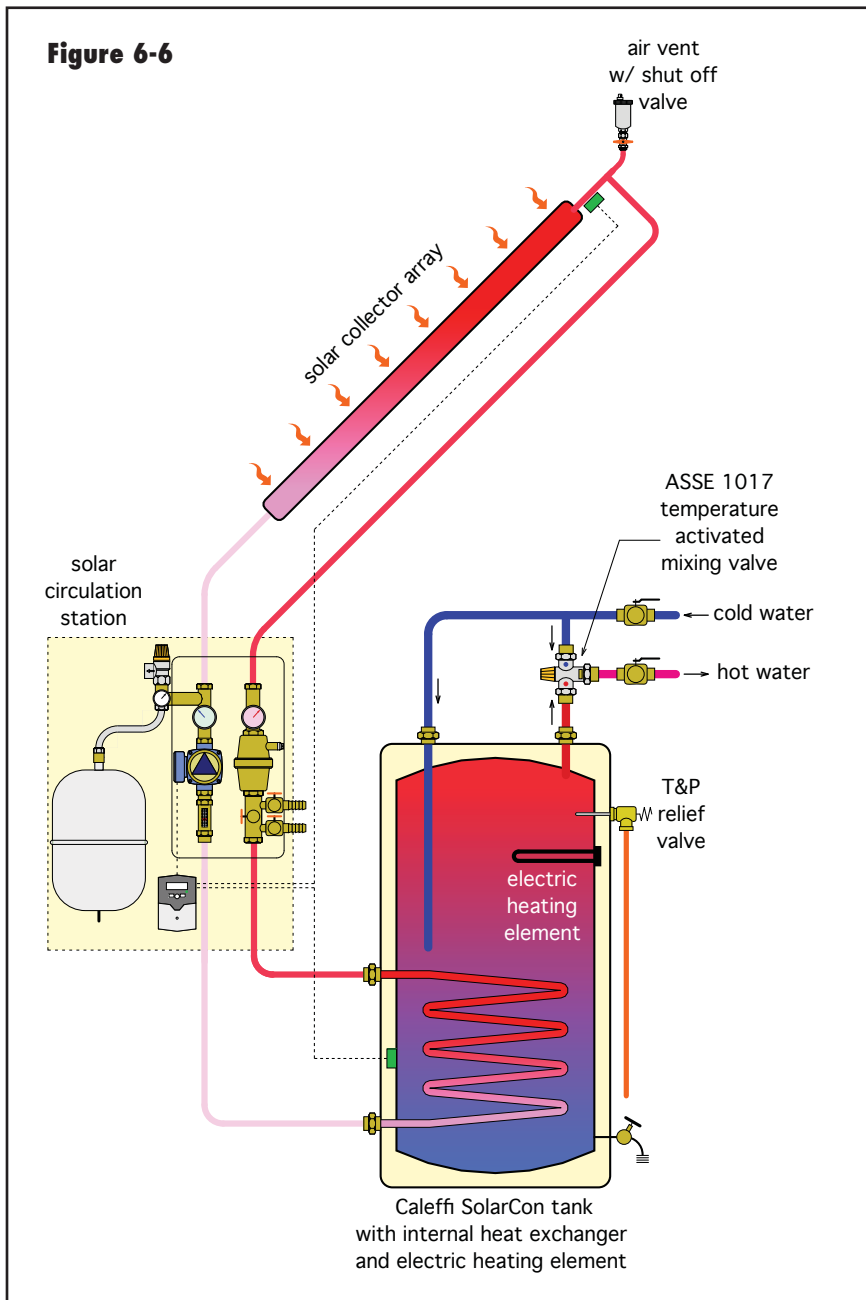
It’s also possible to build an antifreeze-protected solar water heating system around an *external* heat exchanger, as shown in Figure 6-7.

Most systems of this type use a brazed plate stainless steel heat exchanger between the collector circuit and storage tank circuit. The antifreeze solution circulates between the collector array and one side of this heat exchanger. Domestic water, drawn from the lower portion of the storage tank, circulates through the other side of the heat exchanger. The latter flow is created by a bronze or stainless steel circulator. For the most efficient performance, these two flows should always pass through the heat exchanger in opposite directions (e.g., “counterflow”).

Systems with external heat exchangers can sometimes be adapted to an existing storage water heater. This often reduces cost in retrofit situations, provided the existing tank is in good shape and has a volume of 1 to 2 gallons for each square foot of solar collector installed.

Systems with external heat exchangers require two circulators, and thus have slightly higher electrical power consumption.

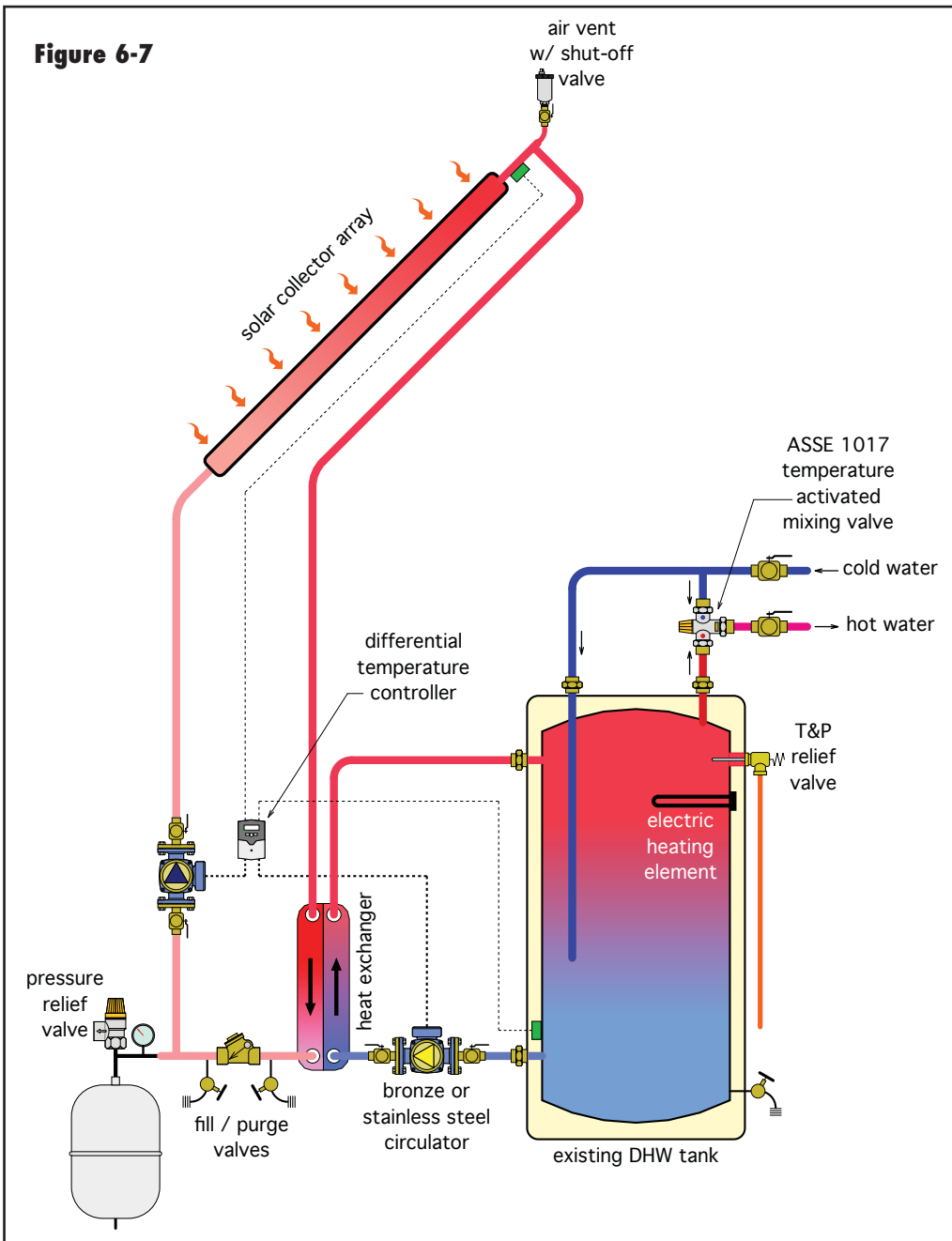
The heat exchanger should be generously sized to maximize system efficiency. A heat exchanger with an *effectiveness*



of 0.55 or higher is recommended. The higher the effectiveness, the smaller the temperature difference between the collectors and storage tank, and the higher the collector's thermal efficiency.

It is also possible to create a "two-tank" solar water heating system using an internal or external heat exchanger for the collector circuit. This type of system is common for residential systems where a conventional water heater is already installed. Figure 6-8 shows the typical configuration.

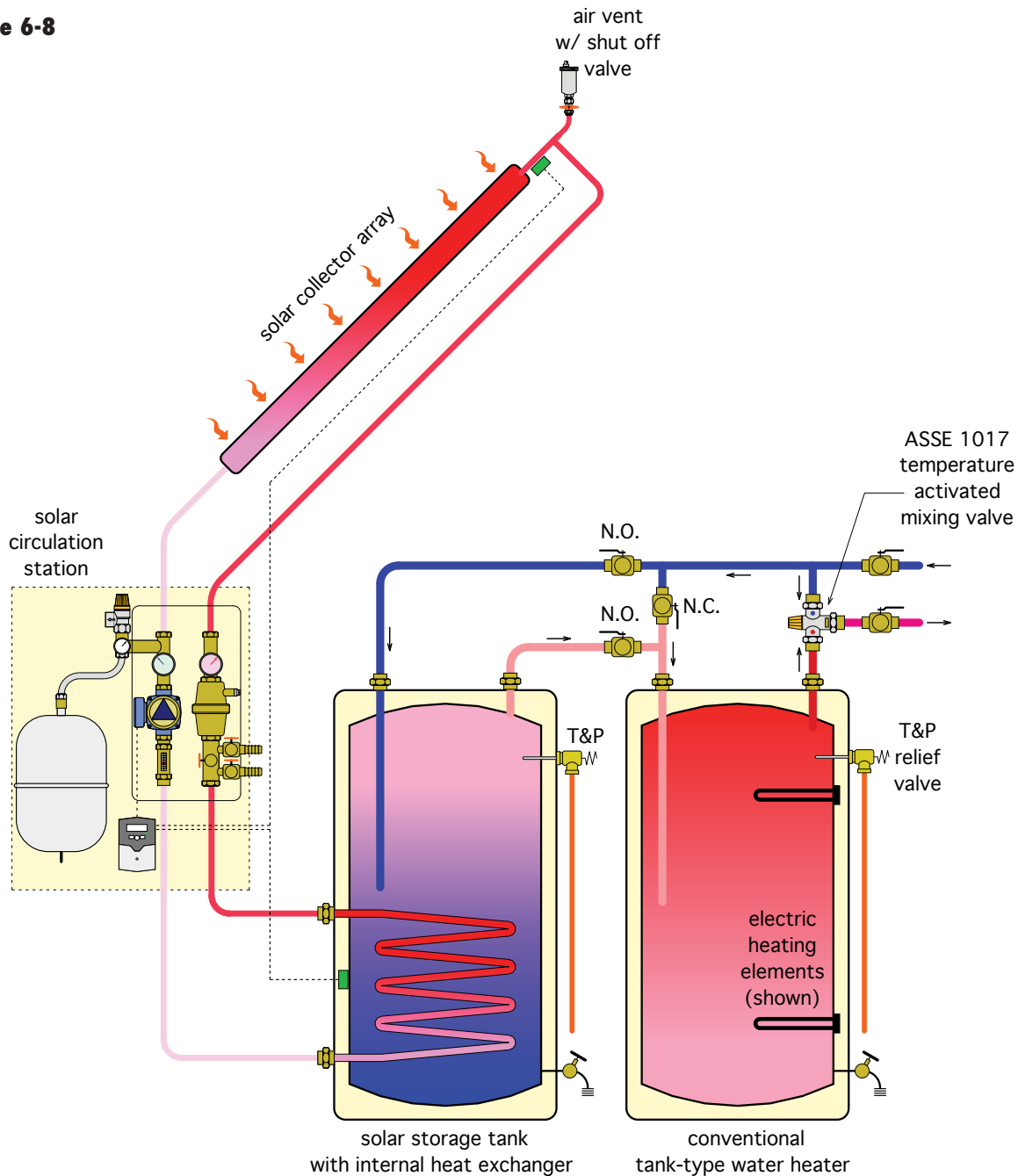
In a two-tank system, all cold water enters the solar storage tank. During sunny weather, this tank may provide all the heating necessary to bring the water to, or above, the desired hot water delivery temperature. However, during less favorable conditions, the water in the solar storage tank may only be partially heated. When there is a demand for domestic hot water, water from the solar storage tank flows to the inlet connection of a conventional tank-type water heater. When necessary, this second tank provides a temperature boost. An ASSE 1017 temperature activated mixing valve should always be installed on the outlet of the second tank.



Even when water leaving the solar storage tank has only been partially heated, there can be a substantial reduction in conventional energy use. For example, water heated from 50° to 90°F represents about (40/70) or 57% of the total energy needed to raise that water to a final delivery temperature of 120°F. It requires just as much heat to raise a gallon of water from 50° to 51°F as it does to raise that water from 119° to 120°F. Energy input at the lower end of the overall temperature rise is ideal for the solar portion of the system because low operating temperatures improve collector efficiency.

Two-tank systems usually provide slightly higher solar energy collection on an annual basis compared to single-tank systems. This is due to increased storage mass and the separation of auxiliary energy input from the solar storage tank. However, poorly insulated storage tanks can all but erase this potential performance advantage through increased heat loss to surrounding air. Unless local codes require higher, all storage tanks should be

**Figure 6-8**



insulated to a minimum of R-12 ( $^{\circ}\text{F}\cdot\text{hr}\cdot\text{ft}^2/\text{Btu}$ ), and all connecting piping should be insulated to at least R-4 ( $^{\circ}\text{F}\cdot\text{hr}\cdot\text{ft}^2/\text{Btu}$ ).

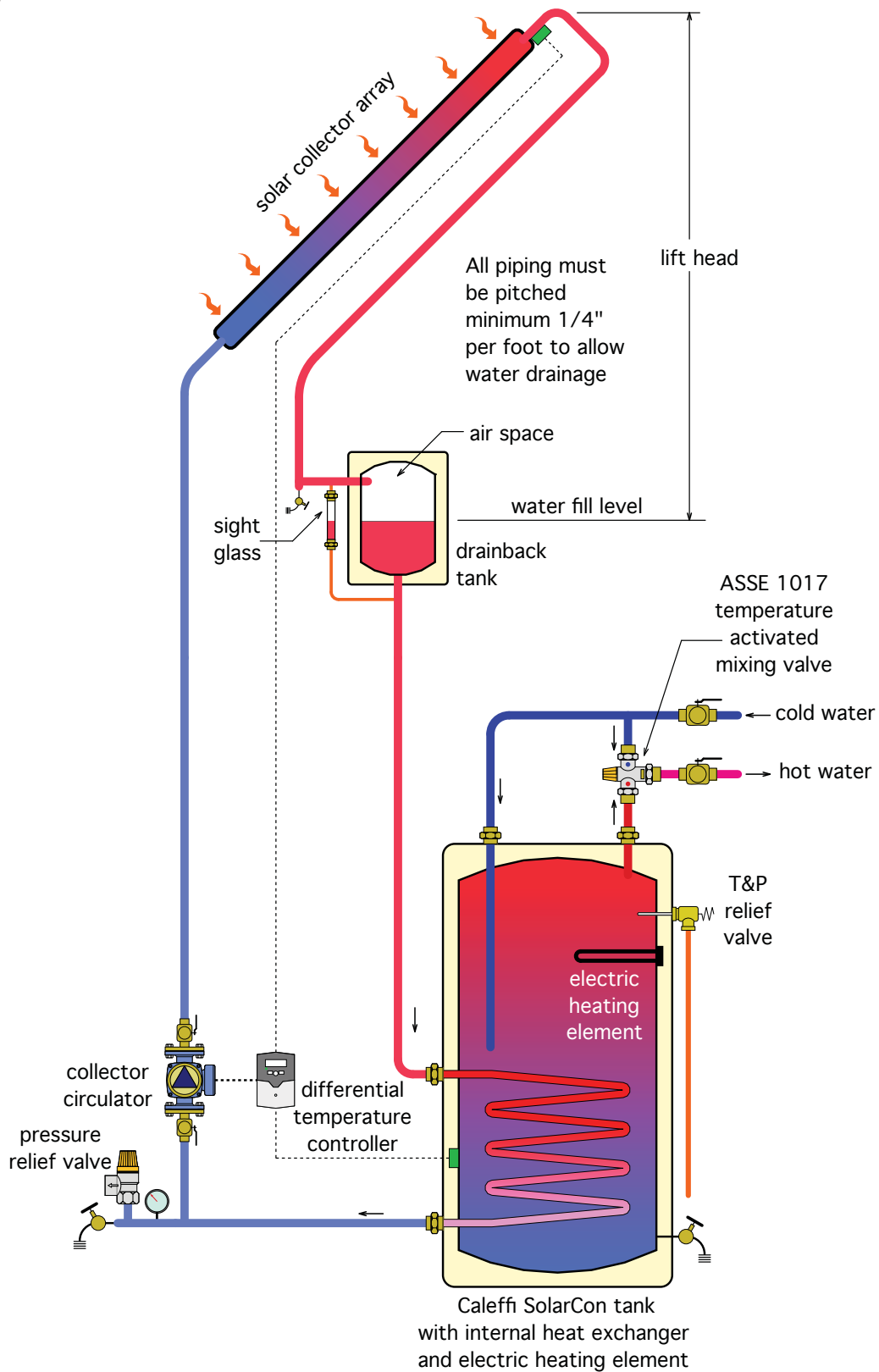
A set of three ball valves is shown on the piping between the tanks. These valves allow the solar storage tank to be completely isolated from the conventional tank, and the latter to act as the sole water-heating device if the solar subsystem is shut down for servicing. Also

note that both tanks are equipped with pressure and temperature relief valves.

### **DRAINBACK SYSTEMS**

Systems using drainback freeze protection do not require antifreeze. Instead, they are designed so that all water in the collector array and exposed piping runs back into a special "drainback" tank whenever the collector circulator is not operating. Figure 6-9 shows the concept.

**Figure 6-9**



In drainback systems, it is crucially important that the solar collectors and all piping between the collectors and the storage tank be pitched for proper drainage. All piping should slope downward with a minimum pitch of 1/4" per foot. This allows water to rapidly drain from the collectors and piping as soon as the circulator turns off.

If standard "harp-style" flat plate collectors are used in a drainback system, they should be sloped sideways to allow proper drainage, as shown in Figure 6-10.

Caleffi North America offers specially designed "StarMax V" collectors that have internally sloped manifolds and a center drain port at the bottom. These collectors can be used in a drainback *without sideways slope*, as shown in Figure 6-11. The bottom center port of each collector is connected to an external supply header. That header must slope a minimum of 1/4" per foot for proper drainage.

The collector circulator in a drainback system must be capable of *lifting* water from its static fill level in the

drainback tank to the top of the collector array. This usually requires a circulator that can produce a higher head than would be required in a closed-loop/antifreeze type system.

When the circulator is first turned on, it must lift water to the top of the collector array *and maintain that water moving through piping at the top of the array at a flow velocity of at least 2 feet per second*. The piping from the collectors back to the drainback tank should also be sized to maintain a *minimum* flow velocity of 2 feet per second. These conditions allow the water to "entrain" air in the piping and efficiently return it to the top of the drainback tank at the beginning of each operating cycle.

Once air is returned to the drainback tank, a siphon is established within the collector circuit. The siphon helps "cancel out" the initial lift head present when the circulator turns on. This greatly reduces the necessary electrical power input to the collector circulator. Modern differential temperature controllers take advantage of this by operating the circulator at full speed when it turns on, and then reducing its speed when the siphon is established.

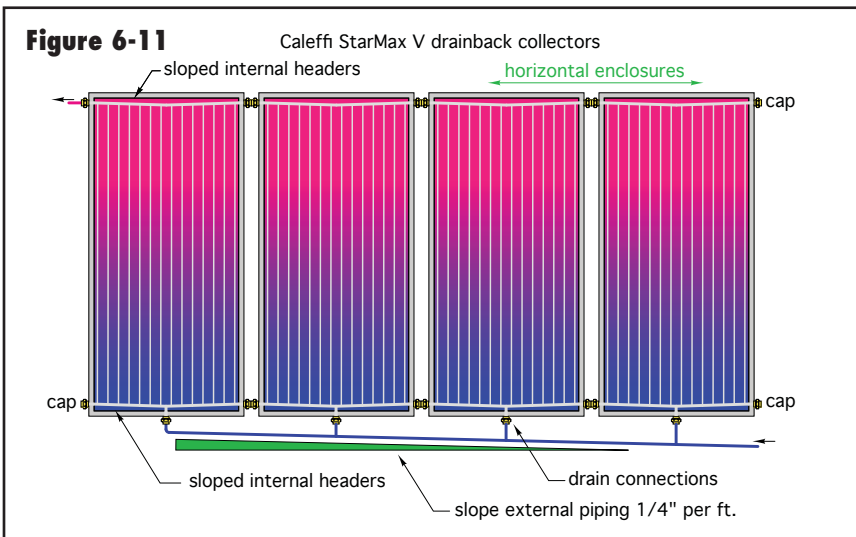
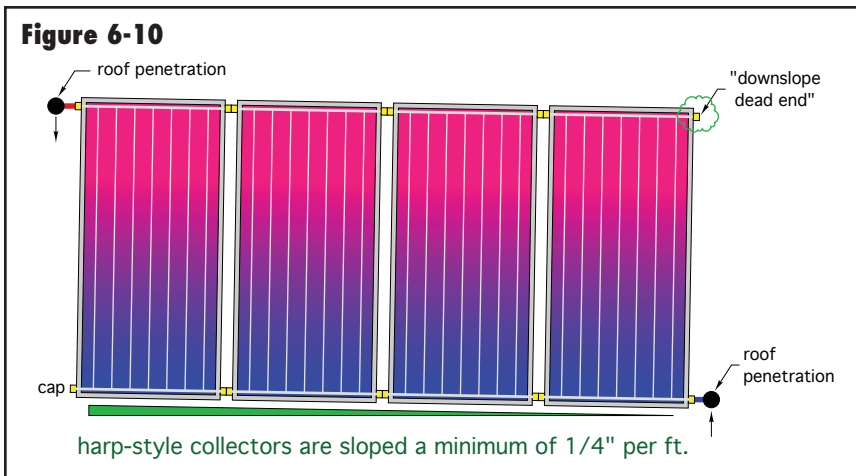
*idronics 6* provides further information on sizing the circulator and piping in a drainback system.

Figure 6-12 shows another way to create a closed-loop/pressurized, drainback-protected solar water heating system.

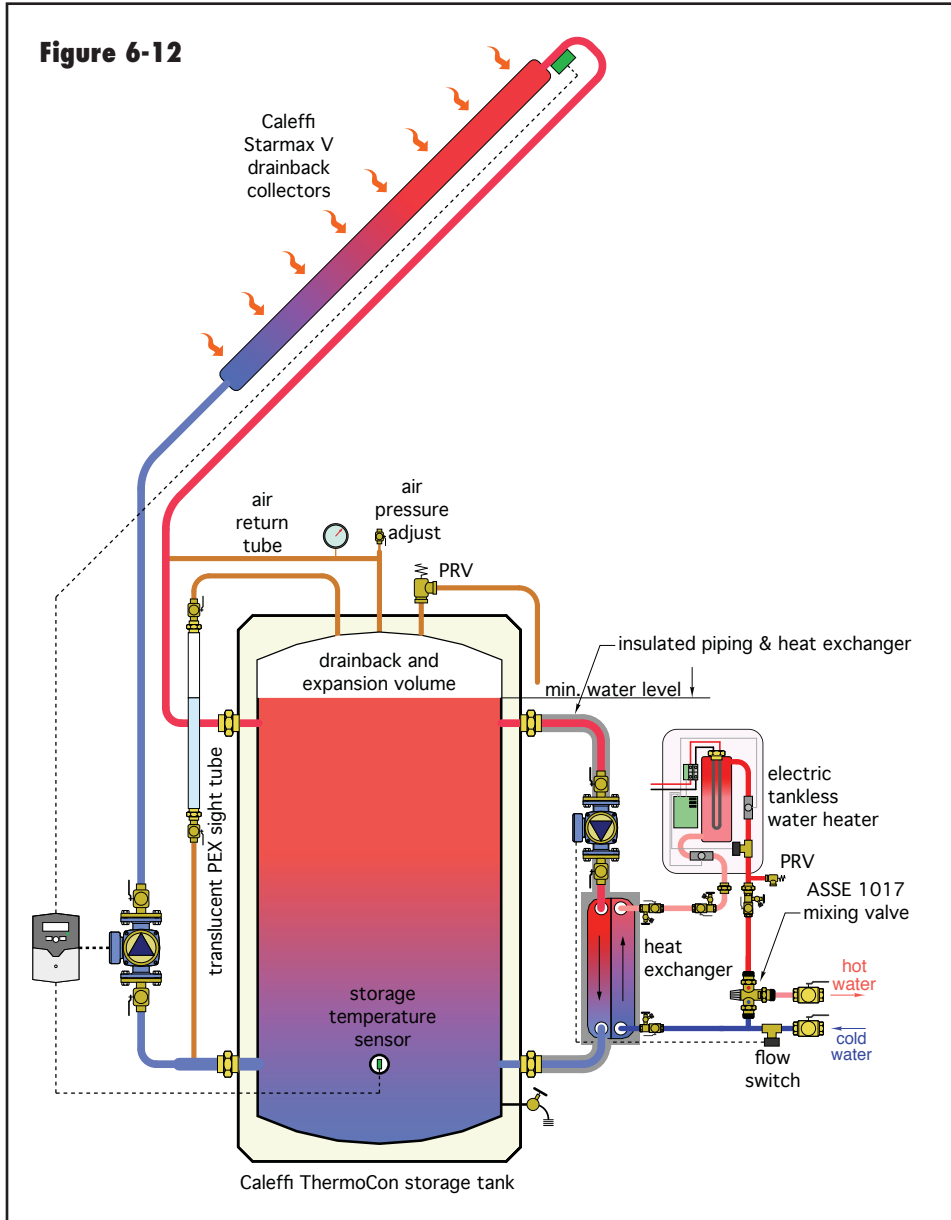
This system combines Caleffi StarMax V drainback collectors with the Caleffi ThermoCon storage tank. The tank is configured to provide thermal storage, a drainback reservoir, and an expansion volume for the water in the system. The "captive" air space at the top of the system provides the latter two functions.

A sight glass is shown on the left side of the tank. It consists of a length of translucent PEX tubing, with brass adapter fittings and isolation valves at each end. While not as transparent as glass, translucent PEX tubing provides sufficient light passage to see the fluid level inside. If this tubing ever loses its translucency, it can be easily replaced.

The solar collection process operates as it would in any other drainback-type system. The differential temperature controller turns on the collector circulator



**Figure 6-12**



Domestic water is heated instantaneously as it is needed. A flow switch detects whenever domestic water is required at a flow rate at or above 0.5 gpm. Under this condition, it turns on a small circulator that moves heated water from the top of the thermal storage tank through the primary side of a stainless steel heat exchanger. Cold water is instantaneously preheated (or fully heated, depending on the tank temperature) as it passes through the other side of the heat exchanger.

A thermostatically controlled electric tankless water heater provides any necessary boost in hot water delivery temperature. If the water entering the tankless water heater is already at or above the heater's setpoint, the electric heating element remains off. An ASSE 1017 temperature activated mixing valve protects against high domestic water delivery when the storage tank is at an elevated temperature. For the fastest possible response, the piping between the storage tank and heat exchanger should be short and fully insulated. Combination isolation/flushing valves should be installed on the domestic water inlet and outlet of the heat exchanger, as well as on the tankless water heater, to allow these components to be isolated and flushed if necessary.

when conditions are favorable for solar energy collection. The circulator lifts water through the upper piping and establishes a siphon in the return piping. The air in the collectors is then entrained by the flowing water and is returned to the top of the storage tank. When the controller turns off the collector circulator, air immediately leaves the top of the tank and flows through the air return tube to allow rapid drainage of the collectors and piping.

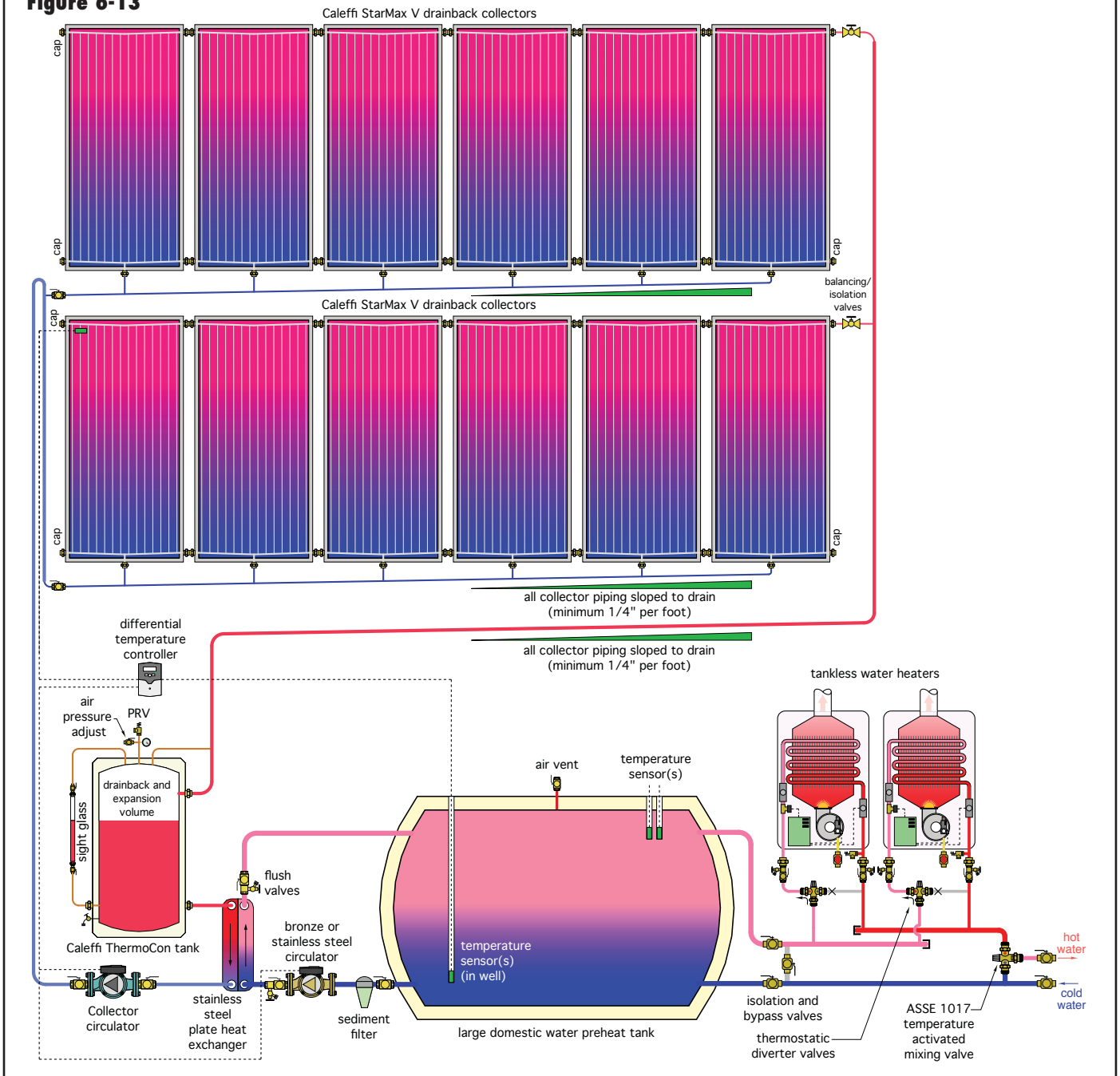
The water stored in the tank is not domestic water. It is "system" water, and as such, remains in the tank for years. Thus, the tank and collector array are a closed-loop system operating under slight (10-15 psi) positive pressure. Any corrosion due to oxidation is minimized in such a system, as is water loss from evaporation.

It is suggested that the stainless steel heat exchanger be sized for an approach temperature difference of not more than 10°F. Thus, if the desired domestic hot water supply temperature is 120°F, the hot water entering the primary side of the heat exchanger from the storage tank should not be assumed higher than 130°F. Closer approach temperature differences are possible, but will increase the required size of the heat exchanger.

The benefits of this approach include:

- The storage tank is never heated by the auxiliary heat source. This improves collector efficiency relative to systems where the upper portion of the storage tank is maintained at elevated temperature by the auxiliary heat source.

**Figure 6-13**



- The full thermal mass of the storage tank is available to stabilize domestic hot water delivery temperature during lengthy demands.
- The standby heat loss associated with a second DHW storage tank is eliminated.
- The stainless steel heat exchanger can be easily inspected, cleaned and replaced as necessary.
- The “warm up” time of this assembly is shorter than that of a gas-fired tankless water heater because there is no need to initiate/prove combustion.
- The possibility of Legionella is reduced, since very little domestic hot water is “stored” in this assembly.
- No antifreeze is required.



## LARGE DRAINBACK SOLAR WATER HEATING SYSTEMS

Drainback freeze protection can also be applied to larger solar water heating systems. An example of such a system is shown in Figure 6-13.

This system has two banks of Caleffi StarMax V drainback collectors. The banks are piped in reverse return to help equally divide the total flow. A combination balancing/isolation valve is located on the inlet header to each bank, along with a ball valve on the outlet of each bank. This allows each bank to be isolated if necessary. As in smaller drainback systems, all piping in the collector circuit must be sloped to drain with a minimum pitch of 1/4" per foot.

The heated water returning from the collector array enters a Caleffi ThermCon tank, which serves as the drainback and expansion vessel for the closed solar collector circuit. This tank is well insulated for minimal heat loss. The connections available on the tank allow for attachment of a sight glass as well as other trim, such as a pressure relief valve, a pressure gauge and a schrader valve for changing the air pressure in the collector circuit. This tank should be as small as possible, while still accommodating the full drainback volume and allowing some volume to reduce pressure fluctuations due to thermal expansion of the water in the collector circuit.

From this tank, the solar heated water passes through an appropriately sized stainless steel heat exchanger. The other side of this heat exchanger has domestic water from the bottom of the main storage tank passing through in the opposite (counterflow) direction. The heat exchanger should be sized for an approach temperature difference not higher than 10°F. A strainer upstream of the domestic water circulator and heat exchanger minimizes sediment entry into these components. A set of isolation/flushing valves are provided on the domestic side of the heat exchanger to allow for flushing.

At times, the domestic water leaving the main storage tank may be hot enough to supply the fixtures without further heating. If so, the thermostatic diverter valves on the inlet of each gas-fired tankless water heater divert this water around the auxiliary tankless water heaters and directly to the main temperature activated mixing valve. When water leaving the storage tank needs a temperature boost, the diverter valves route it through the tankless heaters. A set of isolation and bypass ball valves are provided that allow the solar portion of the system to be completely bypassed if necessary for maintenance.

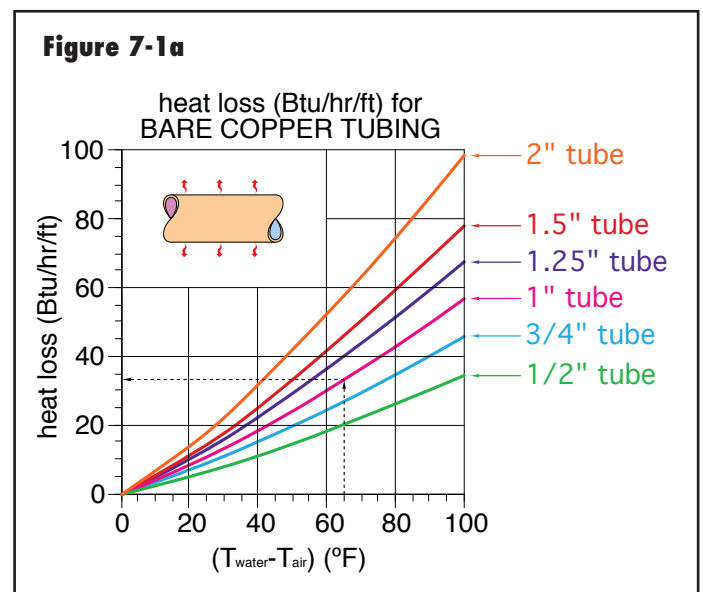
## 7. RECIRCULATING DOMESTIC HOT WATER SYSTEMS

Hot water distribution piping in homes and smaller commercial buildings is often designed with a "main" pipe that supplies several branches leading to individual fixtures. When the distance between the hot water source and the farthest fixture is only a few feet, such a piping system provides acceptable performance.

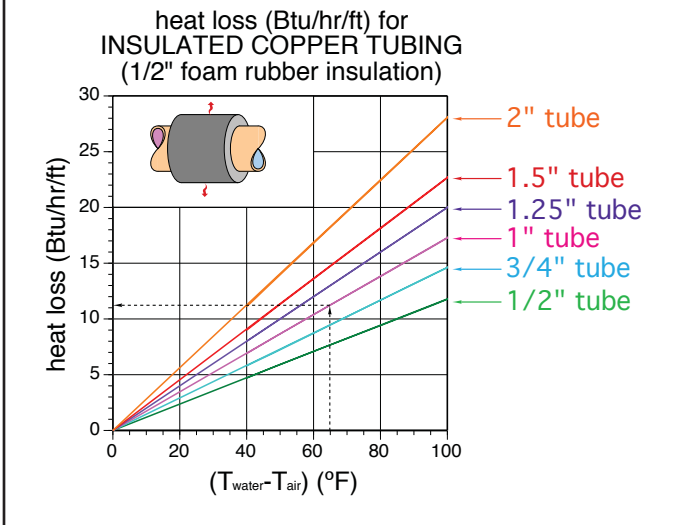
However, as the distance between the hot water source and the farthest fixture increases, so does the "wait time" for hot water delivery to the farthest fixture. This is especially noticeable (and arguably most annoying) when water in the hot water piping has cooled substantially due to lack of demand for several hours.

When the demand for hot water at a fixture has ended, this type of delivery system also causes hot water to remain "stranded" in the distribution piping. The amount of stranded hot water varies with the size(s) of piping involved and the distance to the fixture. Over time, this stranded water cools as the pipe loses heat to its surroundings. The rate of cooling depends on the type of pipe (copper, CPVC, PEX, etc.), its size, the type and thickness of any insulation covering the pipe, and the surrounding air temperature.

Figure 7-1a can be used to estimate the rate of heat loss from *bare copper water tubing* based on the difference in temperature between the water in the tube and the surrounding air temperature. Figure 7-1b can be used to estimate the heat loss from copper tubing wrapped with 1/2" thick foam rubber insulation.



**Figure 7-1b**



To use these graphs, subtract the air temperature surrounding the tube from the average water temperature inside the tube, and then find this difference on the

horizontal axis. Read up to the line corresponding to the tube size, and then over to the vertical axis to find the heat loss per foot of tubing.

For example: Assume that a 1" bare copper tube carries water at an average temperature of 120°F for a distance of 50 feet, through a space where the air temperature is 55°F. Estimate the total rate of heat loss from this tube.

Solution: Since this involves bare copper tubing, use Figure 7-1a. The difference between the average water temperature and surrounding air temperature is  $(120 - 55) = 65^\circ\text{F}$ . Draw a line from 65°F on the horizontal axis up to the curve for 1" tubing, and then a horizontal line over to the vertical axis. The rate of heat loss is about 33 Btu/hr per foot of tubing. The total heat loss from the 50-foot pipe is therefore approximately  $33 \times 50 = 1,650$  Btu/hr.

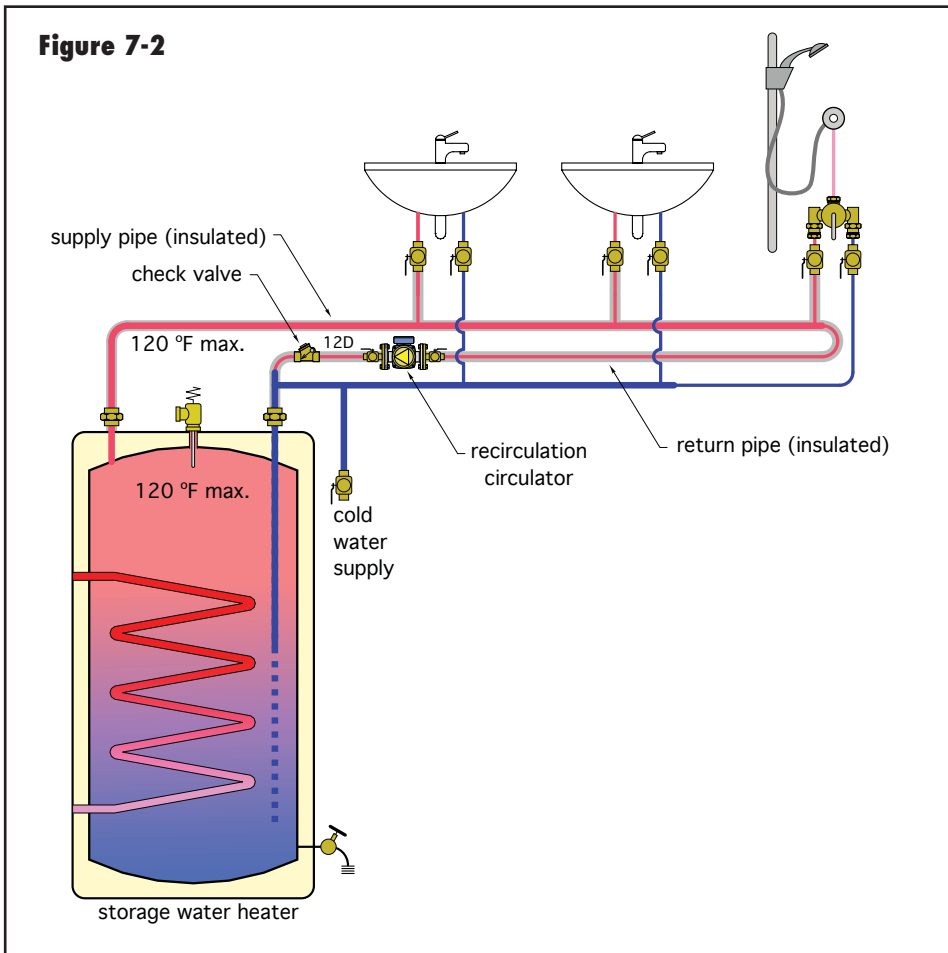
By comparison, Figure 7-1b shows that heat loss from 1" copper piping wrapped with 1/2" thick foam rubber insulation is about 11.2 Btu/hr per foot, about one-third that of the uninsulated copper tube.

All heat lost from hot water distribution piping is undesirable from several standpoints:

- When the water in the pipe has cooled for several hours, it will be close to the surrounding air temperature. This cool water will likely be sent down the drain by a person who *wants* hot water for washing or other purposes. Significant quantities of water, as well as the energy to heat it, are lost each time this occurs. Once source estimates that the average American home wastes over 11,000 gallons of water each year due to the "wait time" for hot water to arrive at fixtures.

- Waiting for hot water to flow from the fixture is annoying, especially in buildings with long "dead end" piping systems, where wait times can be more than 2 minutes. These wait times are often longest in the early morning following a period when little if any hot water has passed through the dead end piping.

**Figure 7-2**



- Heat escaping from hot water piping adds to building cooling loads in warm weather. The greater the cooling load, the greater the cost of operating the cooling system.
- Warm water standing in piping improves the growth environment for any Legionella bacteria.

To alleviate these issues, many hot water distribution systems, especially those used in large homes or commercial buildings, use recirculation. In its simplest form, a recirculating hot water distribution system uses a small stainless steel or bronze circulator and a return pipe, as shown in Figure 7-2.

In this system, hot water at a maximum temperature of 120°F flows from the storage water heater, out through the building along the supply main, and then back to the storage heater through insulated return piping.

This allows hot water to be available within a few feet of each fixture whenever the circulator is operating. Because there is some heat migration in the piping between the hot water main and the fixture, heated water will flow from the fixture approximately one second after the faucet is opened.

As hot water is drawn from a fixture, an equal volume of cold water enters the distribution system. A check valve downstream of the circulator ensures that this cold water flows into the storage water heater, and not backward along the return line (if the circulator happens to be off).

To minimize heat loss, the hot water supply pipe, the return pipe and the hot water risers to each fixture are insulated.

### RECIRCULATION FLOW RATE

The goal of a recirculating hot water distribution system is to keep the water temperature at the last fixture served by the supply pipe within a few degrees of the temperature water at the beginning of the supply pipe. The temperature drop along the supply pipe is caused by the heat loss. This heat loss can be estimated based on the size and length of piping in the loop, as well as the average water temperature, surrounding air temperature and the effect of any insulation on the pipe.

It's common to allow temperature drops of 5° to 10°F between the beginning and end of a recirculating hot water loop. The smaller the allowed temperature drop, the less variation in delivery temperature between fixtures connected near the beginning versus the end of the loop. However, low allowable temperature drops also increase

the required recirculation flow rate and circulator size. Formula 7-1 can be used to estimate the necessary recirculation flow rate based on the total heat loss of the recirculating loop and the allowed temperature drop.

Formula 7-1:

$$f_r = \frac{Q}{500 \times \Delta T}$$

Where:

$f_r$  = the required recirculation flow rate (gpm)

$Q$  = total heat loss of the recirculation loop (Btu/hr)

$\Delta T$  = the allowed temperature drop.

For example: Assume a recirculation loop consists of 100 feet of 1" bare copper tubing between the start of the loop and the last fixture served, as well as 100 feet of 1/2" bare copper tubing from the last fixture connection point back to the heat source. Water enters the loop at 135°F, and the allowed temperature drop of the loop is 10°F. The air temperature surrounding the piping is 70°F. Determine the required recirculation flow rate.

Solution: The heat loss of the recirculation loop is estimated based on the piping heat loss for both the 100 feet of 1" tubing and 100 feet of 1/2" tubing. Figure 7-1a can be used to make these estimates. Since the supply temperature is 135°F and the allowable temperature drop is 10°F, the average water temperature is 130°F. Using data from Figure 7-1a, the estimated heat loss from the 1" piping is 30 Btu/hr/ft, and that from the 1/2" piping is 18 Btu/hr/ft. Thus, the total estimated heat loss of the loop is:

$$Q = \left( 30 \frac{\text{Btu}}{\text{hr} \cdot \text{ft}} \right) 100 \text{ ft} + \left( 18 \frac{\text{Btu}}{\text{hr} \cdot \text{ft}} \right) 100 \text{ ft} = 4,800 \frac{\text{Btu}}{\text{hr}}$$

The recirculation flow rate is now determined using Formula 7-1:

$$f_r = \frac{Q}{500 \times \Delta T} = \frac{4800}{500 \times 10} = 0.96 \text{ gpm}$$

The next step is to estimate the head loss of the recirculating loop at this flow rate. The methods and data in Appendix B can be used to estimate this head loss.

The estimated head loss from 100 feet 1" copper at 0.96 gpm is 0.08 feet.

The estimated head loss from 100 feet of 1/2" copper at 0.96 gpm is 1.52 feet.

Thus, the total estimated head loss of the straight piping in the circuit is (0.08 + 1.52) = 1.6 feet.

**Figure 7-3**



Courtesy of Grundfos

This will be increased by 50% to include an allowance for head loss of fittings and valves, and for possible internal scaling of the pipe walls that could increase head loss over time.

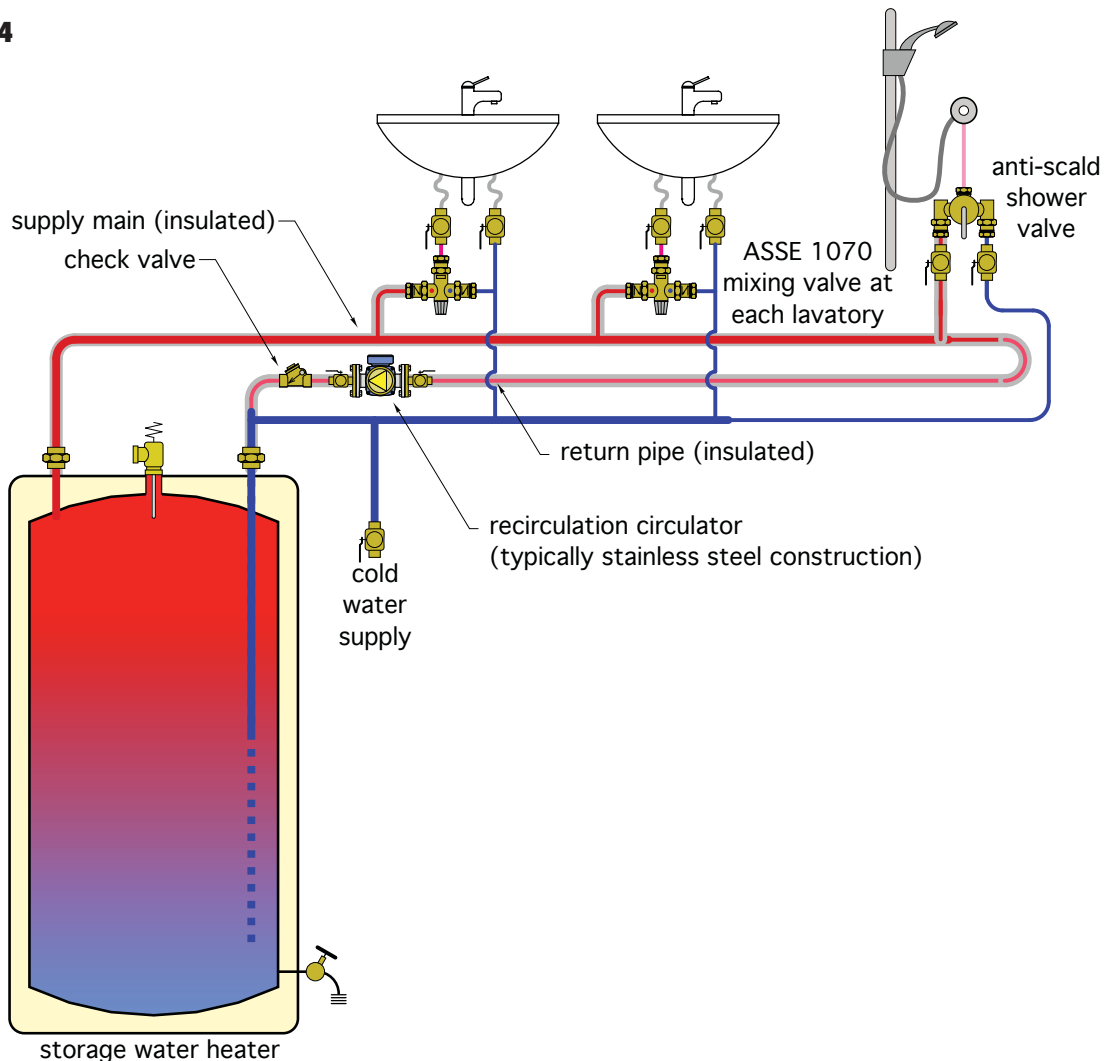
Total estimated (long term) head loss is  $(1.6 \text{ feet}) \times 1.5 = 2.4 \text{ feet}$ .

Thus, the total pumping requirement is 0.96 gpm at 2.4 feet.

This is a relatively small pumping requirement and can be handled by a very small circulator designed specifically for recirculation systems. Such circulators typically operate with electrical inputs of 10 to 40 watts, and thus consume very little electrical energy. An example of a circulator specifically designed for domestic water recirculation is shown in Figure 7-3.

To further reduce electrical consumption and heat loss from piping, some “recirc” circulators are equipped with timers that can be set to turn them off at night or during other periods of low or no hot water demand. Other recirc circulators are equipped with fuzzy logic electronics that

**Figure 7-4**



learn household hot water usage patterns over a period of time. This information is used to turn the circulator on and off to match hot water usage patterns in the building. The goal is to minimize thermal and electrical energy usage while still delivering reliable and nearly instant availability of hot water at fixtures.

**RECIRCULATION WITH MIXING VALVES**

Although the system shown in Figure 7-2 is functional, it lacks the safety associated with either a single ASSE 1017 point-of-distribution (POD) mixing valve or multiple ASSE 1070 point-of-use temperature activated mixing valves, one at each fixture. Without one of these mixing valve configurations, the temperature of the water leaving the fixtures will be essentially the same as the temperature at the top of the tank. If the tank’s thermostat is set above 120°F, or its temperature controller is inaccurate, or the tank is heated by a source such as solar collectors, the water temperature at the fixtures could cause scalding burns.

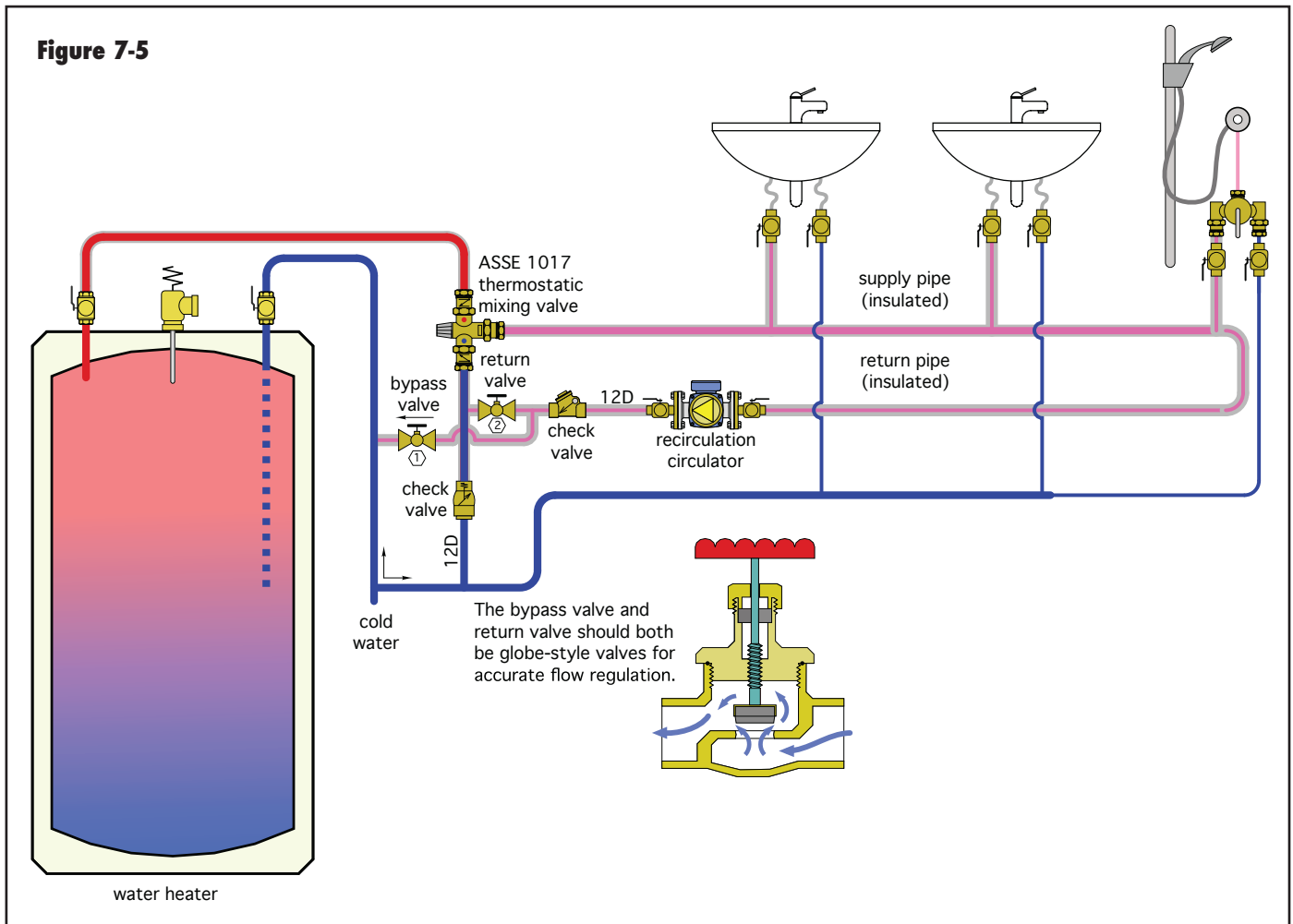
Figure 7-4 shows how the system from Figure 7-2 can be modified to include an ASSE 1070 POU mixing valve at each lavatory and a shower valve with integral anti-scald protection.

This configuration allows the water temperature leaving the hot water source to be above 120°F, such as may be necessary to kill Legionella bacteria. It also allows lower, individually set delivery temperatures at each fixture.

**RECIRCULATION WITH P.O.D. MIXING VALVES**

Figure 7-5 shows a recirculating system that includes a single ASSE 1017 point-of-distribution temperature activated mixing valve.

In any recirculating hot water distribution system there will be times when the circulator is operating, but no hot water is being drawn at the fixtures. Under this condition, heat continually dissipates from the piping forming the recirculation loop. If the loop is relatively short and well insulated, the rate of heat loss should be very small. If the



loop is long and uninsulated, the rate of heat loss could be substantially greater.

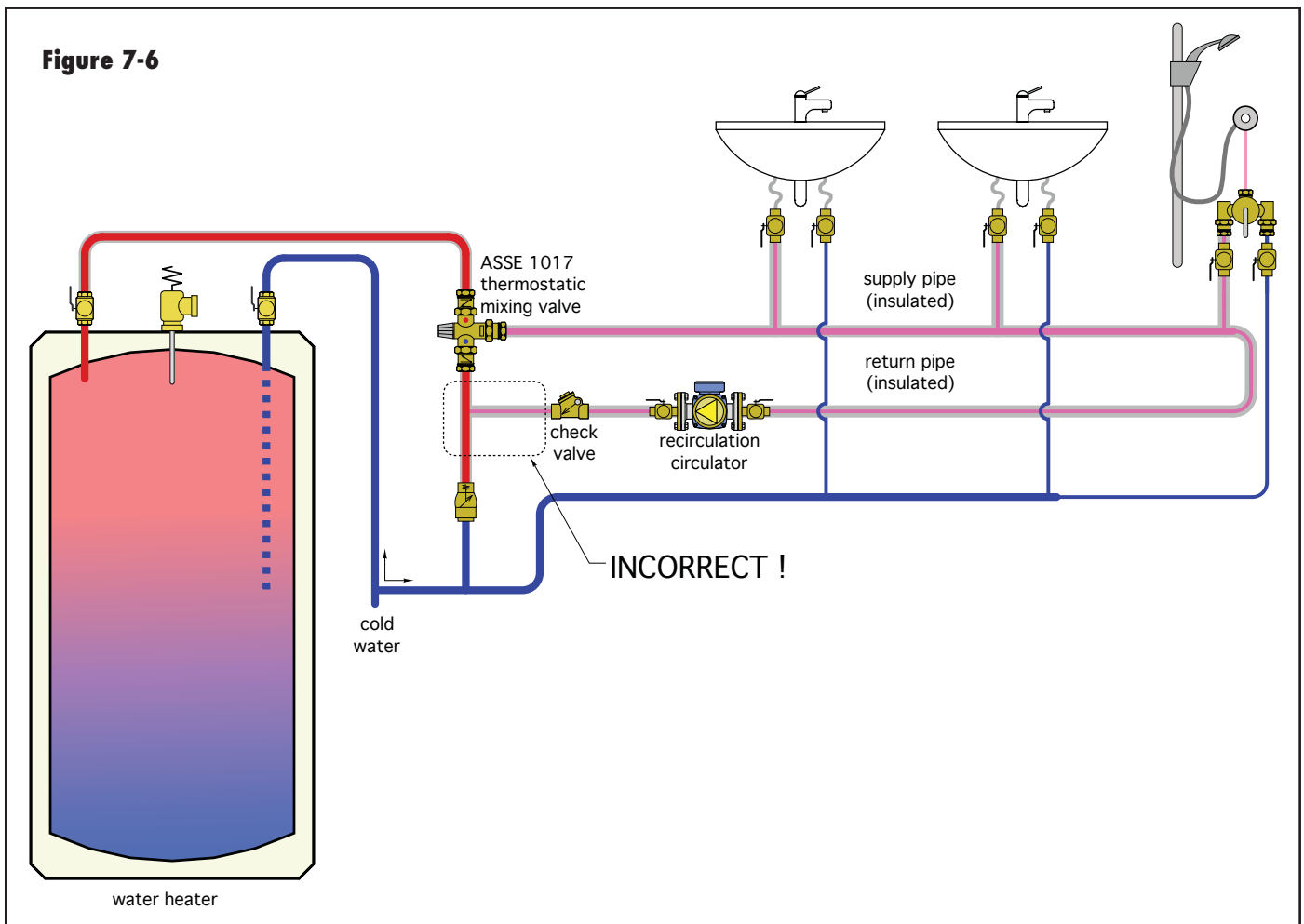
To maintain the recirculating hot water at the desired delivery temperature, the heat lost from the loop must be replaced. This requires some water flow between the loop and the hot water source. *Ideally, this flow is adjusted so that the rate of heat transfer from the hot water source to the loop exactly balances the rate of heat loss from the loop's piping.*

A common *mistake* is to tee the return side of the recirculating loop to the cold water pipe supplying the temperature activated mixing valve, as shown in Figure 7-6.

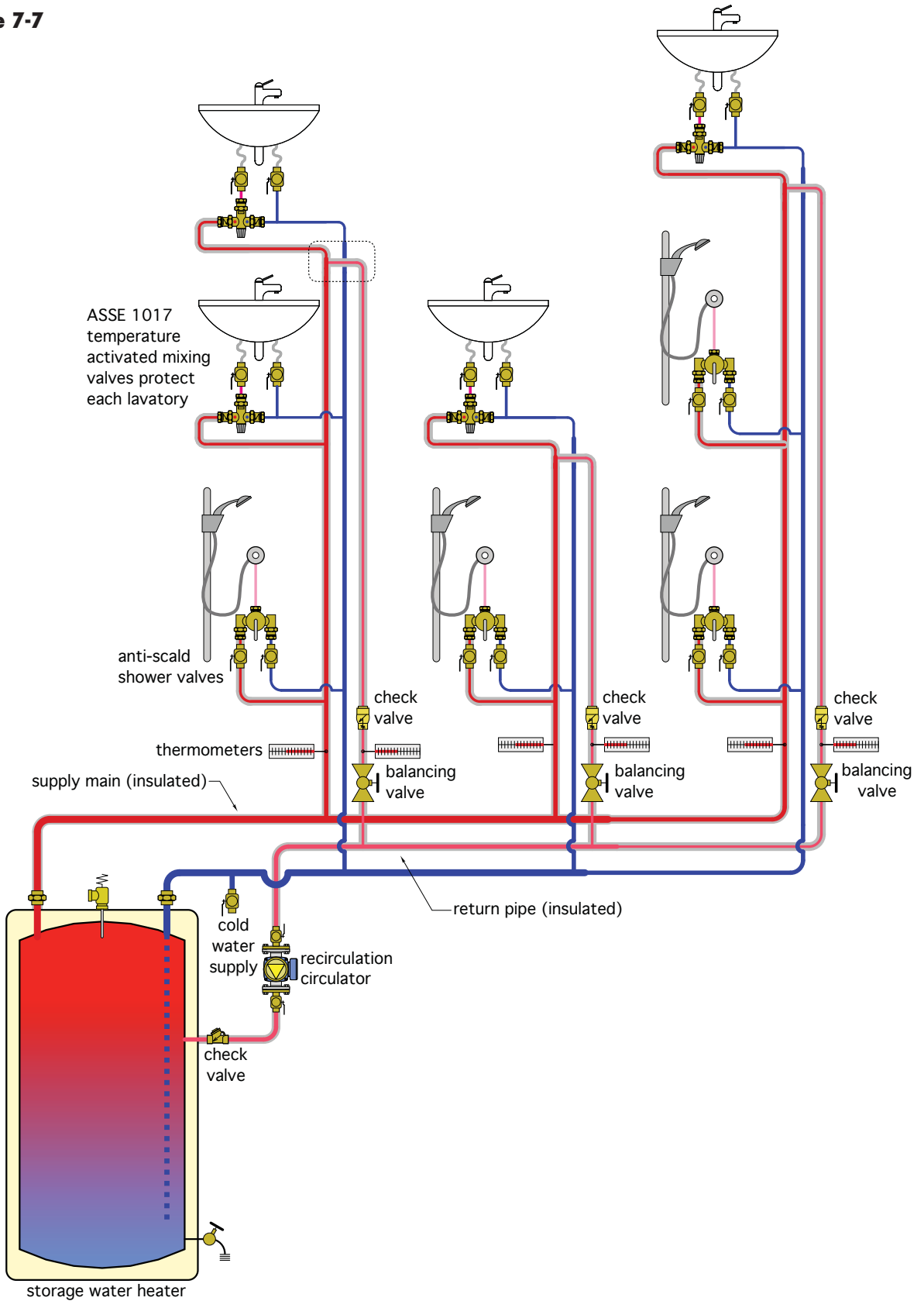
This piping causes the cold port of the mixing valve to approach fully open, while the hot port approaches fully closed. Under this condition, the rate of heat loss from the recirculating loop is greater than the rate of heat "injection" from the tank into the loop. This causes the water temperature in the loop to *drop*, often well below the desired setpoint.

The correct piping, shown in Figure 7-5, includes a "bypass valve" (1) and "return valve" (2). The purpose of these valves is to regulate how much warm water from the return side of the recirculating loop flows back to the storage tank. When there is no demand for hot water at the fixtures, the flow of return water to the tank will equal the rate of hot water flow from the tank to the inlet port of the mixing valve. Ideally, this flow rate should be adjusted so that the rate of heat transfer from the tank to the recirculating loop exactly balances the rate of heat loss from the recirculating loop. This allows the water temperature leaving the temperature activated mixing valve to remain stable.

The bypass valve (1) and *possibly* the return valve (2) must be adjusted when there is *no domestic water draw on the recirculating loop* (e.g., all fixtures are off). Begin with the bypass valve (1) fully closed and the return valve (2) fully open. Turn on the recirculating circulator and let it run for several minutes. Under this condition, the supply water temperature leaving the temperature activated mixing valve will likely be *lower* than the setting of the valve (since there is no return flow to the tank).



**Figure 7-7**



Slowly open the bypass valve (1) and monitor the temperature leaving the mixing valve. It will likely begin rising as some water returns to the tank and an equal flow of hot water moves from the tank to the hot port of the mixing valve. When the temperature leaving the mixing valve remains stable, and is at or very close to the temperature set on the temperature activated mixing valve, the bypass valve is correctly set.

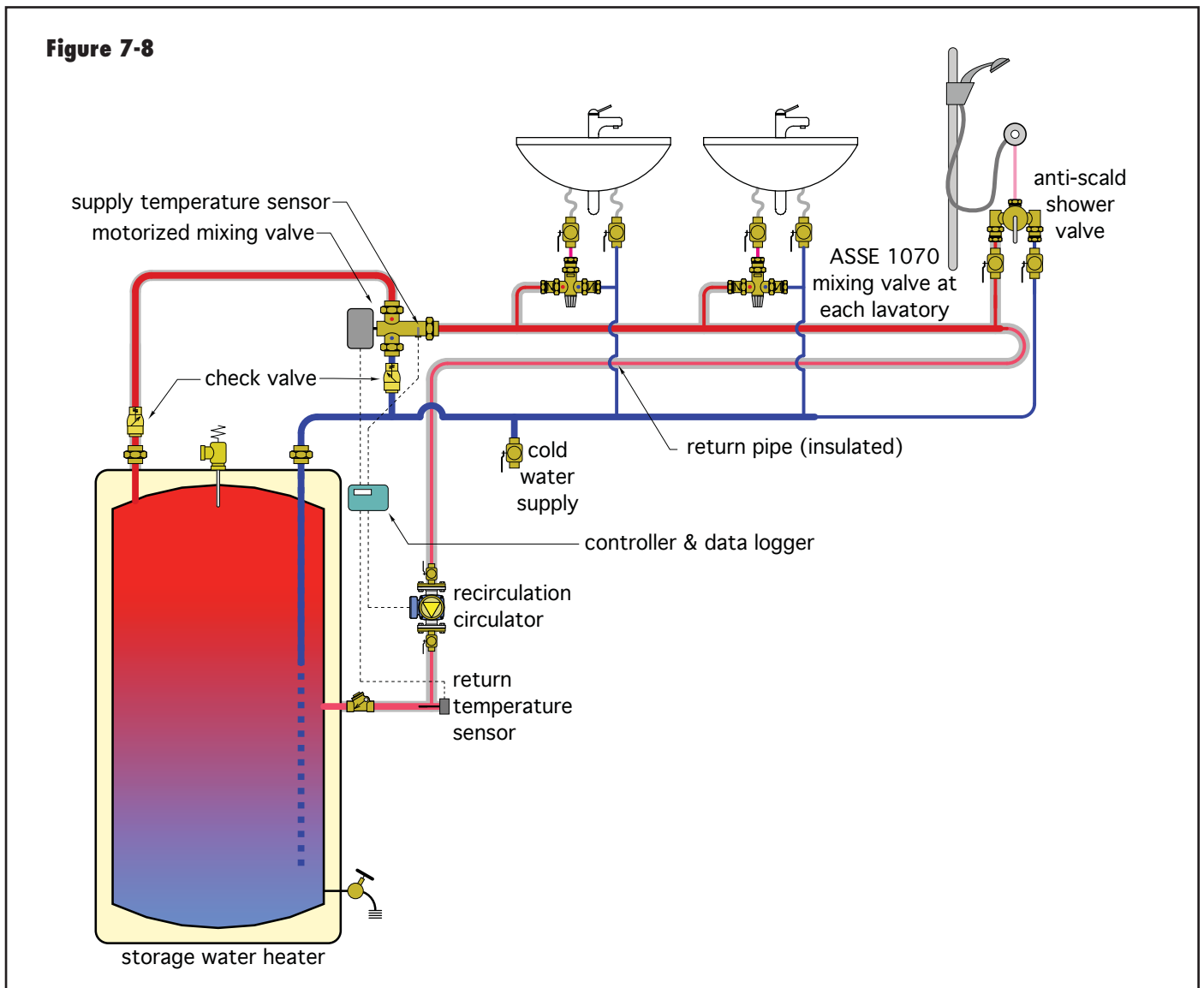
The return valve (2) can remain fully open unless a situation occurs where the bypass valve (1) is fully open, but the temperature leaving the mixing valve is still too low. If this occurs, partially close the return valve (2) to add flow resistance. This forces more flow through the bypass valve (1). Repeat the previously described procedure of slowly opening the bypass valve (1) until the water temperature leaving the mixing valve is stable.

### BALANCED RECIRCULATION SYSTEMS

In some buildings, the recirculation system will be designed as shown in Figure 7-7.

Multiple hot and cold water risers are supplied from common hot and cold water mains. The number and type of fixtures served by each set of risers will often be different. A recirculation riser accompanies each set of hot and cold risers. A single circulator provides recirculation flow through the entire system.

This type of piping network is similar to a 2-pipe direct return distribution system for hydronic heating. Because of differences in the lengths or sizes of both the mains piping and riser piping, the recirculation flow through each set of risers is likely to be different. This can lead to different temperature drops between the beginning of a





given hot water riser and the end of its associated return riser. This may cause the hot water temperature arriving at a distant fixture to be insufficient for the intended usage.

This situation can be corrected by “balancing” the recirculation flow between the various sets of risers. The goal of such balancing is to establish recirculation flow rates that create *equal temperature drop* between the start of each hot water riser and the end of its associated return (recirculation) riser.

Balancing is enabled by installing globe-style valves near the end of each return riser, as shown in Figure 7-7. These valves must be rated for contact with potable water, and thus must be (or soon must be) classified as “lead-free” within the U.S.

Other details in this type of system include installation of a check valve near the end of each recirculation riser to prevent reverse flow. Also, when the risers are vertical, as shown in Figure 7-7, the recirculation pipe should tee into the hot water riser *below the final fixture take off*. This allows any air bubbles that may be present in the hot water riser to leave each time hot water is drawn at the highest fixture.

### **ELECTRONICALLY CONTROLLED MIXING**

It is also possible to use an *electronically controlled* motorized mixing valve to regulate the temperature of domestic hot water. This approach allows control options that are not possible with thermostatically controlled valves.

Figure 7-8 shows an example of a recirculating system using an electronically controlled domestic hot water mixing valve.

Like its thermostatic counterpart, this valve mixes hot water from the heat source with cold water to achieve a set delivery water temperature. A temperature sensor mounted in the outlet port of the mixing valve provides the controller with constant readings of the supply temperature. The controller provides a signal to the valve’s actuator, which adjusts the amounts of hot and cold water entering the valve.

A unique feature of this valve/controller combination is the ability to periodically elevate the water temperature in the recirculation loop to quickly kill any Legionella bacteria that may be present. This “sterilization cycle” typically takes place at night when there is minimal demand for hot water at fixtures. During the cycle, the controller monitors both supply and return water temperature within the recirculation loop, and maintains a specific sterilization temperature at the return side of the loop over a preset

time. The controller also records that such conditions have been maintained. The sterilization cycle ensures that Legionella bacteria are eliminated in all portions of the recirculation loop. A failure to maintain the predetermined sterilization conditions would be logged by the controller and an appropriate alarm message would be dispatched by the controller.

Because the water in the hot water supply and return piping is at an elevated temperature during the sterilization cycle, it is essential to have ASSE 1070 rated point-of-use temperature activated mixing valves on all fixtures that do not have integral anti-scald protection.

### **SUMMARY:**

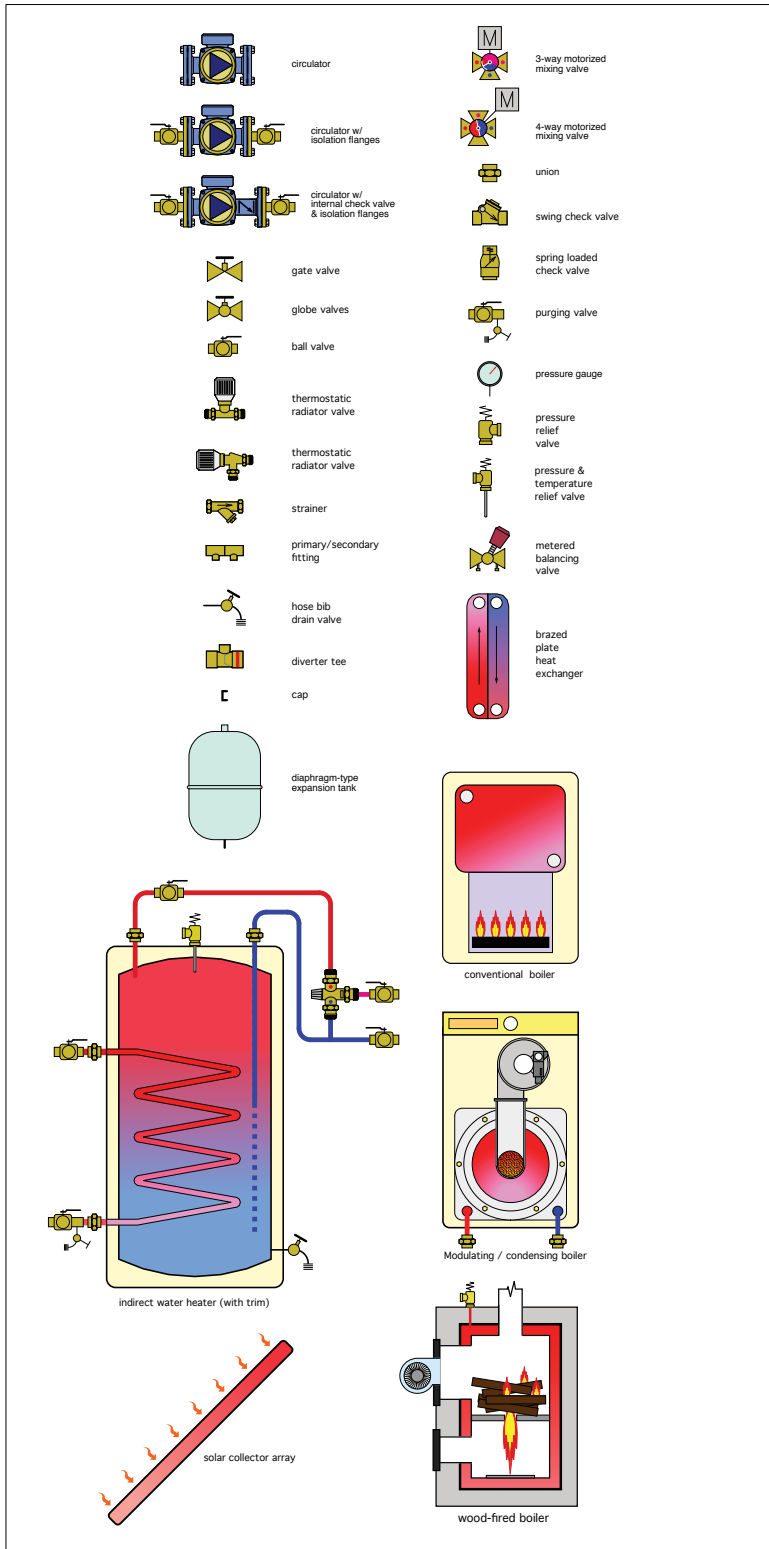
A safe, reliable and energy-efficient source of domestic hot water is now a necessity in nearly every North American building designed for human occupancy. A wide range of devices have been developed to supply this need.

The methods and hardware described in this issue of *idronics* allow plumbing system designers to provide domestic hot water safely and using state-of-the-art techniques.

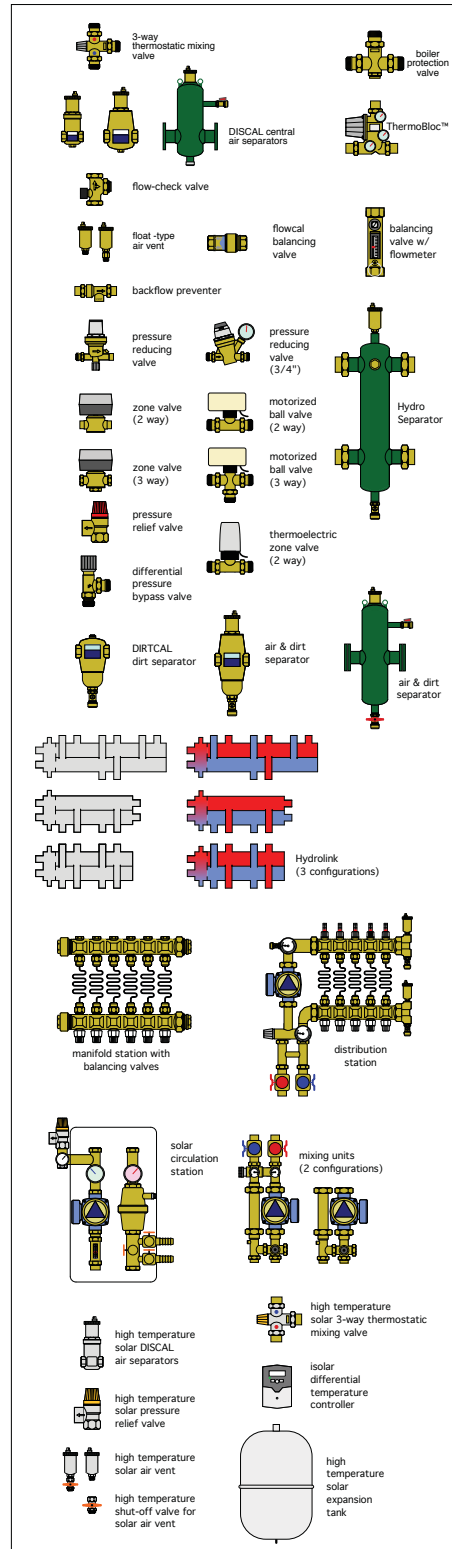
Further design reference information is provided in the appendices that follow.

# APPENDIX A: PIPING SYMBOL LEGEND

## GENERIC COMPONENTS



## CALEFFI COMPONENTS



## APPENDIX B: HEAD LOSS CALCULATION METHOD

This appendix presents a simple method for calculating the head loss of piping paths or circuits constructed of *smooth tubing* (copper, PEX, PERT, PEX-AL-PEX or PP).

The head loss of a piping path or circuit can be determined using Formula B-1.

Formula B-1

$$H_L = (acl)(f)^{1.75}$$

$H_L$  = Head loss of circuit (feet of head)

$a$  = a factor that depends on the average water temperature in piping (see Figure B-1)

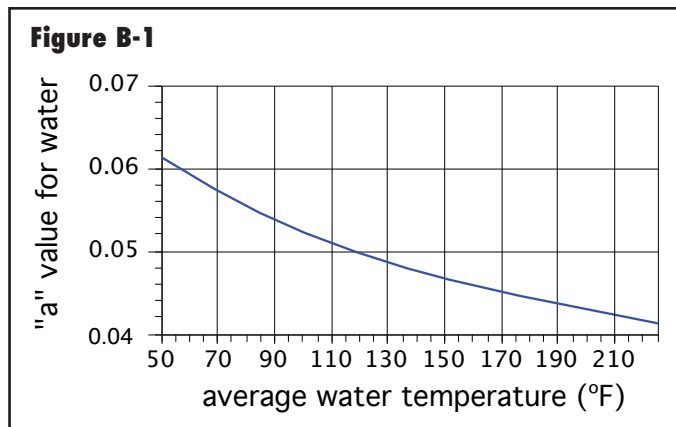
$c$  = a factor determined by the type and size of tubing in the circuit (see Figure B-2)

$l$  = total equivalent length of the circuit (ft) (see Figure B-3)

$f$  = flow rate (gpm)

1.75 = an exponent of flow rate

The values of “ $a$ ” read from Figure B-1 should be based on the average water temperature in the piping. Thus, for a recirculation loop with a supply temperature of 130°F and a return temperature of 120°F, the value of “ $a$ ” would be determined at the average fluid temperature of 125°F.



The equivalent length “ $L$ ” for a segment of pipe is simply its length. The equivalent resistance of a fitting or valve can be found in the table shown in Figure B-3.

For example, the equivalent length of a 1”-size 90° copper elbow would be 2.5 feet of 1” copper tube. If a circuit path contained three such elbows, their total equivalent length would be 3 x 2.5 feet = 7.5 feet. The equivalent lengths of fittings and valves should be added to the linear length of tubing in the circuit path to get a total equivalent length for that path.

Figure B-2

Tube (size & type)	C value
3/8" type M copper	1.0164
1/2" type M copper	0.33352
3/4" type M copper	0.061957
1" type M copper	0.01776
1.25" type M copper	0.0068082
1.5" type M copper	0.0030667
2" type M copper	0.0008331
2.5" type M copper	0.0002977
3" type M copper	0.0001278
3/8" PEX	2.9336
1/2" PEX	0.71213
5/8" PEX	0.2947
3/4" PEX	0.14203
1" PEX	0.04318
1.25" PEX	0.01668
1.5" PEX	0.007554
2" PEX	0.002104
3/8" PEX-AL-PEX	3.35418
1/2" PEX-AL-PEX	0.6162
5/8" PEX-AL-PEX	0.19506
3/4" PEX-AL-PEX	0.06379
1" PEX-AL-PEX	0.019718

Example: A piping path contains 150 feet of 3/4” copper tubing, eight 90° elbows, and 2 ball valves. It carries water at an average temperature of 110°F and at a flow rate of 3.5 gpm. Determine the head loss of this piping path.

**Solution:** The total equivalent length of the circuit is 150 feet, plus 2 feet for each elbow and 2.2 feet for each ball valve. This totals to 170.4 feet. The equivalent lengths of the elbows and valves were read from Figure B-3.

The “ $a$ ” value of water at an average temperature of 110°F is 0.051 (from Figure B-1).

**Figure B-3**

FITTING	NOMINAL TUBING SIZE							
	1/2"	3/4"	1"	1.25"	1.5"	2"	2.5"	3"
90° elbow	1.0	2.0	2.5	3.0	4.0	5.5	7.0	9.0
45° elbow	0.5	0.75	1.0	1.2	1.5	2.0	2.5	3.5
tee(straight)	0.3	0.4	0.45	0.6	0.8	1.0	0.5	1.0
tee(side)	2.0	3.0	4.5	5.5	7.0	9.0	12.0	15.0
gate valve	0.2	0.25	0.3	0.4	0.5	0.7	1.0	1.5
ball valve	1.9	2.2	4.3	7.0	6.6	14.0	0.5	1.0
flow check	N/A	83.0	54.0	74	57	177	N/A	N/A
globe valve	15.0	20.0	25.0	36.0	46.0	56.0	104.0	130.0

The “c” value for 3/4” copper tubing is 0.061957 (from Figure B-2).

Putting these values into Formula B-1 yields:

$$H_L = [acL](f)^{1.75} = [(0.051)(0.061957)(170.4)](3.5)^{1.75} = 4.82 \text{ ft}$$

**APPENDIX C: SIZING THERMAL EXPANSION TANKS FOR DHW SYSTEMS**

The *minimum* size of a thermal expansion tank for a domestic water heating system can be determined using Formula C-1.

Formula C-1:

$$V_{\min} = V_s \times \left( \frac{P_{\max} + 14.7}{P_{\max} - P_L} \right) \times \left( \frac{D_c}{D_H} - 1 \right)$$

Where:

$V_{\min}$  = minimum total volume (not acceptance volume) of thermal expansion tank (gallons)

$V_s$  = total volume of heated water in system (gallons)

$P_{\max}$  = maximum allowed pressure in water heater (usually the T&P rating) (psi)

$P_L$  = pressure in cold water line supplying water heater (psi)

$D_c$  = density of cold water (Figure C-1) (lb/ft<sup>3</sup>)

$D_H$  = density of water at maximum allowed temperature (Figure C-1) (lb/ft<sup>3</sup>)

For example: A solar-supplemented tank-type water heater contains 119 gallons of hot water at 180°F. The tank’s pressure relief valve is rated for 125 psi, and the local cold water line pressure is 50 psi. If cold water enters this system at 40°F, determine the minimum size thermal expansion tank required for the system.

Solution: Using Figure B-2, the density of 40°F water is 62.43 lb/ft<sup>3</sup>. The density of 180°F water is 60.6 lb/ft<sup>3</sup>. Putting these along with the other stated values into the Formula 2-1 yields a minimum required thermal expansion tank volume of:

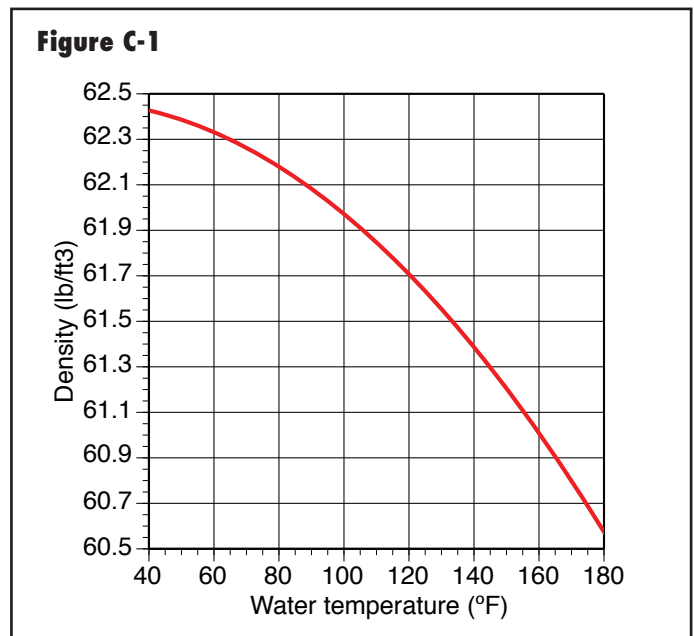
$$V_{\min} = 119 \times \left( \frac{125 + 14.7}{125 - 50} \right) \times \left( \frac{62.43}{60.60} - 1 \right) = 6.7 \text{ gallons}$$

An expansion tank should now be selected with a volume equal to, or slightly larger than, 6.7 gallons. Slight oversizing is fine, and slightly reduces pressure fluctuations; however, excessive oversizing adds cost without returning tangible benefit.

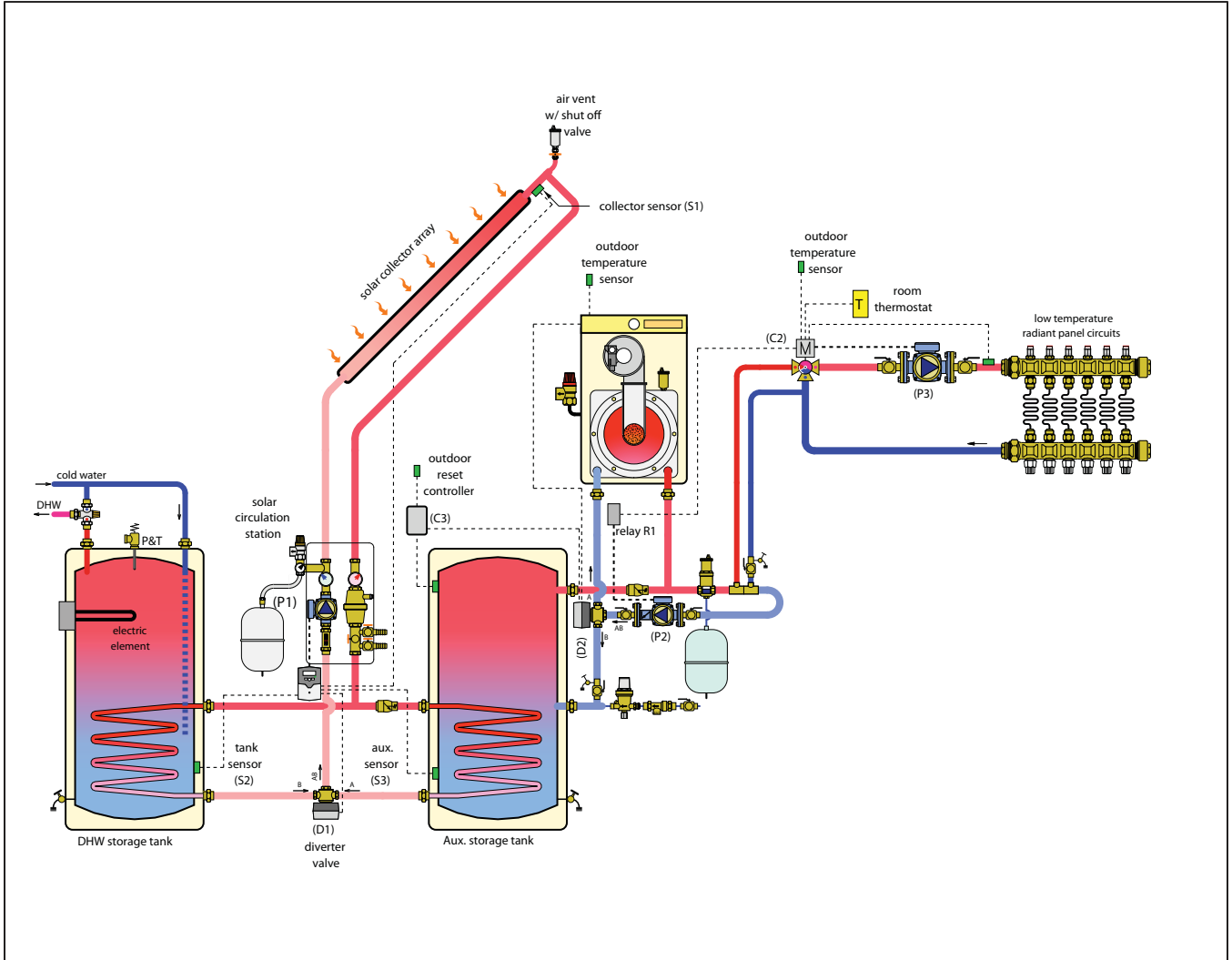
In a system using storage-type water heaters, the volume of heated water in the system ( $V_s$  in Formula C-1) is generally considered to be the storage tank volume. In most cases, this assumption adds an inherent safety factor to the calculation, since not all the water in the storage tank will reach the maximum allowed temperature at the same time due to temperature stratification.

It should also be noted that this sizing procedure assumes that the expansion tank connection is located at approximately the same elevation as the pressure relief valve and the cold water inlet to the plumbing system.

**Figure C-1**



## MIXING VALVES FOR DOMESTIC WATER HEATING SYSTEMS



MixCal™ thermostatic mixing valves

Scald protection thermostatic mixing valves

Large flow thermostatic mixing valves

ThermoCon™ buffer storage tanks

SolarCon™ indirect water heaters

Solar water heater systems

# MixCal™ adjustable three-way thermostatic mixing valve

## 521 series



### Function

The Caleffi MixCal™ three-way thermostatic mixing valve is used in systems producing domestic hot water or in radiant panel heating systems. It maintains the desired output temperature of the mixed water supplied to the user at a constant set value compensating for both temperature and pressure fluctuations of the incoming hot and cold water. The MixCal™ is fail cold: for any failure of cold or hot inlets or valve function, the hot water port closes.

The valve is specifically certified to ASSE 1017 and IAPMO R&T.



ASSE 1017



Lead Plumbing Law Certified by IAPMO R&T

### Product range

- 521\_\_A Adjustable three-way thermostatic mixing valve, threaded and sweat connections ..... sizes 1/2", 3/4", 1"
- 521\_\_AC Adjustable three-way thermostatic mixing valve, threaded and sweat connections, inlet port check valves ..... sizes 1/2", 3/4", 1"
- 521519A, (AC) Adjustable three-way thermostatic mixing valve, sweat connections, outlet temperature gauge (check valves)..... size 3/4"
- 521619A, (AC) Adjustable three-way thermostatic mixing valve, sweat connections, outlet temperature gauge (check valves)..... size 1"

### Technical specifications

#### Materials

- Body: low-lead brass (<0.25% Lead content)
- Shutter: PPO
- Springs: stainless steel
- Seals: EPDM

#### Performance

- Setting range: 85–150°F (30–65°C)
- Tolerance: ±3°F (±2°C)
- Max working pressure (static): 200 psi (14 bar)
- Max working pressure (dynamic): 70 psi (5 bar)
- Max hot water inlet temperature: 200°F (93°C)
- Maximum inlet pressure ratio (H/C or C/H): 2:1

Minimum temperature difference between hot water inlet and mixed water outlet for optimum performance:

27°F (15°C)

Minimum flow rate to ensure

optimal performance: 1.3 GPM (5 l/min)

Approval:

ASSE 1017 Listed

Lead Plumbing Law Compliance:

(0.25% Max. weighted average lead content)

Lead Plumbing Law Certified by IAPMO R&T

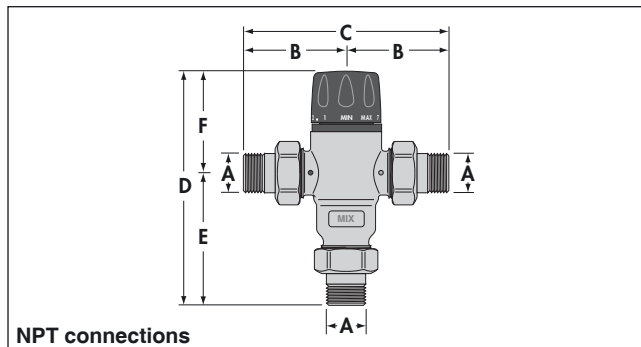
**Connections** - NPT male union

1/2", 3/4" and 1"

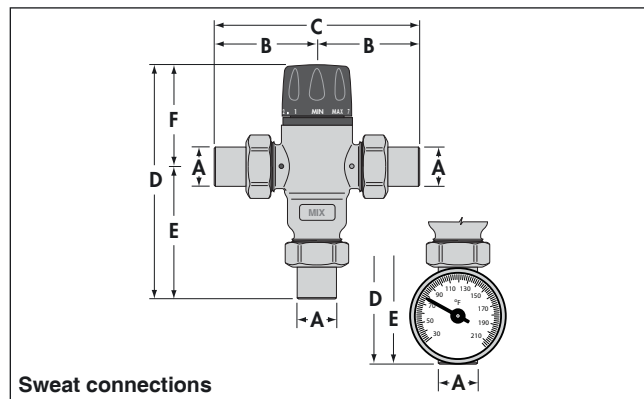
- sweat union

1/2", 3/4" and 1"

### Dimensions



Code	A	B	C	D	E	F
521400A	1/2"	2 5/8"	5 1/4"	5 15/16"	3 3/8"	2 9/16"
521400AC	1/2"	2 5/8"	5 1/4"	5 15/16"	3 3/8"	2 9/16"
521500A	3/4"	2 5/8"	5 1/4"	5 15/16"	3 3/8"	2 9/16"
521500AC	3/4"	3"	6"	5 15/16"	3 3/8"	2 9/16"
521600A	1"	2 7/8"	5 3/4"	6 1/4"	3 11/16"	2 9/16"
521600AC	1"	3 1/16"	6 1/8"	6 1/4"	3 11/16"	2 9/16"

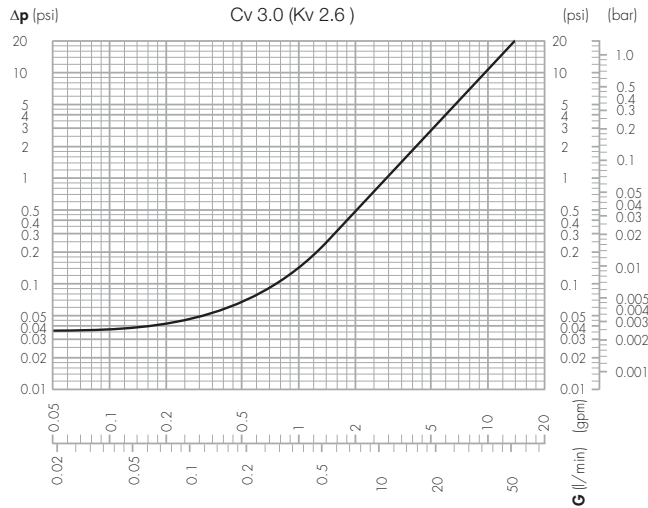


Code	A	B	C	D	E	F
521409A	1/2"	2 1/4"	4 1/2"	5 5/8"	3 1/16"	2 9/16"
521409AC	1/2"	2 7/8"	5 3/4"	5 5/8"	3 1/16"	2 9/16"
521509A	3/4"	2 1/2"	5"	5 13/16"	3 1/4"	2 9/16"
521519A	3/4"	2 1/2"	5"	7 3/16"	4 5/8"	2 9/16"
521509AC	3/4"	3 1/16"	6 1/8"	5 13/16"	3 1/4"	2 9/16"
521519AC	3/4"	3 1/16"	6 1/8"	7 3/16"	4 5/8"	2 9/16"
521609A	1"	3 1/16"	6 1/8"	6 7/16"	3 7/8"	2 9/16"
521619A	1"	3 1/16"	6 1/8"	7 13/16"	5 1/4"	2 9/16"
521609AC	1"	3 1/4"	6 1/2"	6 7/16"	3 7/8"	2 9/16"
521619AC	1"	3 1/4"	6 1/2"	7 13/16"	5 1/4"	2 9/16"

## Operating principle

The controlling element of the three-way thermostatic mixing valve is a thermostatic sensor fully immersed in the mixed water outlet tube which, as it expands or contracts, continuously establishes the correct proportion of hot and cold water entering the valve. The regulation of these flows is by means of a piston sliding in a cylinder between the hot and cold water passages. Even when there are pressure drops due to the drawing off of hot or cold water for other uses, or variations in the incoming temperature, the thermostatic mixing valve automatically regulates the water flow to obtain the required temperature.

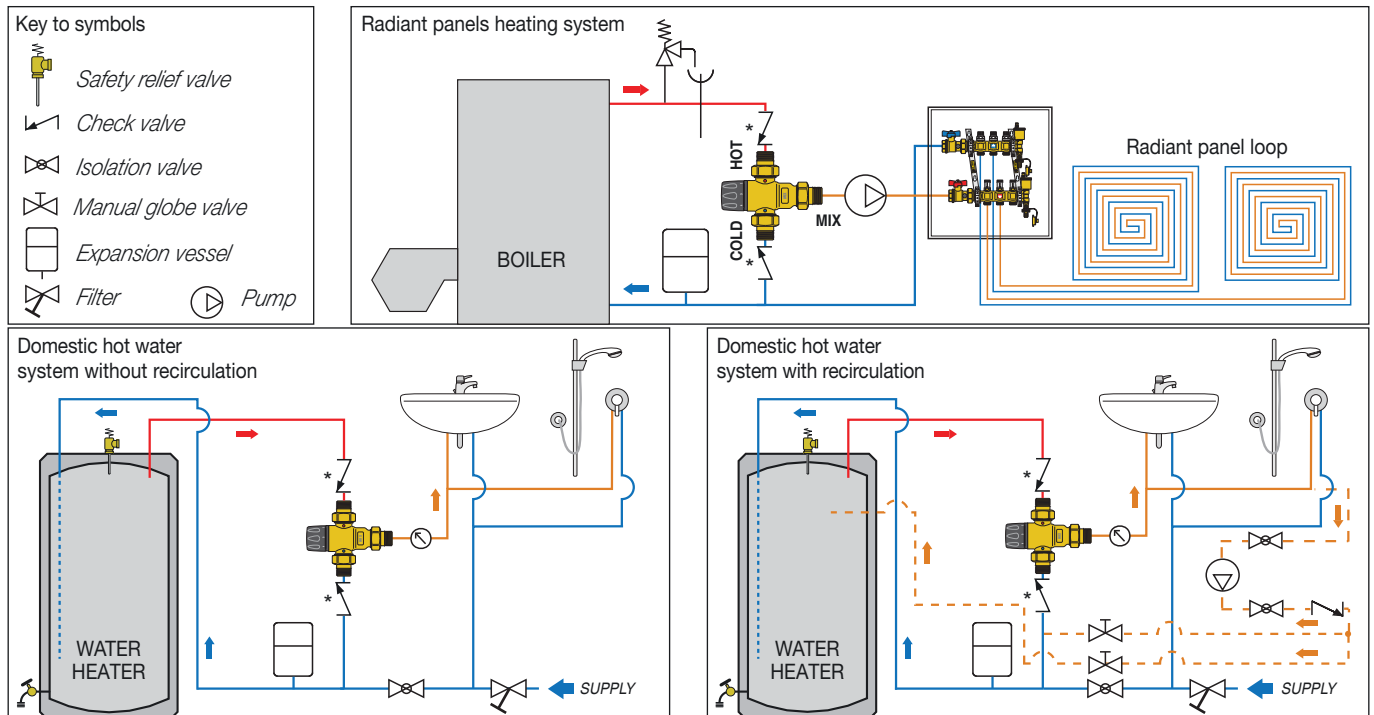
## Flow curve



## Use

Caleffi MixCal™ 521 series thermostatic mixing valves are designed to be installed at the hot water heater. They should not be used where ASSE 1070 devices are required. Wherever a point-of-use scald protection feature is required, Caleffi series 5213 high performance mixing valves need to be installed. For safety, it is advisable to limit the maximum mixed water temperature to 120°F.

## Application Diagrams



\*MixCal™ thermostatic mixing valves with inlet check valve, "AC" models, can be used instead of separately installed check valves.

## Installation

Before installing a Caleffi MixCal™ 521 series three-way thermostatic mixing valve, the system must be inspected to ensure that its operating conditions are within the range of the mixing valve, checking, for example, the supply temperature, supply pressure, etc.

Systems where the Caleffi MixCal™ 521 series thermostatic mixing valve is to be fitted must be drained and cleaned out to remove any dirt or debris which may have accumulated during installation.

The installation of filters of appropriate capacity at the inlet of the water from the mains supply is always advisable. Caleffi MixCal™ 521 series thermostatic mixing valves must be installed by qualified personnel in accordance with the diagrams in the product brochure, taking into account all current applicable standards.

Caleffi MixCal™ 521 series thermostatic mixing valves can be installed in any position, either vertical or horizontal, or upside down. The following are shown on the thermostatic mixing valve body:

- Hot water inlet, color red and marked "HOT."
- Cold water inlet, color blue and marked "COLD."
- Mixed water outlet, marked "MIX".

## Temperature adjustment

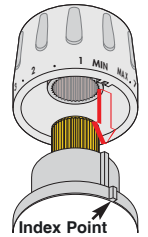
The temperature is set to the required value by means of the knob with a graduated scale, on the top of the valve.

Pos.	Min	1	2	3	4	5	6	7	Max
T (°F)	81	90	100	111	120	127	136	145	152
T (°C)	27	32	38	44	49	53	58	63	67

with:  $T_{HOT} = 155\text{ }^{\circ}\text{F} (68^{\circ}\text{C})$  ·  $T_{COLD} = 55\text{ }^{\circ}\text{F} (13^{\circ}\text{C})$  ·  $P = 43\text{ psi} (3\text{ bar})$

## Locking the setting

Position the handle to the number required with respect to the index point. Unscrew the head screw, pull off the handle and reposition it so that the handle fits into the internal slot of the knob. Tighten the head screw.



# Adjustable thermostatic mixing valve for solar systems

## 252 series



### General

In solar systems, the temperature in the storage tank can vary considerably, depending on the solar radiation, and can reach very high temperatures over long periods. In summer, and if there is little water usage, the hot water at the storage tank outlet can actually reach temperatures around 200°F. At these temperatures, the hot water cannot be used directly because of the danger of scalding.

### Function

The thermostatic mixing valve is used in systems for scald protection in the production of domestic hot water. It maintains the desired output temperature of the mixed water supplied to the user at a constant set value compensating for both temperature and pressure fluctuations of the incoming hot and cold water. The Caleffi 2521 series of mixing valves can function continuously at the high temperatures of the incoming hot water from the solar storage tank.

The valve is specifically certified to ASSE 1017 and IAPMO R&T.



ASSE 1017



Lead Plumbing Law Certified by IAPMO R&T

### Product range

2521_9A	Adjustable three-way thermostatic mixing valve with sweat connections	sizes 1/2", 3/4", 1"
2521_8A	Adjustable three-way thermostatic mixing valve with sweat connections, outlet temperature gauge	sizes 1/2", 3/4", 1"

### Technical specifications

#### Materials

Body:	low-lead brass (<0.25% Lead content)
Shutter:	PSU
Springs:	stainless steel
Seals:	EPDM

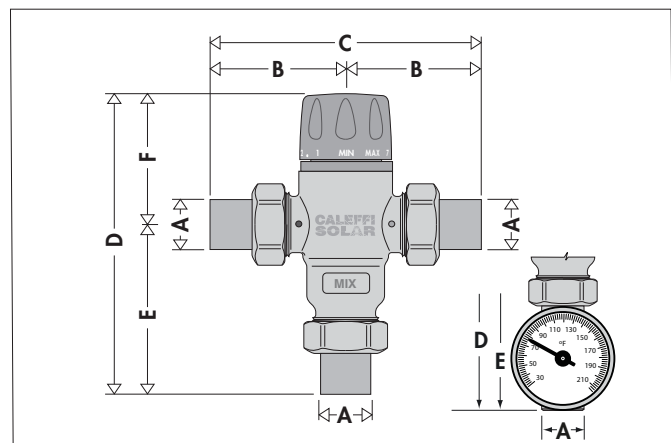
#### Performance

Setting range:	80–150°F (27–65°C)
Tolerance:	±3°F (±2°C)
Max. working pressure (static):	150 psi (10 bar)
Max. working pressure (dynamic):	75 psi (5 bar)
Min. working pressure (dynamic):	30 psi (2 bar)
Max hot water inlet temperature:	210°F (100°C)
Maximum inlet pressure ratio (H/C or C/H):	2:1
Minimum temperature difference between hot water inlet and mixed water outlet for optimum performance:	30°F (15°C)
Minimum flow rate to ensure stable temperature:	1.3 GPM (5 l/min)
Approval:	ASSE 1017 Listed
Lead Plumbing Law Compliance:	(0.25% Max. weighted average lead content)
Lead Plumbing Law Certified by IAPMO R&T	

#### Connections

- sweat union	1/2", 3/4" and 1"
---------------	-------------------

### Dimensions



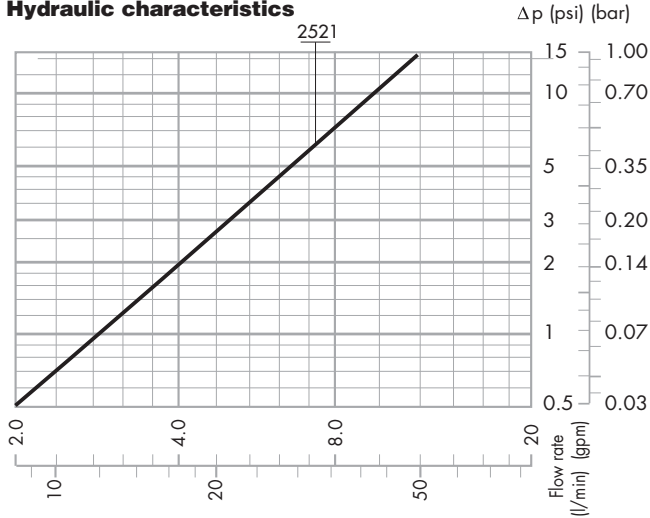
Code	A	B	C	D	E	F	Weight (lb)
2521 49A	1/2"	2 1/4"	4 1/2"	5 5/8"	3 1/8"	2 5/8"	2.2
2521 58A	3/4"	2 1/2"	5"	5 7/8"	3 1/4"	2 5/8"	2.4
2521 59A	3/4"	2 1/2"	5"	5 7/8"	3 1/4"	2 5/8"	3.0
2521 68A	1"	3 1/8"	6 1/4"	7 3/4"	5 1/4"	2 5/8"	2.6
2521 69A	1"	3 1/8"	6 1/4"	6 3/8"	3 7/8"	2 5/8"	3.2



### Operating principle

The controlling element of the solar thermostatic mixing valve is a temperature sensor that is fully immersed in the mixed water outlet passage. As it expands or contracts, the sensor continuously establishes the correct proportion of hot and cold water entering the valve. The flow is regulated by a piston sliding in a cylinder between the hot and cold water passages. Even when there are pressure drops due to the drawing off of hot or cold water for other uses or variations in the incoming temperature, the thermostatic mixing valve automatically regulates the water flow to obtain the required temperature.

### Hydraulic characteristics

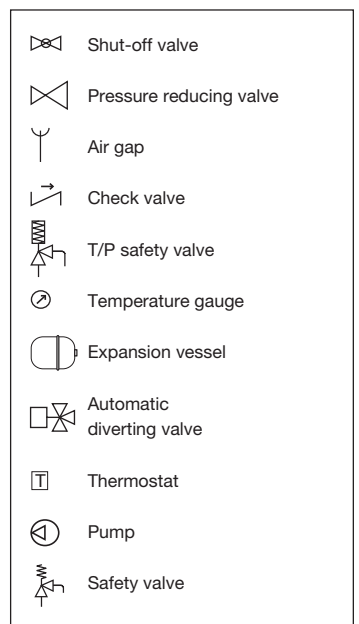
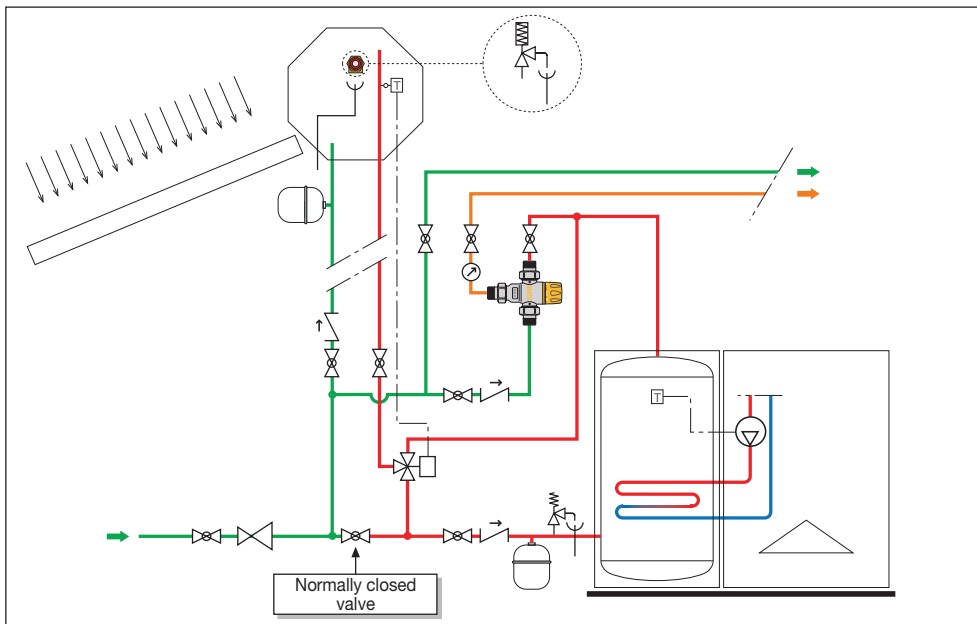


2521 series Cv 3.0 (gpm) (Kv 2.6 (l/min))

### Use

Thermostatic mixing valves are typically installed at the outlet of hot water storage tanks in solar systems to ensure constant temperature of the mixed water supplied to the end user. Because of their flow characteristics, the valves can be installed to control the temperature for both single point of use and for point of distribution. In order to guarantee the delivery of mixed water at the set temperature, the Caleffi 2521 series thermostatic mixing valves must have a minimum flow rate of 1.3 gpm (5 lpm).

### Application diagrams - System with thermal integration



### Installation

Before installing the Caleffi 2521 series thermostatic mixing valve, the piping must be flushed out to ensure there are no circulating impurities to harm the system. Caleffi recommends always installing filters of sufficient capacity at the inlet of the water system.

Thermostatic mixing valve can be installed horizontally or vertically.

The following are indicated on the body of the mixing valve:

- Hot water inlet, color red and marked "HOT."
- Cold water inlet, color blue and marked "COLD."
- Mixed water outlet, marked "MIX".

### Temperature adjustment

The temperature is set at the desired value by the knob with the graduated scale, located on the top of the valve.

### Temperature adjustment table

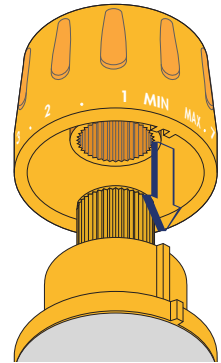
Position	Min.	1	2	3	4	5	6	7	Max.
T (°F)	80	90	100	110	120	130	135	145	150

Reference values:  $T_{hot} = 155^{\circ}F$ ;  $T_{cold} = 55^{\circ}F$ ; Hot and cold water inlet pressures = 45 psi

### Locking the setting

After selecting the temperature, the setting can be locked at the desired value using the control knob.

To do this, unscrew the lock screw on the upper part of the control knob, remove the knob and put it back on so that the internal reference couples with the protrusion on the knob carrier ring nut.



# Scald protection point of use thermostatic mixing valve

## 5213 series



**LOW LEAD**

### Function

Thermostatic mixing valves are used in applications where the user must be protected from the danger of scalding caused by hot water. The Caleffi 5213 series provides water at a safe and usable temperature in situations where the control of the temperature of the water discharging from a terminal fitting is of the utmost importance, i.e. within hospitals, schools, nursing homes, etc. The valve is designed to prevent the flow of water discharging from the mixed water outlet in the event of the failure of hot or cold supply. The Caleffi 5213 series is a high performance combination thermostatic and pressure balanced mixing valve and is ASSE 1070 listed (temperature can not exceed 120°F). The valve is complete with check valve at both hot and cold inlets.



ASSE 1070



Lead Plumbing Law Certified by IAPMO R&T

### Product range

- 5213\_2A Scald protection and anti-chill point of use thermostatic mixing valve with threaded connections ..... sizes 1/2", 3/4", 1"
- 5213\_9A Scald protection and anti-chill point of use thermostatic mixing valve with sweat connections ..... sizes 1/2", 3/4", 1"

### Technical specifications

#### Materials

- Body: low-lead brass (<0.25% Lead content)
- Regulating spindle: low-lead brass (<0.25% Lead content)
- Internal shutter: PPO
- Sealing elements: EPDM
- Cover: ABS

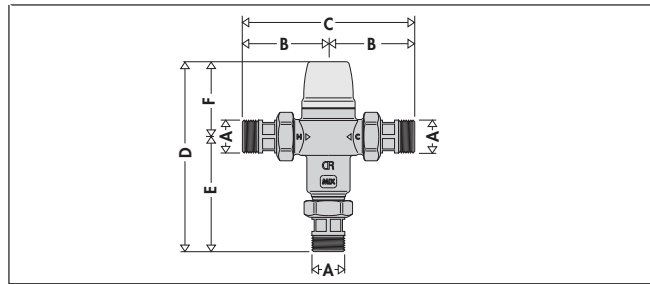
#### Performance

- Setting range: 85–120°F (30–50°C)
- Temperature set: must be commissioned on site to achieve desired temperature
- Temperature control: ±3°F (±2°C)
- Min. cold inlet temperature: 39°F (4°C)
- Max. cold inlet temperature: 85°F (29°C)
- Min. hot inlet temperature: 120°F (49°C)
- Max. hot inlet temperature: 185°F (85°C)
- Max working pressure (static): 140 psi (10 bar)
- Max working pressure (dynamic): 70 psi (5 bar)
- Min. working pressure (dynamic): 1.5 psi (0.1 bar)
- Max hot water inlet temperature: 200°F (93°C)
- Max. unbalanced dynamic supply ration (H/C or C/H): 6:1
- Min. temperature differential between hot water inlet and mixed water outlet to ensure thermal shutoff function: 18°F (10°C)
- Min. temperature differential between mixed water outlet and cold water inlet to ensure stable operation: 9°F (5°C)
- Min. flow rate for stable operation: 1 GPM (4 l/min)
- Approval: ASSE 1070 Listed
- Lead Plumbing Law Compliance: (0.25% Max. weighted average lead content)

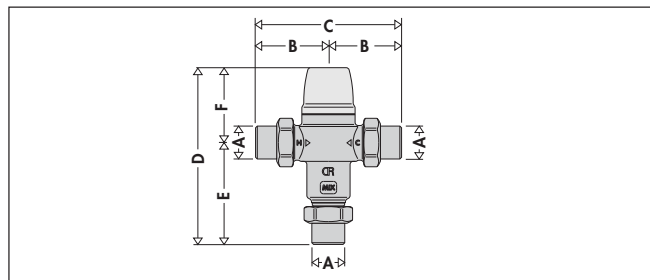
Lead Plumbing Law Certified by IAPMO R&T

- Connections** - NPT male union 1/2", 3/4" and 1"
- sweat union 1/2", 3/4" and 1"

### Dimensions



Code	A	B	C	D	E	F	Weight (lb)
521342A	1/2"	2 13/16"	5 11/16"	4 15/16"	3"	1 15/16"	1.50
521352A	3/4"	2 13/16"	5 11/16"	4 15/16"	3"	1 15/16"	1.65
521362A	1"	2 15/16"	5 7/8"	5 3/16"	3 1/4"	1 15/16"	1.85

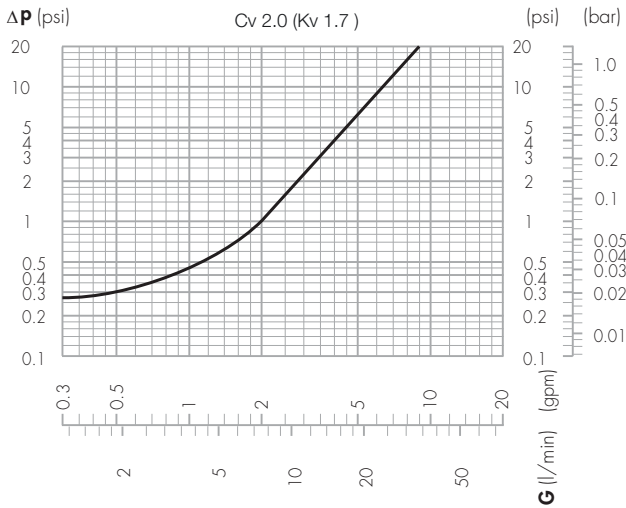


Code	A	B	C	D	E	F	Weight (lb)
521349A	1/2"	2 11/16"	5 7/16"	4 5/8"	2 11/16"	1 15/16"	1.40
521359A	3/4"	2 7/8"	5 3/4"	4 13/16"	2 15/16"	1 15/16"	1.55
521369A	1"	3 1/8"	5 5/16"	5 3/8"	3 1/4"	1 15/16"	1.74

## Operating principle

The thermostatic mixing valve mixes hot and cold water in such a way as to maintain constant set temperature of the mixed water at the outlet. A thermostatic element is fully immersed into the mixed water. This element then contracts or expands causing movement of the piston, closing either the hot or cold inlets, regulating the flow rates entering the valve. If there are variations of temperature or pressure at the inlets, the internal element automatically reacts to restore the original temperature setting. In the event of a failure of either the hot or cold supply, the piston will shut off, stopping water discharging from the mixed water outlet. The Caleffi 5213 series thermostatic mixing valve requires a minimum temperature differential from hot inlet to mixed water outlet of 18°F (10°C) to ensure the correct operation of the thermal shutoff function.

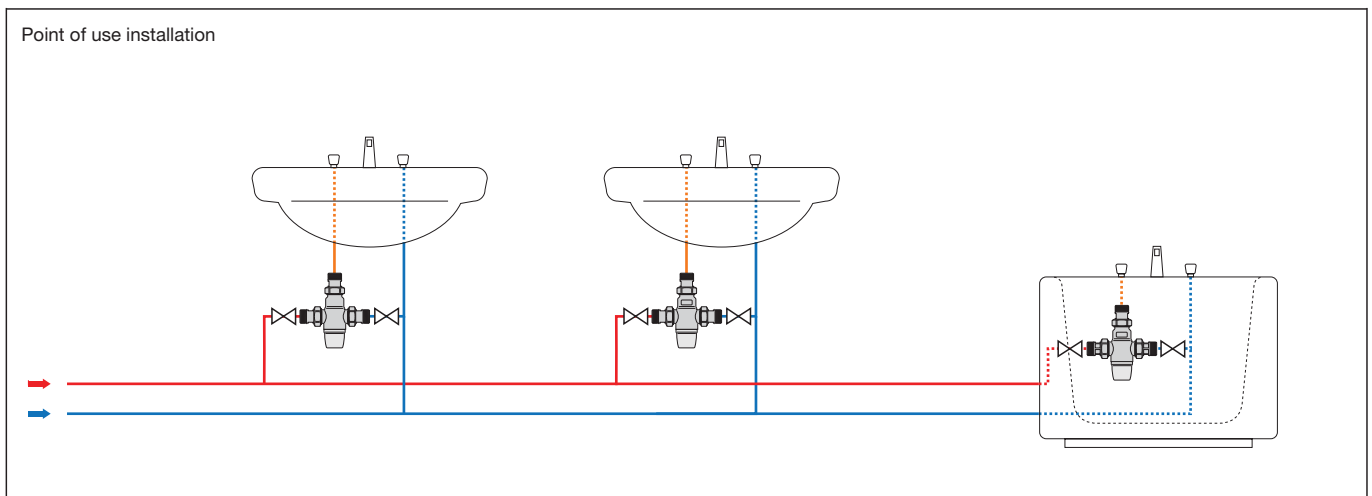
## Flow curve



## Use

The Caleffi 5213 series is a thermostatic mixing valve suitable for point of use application. For this reason, the flow rate through the valve is the same as that of the final outlet, e.g. thermostatic mixing valve or tap for washbasin, shower or bath. In order to ensure the set temperature, the thermostatic mixing valve must have a minimum flow rate of 1 gpm (4 l/min). The system must be sized in accordance with local regulations with regard to the nominal flow rate of each outlet.

## Application Diagram



## Installation

Before installing a Caleffi 5213 series three-way thermostatic mixing valve, the system must be inspected to ensure that its operating conditions are within the range of the mixing valve, checking, for example, the supply temperature, supply pressure, etc.

Systems where the Caleffi 5213 series thermostatic mixing valve is to be fitted must be drained and cleaned out to remove any dirt or debris which may have accumulated during installation.

The installation of filters of appropriate capacity at the inlet of the water from the mains supply is always advisable. Caleffi 5213 series thermostatic mixing valves must be installed by qualified personnel in accordance with the diagrams in the product brochure, taking into account all current applicable standards.

Caleffi 5213 series thermostatic mixing valves can be installed in any position, either vertical or horizontal, or upside down. The following are shown on the thermostatic mixing valve body:

- Hot water inlet, marked "H" (Hot).
- Cold water inlet, marked "C" (Cold).
- Mixed water outlet, marked "MIX."

## Temperature adjustment

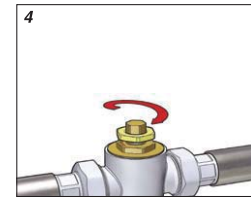
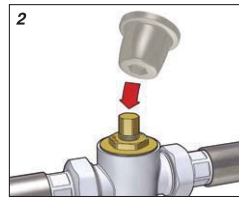
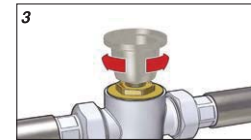
Temperature setting can be adjusted by removing the cap from the valve body and reversing the cap onto the temperature adjustment spindle. In accordance with the scald-protection requirements, mixed water at the outlet of the sanitary fixtures must not exceed the following values:

120°F (49°C) for domestic or normal buildings

110°F (43°C) for hospitals or special buildings

100°F (38°C) for children

Temperature setting can then be locked at the desired value using the locking nut.



# Commercial thermostatic mixing valves with replaceable cartridge

## 5230 series



### Function

Thermostatic mixing valves are used in systems producing domestic hot water or in hydronic and radiant heating systems. Their function is to maintain the temperature of the mixed water supplied to the user at a constant set value when there are variations in the supply pressure and temperature of the incoming hot and cold water or in the flow rate.

Valve models with integral inlet port check valves are ASSE 1070 approved for point of use installations. Models without check valves are ASSE 1017 approved for point of distribution and are designed specifically for systems requiring high flow rates and precise, stable temperature control.

Patent Pending. MI2001A001645.



ASSE 1017  
ASSE 1070

### Product range

5230_0A	Thermostatic mixing valve (ASSE 1017), with replaceable cartridge and threaded connections _____ sizes 1", 1¼", 1½", 2"
5230_6A	Thermostatic mixing valve (ASSE 1017), with replaceable cartridge and sweat connections _____ size 1"
5230_8A	Thermostatic mixing valve (ASSE 1017), with replaceable cartridge and sweat connections _____ sizes ¾", 1", 1¼"
5230_5A	Thermostatic mixing valve (ASSE 1070), with replaceable cartridge and threaded connections _____ sizes ¾" and 1"
5230_7A	Thermostatic mixing valve (ASSE 1070), with replaceable cartridge and sweat connections _____ sizes ¾" and 1"
523005, 523006, 523008	Replacement cartridges for 5230 series Thermostatic mixing valves

### Technical specifications

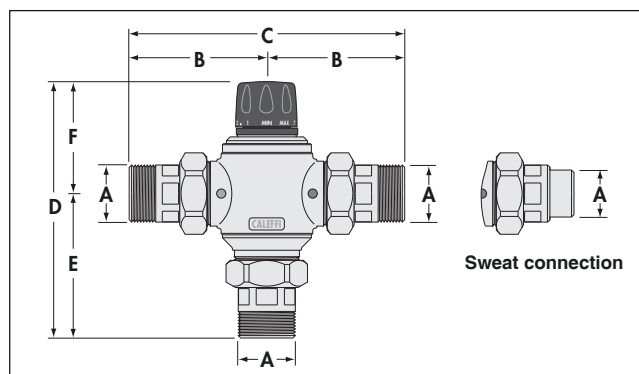
#### Materials

Materials:	
Body:	Brass
Shutter:	Brass, nickel plated
Springs:	Stainless steel
Seals:	EPDM

#### Performance

Suitable fluids:	water, glycol solutions
Max. percentage of glycol:	30%
Setting range:	See table on opposite page
Temperature stability:	± 5°F (± 3°C)
Max working pressure (static):	200 psi (14 bar)
Max working pressure (dynamic):	70 psi (5 bar)
Hot water inlet temperature range:	120–185°F (49–85°C)
Cold water inlet temperature range:	40–80°F (4.4–26.6°C)
Maximum inlet pressure ratio (H/C or C/H):	2:1
Minimum temperature difference between hot water inlet and mixed water outlet for optimum performance:	20°F (11°C)
Maximum water hardness:	10 grains
Approval:	ASSE 1017 and 1070 Listed depending on model

### Dimensions



	Code	A	B	C	D	E	F	Weight (lb)
ASSE 1070	523055A	¾" NPT	3 5/16"	7 7/8"	7 3/16"	4 1/8"	2 15/16"	5
	523057A	¾" SWT	3 5/16"	7 7/8"	5 15/16"	3"	2 15/16"	5
	523065A	1" NPT	3 13/16"	7 5/8"	7 1/16"	4 1/8"	2 15/16"	5
	523067A	1" SWT	3 5/16"	7 7/8"	6 3/16"	3 1/4"	2 15/16"	5
ASSE 1017	523058A	¾" SWT	2 3/4"	5 1/2"	6 1/8"	3 1/4"	2 15/16"	5
	523066A	1" SWT	2 15/16"	5 7/8"	6 5/16"	3 7/16"	2 15/16"	5
	523060A	1" NPT	4 7/16"	8 7/8"	8 1/16"	4 5/8"	3 7/16"	7
	523068A	1" SWT	3 9/16"	7 1/8"	7 3/16"	3 3/4"	3 7/16"	6.5
	523070A	1¼" NPT	4 5/8"	9 5/16"	8 1/4"	4 13/16"	3 7/16"	7
	523078A	1¼" SWT	3 11/16"	7 5/16"	7 5/16"	3 13/16"	3 7/16"	6.5
	523080A	1½" NPT	5 3/16"	10 5/16"	9 3/4"	5 1/2"	4 1/4"	17
523090A	2" NPT	5 3/16"	10 3/8"	9 3/4"	5 1/2"	4 1/4"	18	

## Operating principle

A thermostatic mixing valve mixes hot and cold water in such a way as to maintain a constant set temperature of the mixed water at the outlet. A thermostatic element is fully immersed into the mixed water. It then contracts or expands causing movement of the piston, closing either the hot or cold inlets, regulating the flow rates entering the valve. If there are variations of temperature or pressure at the inlets, the internal element automatically reacts attempting to restore the original temperature setting.

In the event of a failure of either the hot or cold supply, the piston will shut off, stopping water discharging from the mixed water outlet.

The Caleffi 5230 series thermostatic mixing valve requires a minimum temperature differential from hot inlet to mixed water outlet of 20°F (11°C) to ensure the correct operation of the thermal shutoff feature.

## Use

Caleffi 5230 series thermostatic mixing valves are designed to be installed at the hot water heater (ASSE 1017 models) or at the point of distribution (ASSE 1070 models).

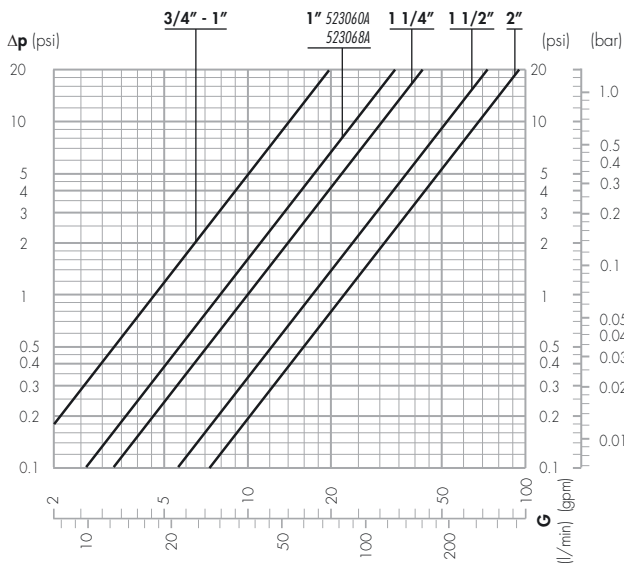
**ASSE 1017 models** are designed to be installed at the hot water heater and cannot be used for tempering water temperature at fixtures as a point-of-use valve. They are not designed to provide scald protection or anti-chill service and should not be used where ASSE 1070 devices are required. Wherever a scald protection feature is required, ASSE 1070 model mixing valves need to be installed. For safety reasons, it is advisable to limit the maximum mixed water temperature to 120°F.

**ASSE 1070 models** are suitable for point of use application. For this reason the flow rate through the valve is the same as that of the final outlet; e.g., mixer or tap for washbasin, shower or bath. The system must be sized taking into account the current legislation with regard to the nominal flow rate of each outlet.

## Hydronic and radiant heating systems

Caleffi 5230 series thermostatic mixing valves can also be used for regulating the flow temperature in hydronic and radiant heating systems, to which it assures a constant and accurate control with ease of installation.

## Flow curve

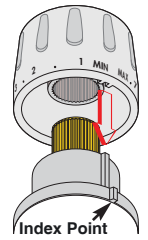


## Temperature adjustment

The temperature is set to the required value by means of the knob with a graduated scale, on the top of the valve.

## Locking the setting

Position the handle to the number required with respect to the index point. Unscrew the head screw, pull off the handle and reposition it so that the handle fits into the internal slot of the knob. Tighten the head screw.



## Recommended flow rates for temperature stability

Valve body size	Connection size	Min. (gpm)	Max. (gpm)
S	3/4" - 1"	2	24
M	1" 523060A - 523068A - 1 1/4"	4.5	40
L	1 1/2" - 2"	13	83

## Point of Use ASSE 1070 Approved

(packaged with pipe fittings and check valves)

### Valve body size S (Small)

Code	Description	Flow
523055A	3/4" Union Thread NPT male	4.8 Cv
523057A	3/4" Union Sweat	4.8 Cv
523065A	1" Union Thread NPT male	4.8 Cv
523067A	1" Union Sweat	4.8 Cv

Temperature adjustment (see paragraph entitled Temperature adjustment)

Pos.	Min	1	2	3	4	5	6	7	Max
T (°F)	77	84	91	102	109	118	126	136	149
T (°C)	25	29	33	39	43	48	52	58	65

with:  $T_{HOT} = 155\text{ }^{\circ}\text{F}$  (68°C) ·  $T_{COLD} = 55\text{ }^{\circ}\text{F}$  (13°C) ·  $P = 43\text{ psi}$  (3 bar)

Replacement Cartridge code 523005

## Point of Distribution ASSE 1017 Approved

### Valve body size S (Small)

Code	Description	Flow
523058A	3/4" Union Sweat	4.8 Cv
523066A	1" Union Sweat	4.8 Cv

Temperature adjustment (see paragraph entitled Temperature adjustment)

Pos.	Min	1	2	3	4	5	6	7	Max
T (°F)	77	84	91	102	109	118	126	136	149
T (°C)	25	29	33	39	43	48	52	58	65

with:  $T_{HOT} = 155\text{ }^{\circ}\text{F}$  (68°C) ·  $T_{COLD} = 55\text{ }^{\circ}\text{F}$  (13°C) ·  $P = 43\text{ psi}$  (3 bar)

Replacement Cartridge code 523005

### Valve body size M (Medium)

Code	Description	Flow
523060A	1" Union Thread NPT male	8 Cv
523068A	1" Union Sweat	8 Cv
523070A	1-1/4" Union Thread NPT male	10 Cv
523078A	1-1/4" Union Sweat	10 Cv

Temperature adjustment (see paragraph entitled Temperature adjustment)

Pos.	Min	1	2	3	4	5	6	7	Max
T (°F)	81	90	100	111	120	127	136	145	153
T (°C)	27	32	38	44	49	53	58	63	67

with:  $T_{HOT} = 155\text{ }^{\circ}\text{F}$  (68°C) ·  $T_{COLD} = 55\text{ }^{\circ}\text{F}$  (13°C) ·  $P = 43\text{ psi}$  (3 bar)

Replacement Cartridge code 523006

### Valve body size L (Large)

Code	Description	Flow
523080A	1-1/2" Union Thread NPT male	17 Cv
523090A	2" Union Thread NPT male	22 Cv

Temperature adjustment (see paragraph entitled Temperature adjustment)

Pos.	Min	1	2	3	4	5	6	7	Max
T (°F)	97	102	108	113	118	126	129	135	140
T (°C)	36	39	42	45	48	52	54	57	60

with:  $T_{HOT} = 155\text{ }^{\circ}\text{F}$  (68°C) ·  $T_{COLD} = 55\text{ }^{\circ}\text{F}$  (13°C) ·  $P = 43\text{ psi}$  (3 bar)

Replacement Cartridge code 523008

# ThermoCon™ buffer storage tanks

## NAS200 series



### Function

ThermoCon™ tanks are designed to be used for wood boilers, solar and geothermal storage, plus in heating systems with low-mass boilers, chilled water systems and low-mass radiation. ThermoCon tanks are used in systems operating below the design load condition, which is most of the time, or in systems having several low cooling or heating loads demands at different times. Boilers operating at low loads will short cycle, resulting in reduced operating efficiency and shorter equipment life. When piped correctly, the ThermoCon will serve as both a thermal buffer and a hydraulic separator. The solar, boiler or chiller system will be hydraulically separated from the distribution system.

Meets and exceeds CSA C309 requirements

### Product range

Code NAS20025	Storage tank	.....	25 gallon
Code NAS20050	Storage tank	.....	50 gallon
Code NAS20080	Storage tank	.....	80 gallon
Code NAS20120	Storage tank	.....	120 gallon

### Technical specifications

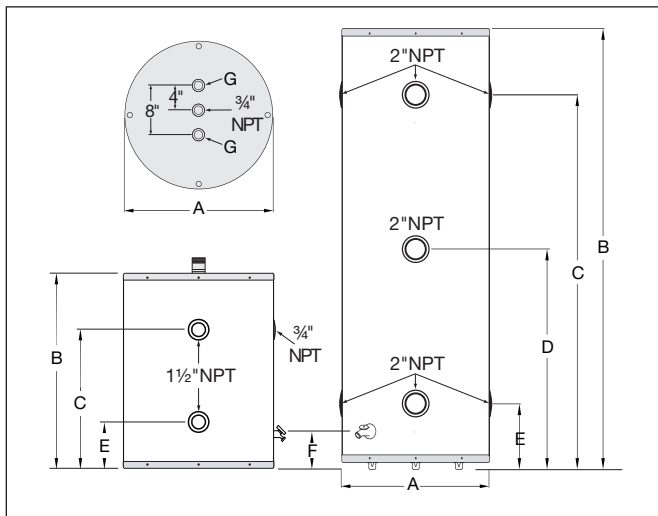
Tank materials:	porcelain coated steel
Tank insulation:	2" non-CFC foam
Tank external cover:	powder-coated steel (20-24 ga.)
Insulation thermal conductivity:	R16
Connections:	25 gal. top (2) 1½" & (1) ¾" NPT
	25 gal. side (4) 1½" & (1) ¾" NPT female
	50, 80, 120 gal. top (3) ¾" NPT female
	50, 80, 120 gal. side (7) 2" NPT female
Maximum working pressure:	150 psi
Testing pressure:	300 psi
Maximum tank temperature:	180°F
Recommended maximum delivery hot water temperature:	120°F

### Construction details

The ThermoCon 25 gallon tank is engineered with six (6) 1½" NPT connections. Two top connections can be piped right below a wall hung modulating / condensing boiler. One of the top connections has a 1½" NPT male thread with a dip tube to draw cooler water from the bottom of tank. The other top 1½" NPT connection is female. The four side 1½" NPT female connectons can be piping to the load.

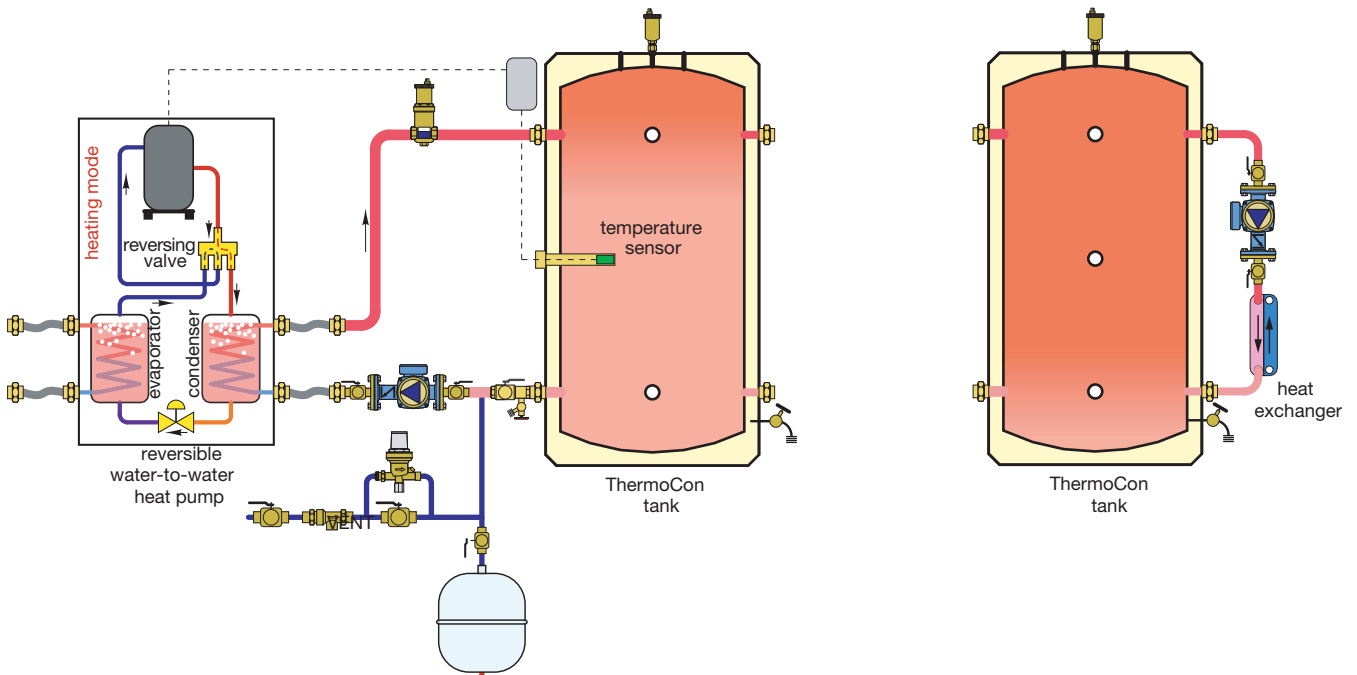
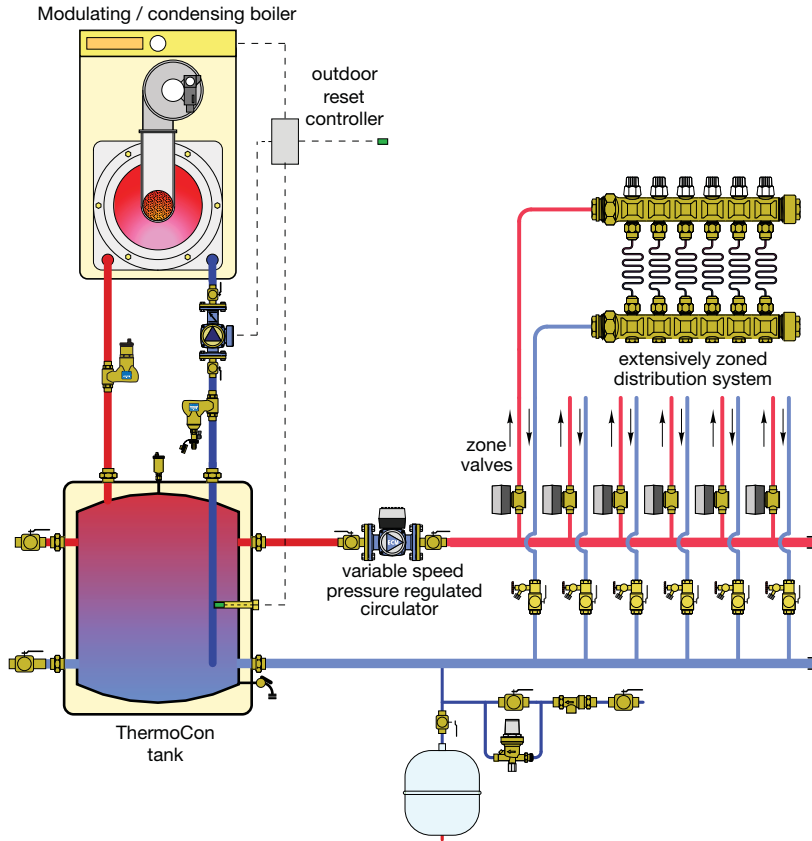
The ThermoCon 50, 80 & 120 gallon tanks are engineered with seven (7) 2" NPT connections. Two connections can be piped to the solar, boiler or chiller side and two connections can be piped to the distribution system. Two additional connection are 90 degree from another which allows for positioning tank into a corner with the piping at a right angle. The tank has one 2" NPT connection for connecting an external heat exchange in the middle of the tank.

### Dimensions



Code	Gal.	A	B	C	D	E	F	G	Wt. lbs.
NAS20025	25	22"	28½"	20½"	—	6¾"	4"	1½"	100
NAS20050	50	22"	48¼"	39½"	23½"	7¾"	4½"	¾"	200
NAS20080	80	24"	64"	53"	32"	11"	5"	¾"	250
NAS20120	120	28"	65"	53"	32"	11"	7"	¾"	350

**Applications**



# SolarCon indirect water heater tank

## NAS200 series



Meets and exceeds CSA C309 requirements

### Function

The indirect water heater has either one or two internal coils and backup electric heating element in the single coil units. A heating medium is passed through the solar panels and internal coil as long as there is an adequate temperature difference between the heating medium and stored water in the tank. The internal coil is located as close to the bottom to facilitate the transfer of heat even at lower solar panel temperatures.

During periods of water flow through the water heater, hot water is drawn from the top of the heater and cold water comes into the bottom of the tank (by a dip tube or bottom inlet). On single coil tanks, if the hot water demand should exceed the solar heat input or there is an insufficient temperature difference between the heating medium and stored water, the heating element thermostat will activate the electrical heating element for backup heat. On double coil tanks, the upper tank is connected to the boiler for backup heat.

Solar heat output from the internal coil will vary depending on outside conditions and the temperature of the stored water.

### Product range

NAS20053	Storage tank with lower coil and back up electric element	50 gallon
NAS20083	Storage tank with lower coil and back up electric element	80 gallon
NAS20123	Storage tank with lower coil and back up electric element	119 gallon
NAS20082	Storage tank with lower coil and top coil for boiler back up	80 gallon
NAS20122	Storage tank with lower coil and top coil for boiler back up	119 gallon
NAS20124	Storage tank with lower coil and top coil heat exchanger with back up electric element	119 gallon

### Technical specifications

Tank materials:	porcelain coated steel	Connections:	3/4" NPT (50 gal.), 1" NPT (80, 119 gal.)
Tank insulation:	2" non-CFC foam	Maximum working pressure:	150 psi
Tank external cover:	powder-coated steel (20-24 ga.)	Testing pressure:	300 psi
Insulation thermal conductivity:	R16	Temperature and pressure relief valve:	210°F/150 psi max
Anode rods:	2 each magnesium	Maximum tank temperature:	180°F
Internal heat exchanger coil (lower):	1-1/2" x 30' (50 gallon)	Recommended maximum delivery hot water temperature:	120°F
	1-1/2" x 36' (80, 119 gallon)	Power requirements (electric element):	240 VAC
Internal heat exchanger coil (top):	1-1/2" x 24' (80, 119 gallon)	Power consumption (electric element):	4.5 KW
		Agency approval:	UL listed

### Capacity and performance

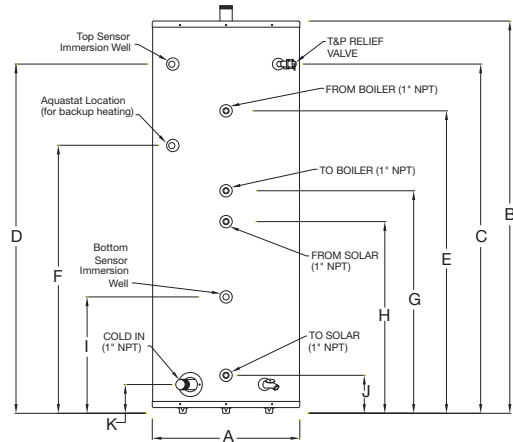
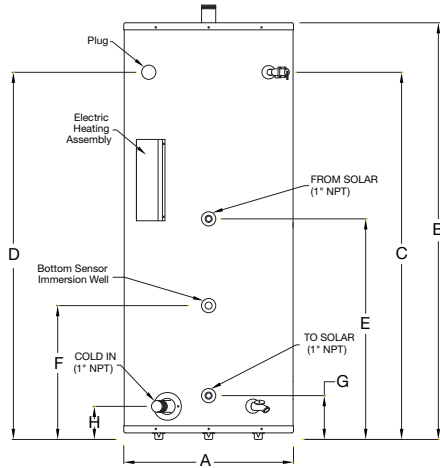
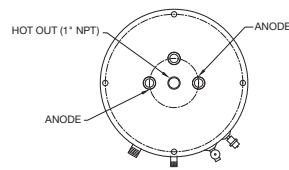
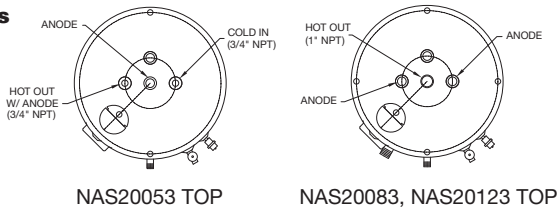
Model	Actual Tank Volume (gal)	Coil Volume Solar/Boiler (gal)	Coil Surface Area Solar/Boiler (ft <sup>2</sup> )	Coil Friction Loss* Solar/Boiler (ft. of head)	First Hour Rating (gal)	Recovery Rate Solar & Backup <sup>#</sup> (gal/hr)	Standby Loss Rating (°F/hr)
NAS20053	45	2.30/ -	11.78/ -	0.50/ -	91	51	1.1
NAS20083	75	2.76/ -	14.14/ -	0.60/ -	126	56	0.8
NAS20123	110	2.76/ -	14.14/ -	0.60/ -	158	56	1.2
NAS20082	73	2.76/1.84	14.14/9.42	0.60/0.40	226	158	0.8
NAS20122	108	2.76/1.84	14.14/9.42	0.60/0.40	258	158	1.2
NAS20124	108	2.76/1.84	14.14/9.42	0.60/0.40	282	182	1.2

NOTES: \* Based on 5 GPM flow rate.

# Based on solar input of 140°F @ 2 GPM. Depending on model, backup heat recovery is calculated with either a 4500W heating element or a boiler with output of 180°F at 14 GPM. Potable water temperature rise is 77°F.



**Dimensions**

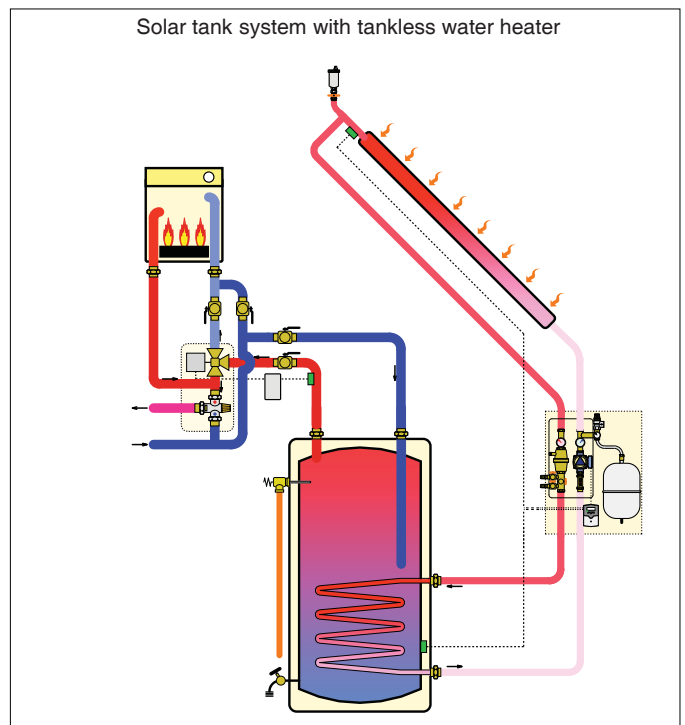
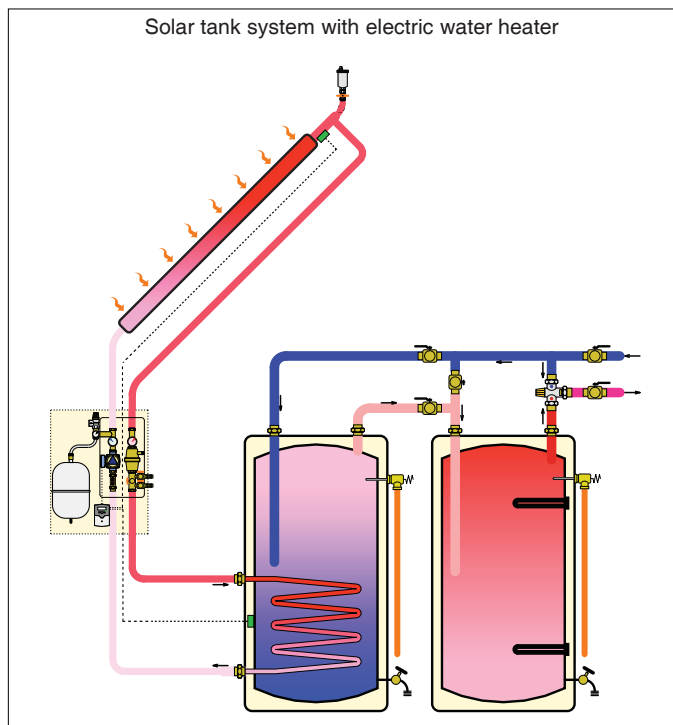


**Figure 1:** NAS20053, NAS20083, NAS20123

**Figure 2:** NAS20082, NAS20122, NAS20124

Model	A	B	C	D	E	F	G	H	I	J	K
NAS20053	22"	48 $\frac{1}{4}$ "	39 $\frac{3}{4}$ "	39 $\frac{3}{4}$ "	31 $\frac{1}{2}$ "	16 $\frac{3}{4}$ "	6 $\frac{1}{2}$ "	n/a	n/a	n/a	n/a
NAS20083	24"	64"	57 $\frac{1}{8}$ "	57 $\frac{1}{8}$ "	31 $\frac{1}{2}$ "	19 $\frac{1}{4}$ "	6 $\frac{1}{2}$ "	5"	n/a	n/a	n/a
NAS20123	28"	65"	57 $\frac{3}{4}$ "	57 $\frac{3}{4}$ "	33 $\frac{3}{4}$ "	16 $\frac{1}{4}$ "	8 $\frac{3}{4}$ "	6 $\frac{1}{2}$ "	n/a	n/a	n/a
NAS20082	24"	64"	57 $\frac{1}{8}$ "	57 $\frac{1}{8}$ "	49 $\frac{1}{2}$ "	46 $\frac{7}{8}$ "	36 $\frac{1}{2}$ "	31 $\frac{1}{2}$ "	19 $\frac{1}{4}$ "	6 $\frac{1}{2}$ "	5"
NAS20122	28"	65"	57 $\frac{3}{4}$ "	57 $\frac{3}{4}$ "	51 $\frac{3}{4}$ "	49 $\frac{1}{8}$ "	38 $\frac{3}{4}$ "	33 $\frac{3}{4}$ "	16 $\frac{1}{4}$ "	8 $\frac{3}{4}$ "	6 $\frac{1}{2}$ "
NAS20124	28"	65"	57 $\frac{3}{4}$ "	57 $\frac{3}{4}$ "	51 $\frac{3}{4}$ "	49 $\frac{1}{8}$ "	38 $\frac{3}{4}$ "	33 $\frac{3}{4}$ "	16 $\frac{1}{4}$ "	8 $\frac{3}{4}$ "	6 $\frac{1}{2}$ "

**Application diagrams**



# Solar water heater systems

## NAS300 series



### Function

The prepackaged, specially engineered solar water heating system includes all of the components needed for a standard installation — from the solar collectors, to the pump station and controller, to pre-insulated piping, to the storage tank, and all of the necessary hardware and components.



### Product range

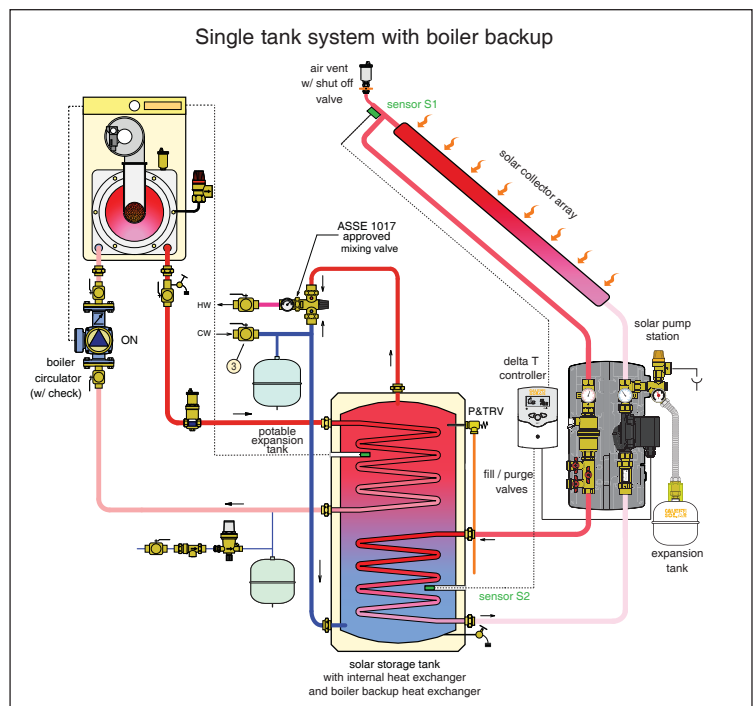
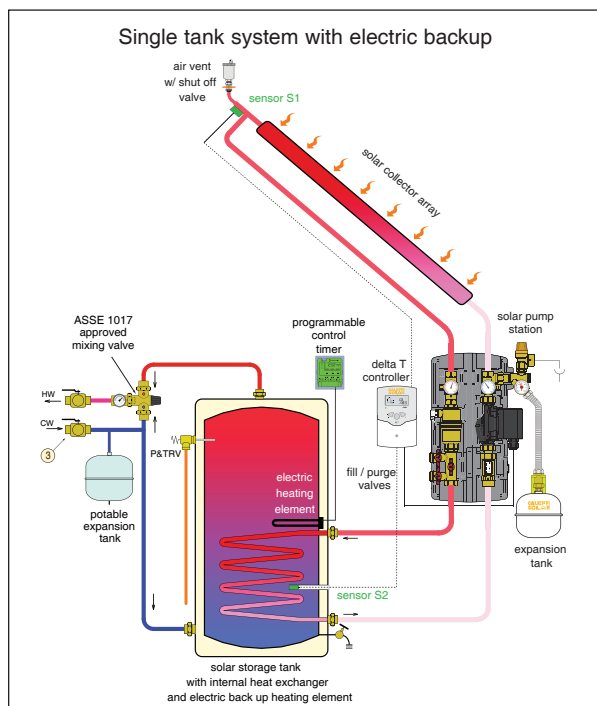
Code	Description	Collectors	Tank	Energy Star Solar Fraction	Lbs.
NAS30020-P	no collector		50 gal. single coil		490
NAS30020	4' x 6.5' collector	1	50 gal. single coil		590
NAS300201	4' x 6.5' collector	2	50 gal. single coil	0.63	680
NAS30020P8	4' x 8' collector	1	50 gal. single coil		615
NAS300201P8	4' x 8' collector	2	50 gal. single coil	0.72	730
NAS30020P10	4' x 10' collector	1	50 gal. single coil	0.50	655
NAS300201P10	4' x 10' collector	2	50 gal. single coil	0.82	810
NAS30040-P	no collector		80 gal. single coil		660
NAS30040	4' x 6.5' collector	2	80 gal. single coil	0.63	760
NAS300401	4' x 6.5' collector	3	80 gal. single coil	0.82	850
NAS30040P8	4' x 8' collector	2	80 gal. single coil	0.74	785
NAS300401P8	4' x 8' collector	3	80 gal. single coil	0.94	900
NAS30040P10	4' x 10' collector	2	80 gal. single coil	0.83	825
NAS300401P10	4' x 10' collector	3	80 gal. single coil	0.95	980
NAS30042-P	no collector		80 gal. dual coil		610
NAS30042	4' x 6.5' collector	2	80 gal. dual coil	0.73	810
NAS300421	4' x 6.5' collector	3	80 gal. dual coil	0.88	900
NAS30042P8	4' x 8' collector	2	80 gal. dual coil	0.80	835
NAS300421P8	4' x 8' collector	3	80 gal. dual coil	0.96	950
NAS30042P10	4' x 10' collector	2	80 gal. dual coil	0.88	875
NAS300421P10	4' x 10' collector	3	80 gal. dual coil	0.97	1030
NAS30060-P	no collector		120 gal. single coil		670
NAS30060	4' x 6.5' collector	3	120 gal. single coil	0.75	970
NAS300601	4' x 6.5' collector	4	120 gal. single coil	0.92	1060
NAS30060P8	4' x 8' collector	3	120 gal. single coil	0.87	995
NAS300601P8	4' x 8' collector	4	120 gal. single coil	0.95	1110
NAS30060P10	4' x 10' collector	3	120 gal. single coil	0.95	1035
NAS300601P10	4' x 10' collector	4	120 gal. single coil	0.95	1190
NAS30062-P	no collector		120 gal. dual coil		700
NAS30062	4' x 6.5' collector	3	120 gal. dual coil	0.82	1000
NAS300621	4' x 6.5' collector	4	120 gal. dual coil	0.93	1090
NAS30062P8	4' x 8' collector	3	120 gal. dual coil	0.91	1025
NAS300621P8	4' x 8' collector	4	120 gal. dual coil	0.97	1140
NAS30062P10	4' x 10' collector	3	120 gal. dual coil	0.97	1065
NAS300621P10	4' x 10' collector	4	120 gal. dual coil	0.97	1220

## Content



Key	Code	Description
1	255060A	Dual-line solar pump station with 3/4" SolarFlex™ fittings
2	255007	Expansion tank mounting kit with double-check valve
3	259012	3 gallon
	259018	5 gallon
	259024	7 gallon
	259035	9 gallon
		Tank size is system dependent
4	NA267003	Bracket to mount solar pump station to storage tank
5	257260A	iSolar™ Plus differential temperature controller
6	NA15006	Lightning protector
7	NA10092	18" SJ round cord connects pump to controller
8	NA3540-15	SolarFlex™ 3/4" x 50 ft. coil piping with fittings
9	NA12133	Hangers for 3/4" SolarFlex™ (4 pcs)
10	NA3140-02	Two 3/4" flex pipes with insulation, 6' long
11	NA10093	Two 90-degree brass elbows 1" male union half
12	250041A	Automatic solar air vent, 1/2" NPT male
13	NA29284	Solar air vent shut-off valve, 1/2" NPT MxF
14	NAT624162	Tee 1" M union x 1/2" NPT F x 1" union nut
15	NA35001	EPDM insulation black tape, 1/8" x 2" x 25' roll
16	NA35002	UV-resistant black film tape, 2" x 30' roll
17	NA12145	Connection kit for 6.5' collectors
	NA12146	Connection kit for even 8' and 10' collectors
	NA12147	Connection kit for odd 8' and 10' collectors
18	NAS10001	Universal foot mounts for solar collectors
19	NA10103	5-15 gallons glycol. NSF listed (amount model specific)

## Application





# MIXCAL™

SURE, SAFE AND COMFORTABLE

## MIXCAL™ THERMOSTATIC MIXING VALVES

- 521 Series valves are ASSE 1017 listed for point-of-distribution applications such as water heaters. Also available with a mixed outlet temperature gauge.
- 5213 Series scald protection valves are ASSE 1070 listed for operation in point-of-use applications such as sinks and faucets.
- 5230 Series valves are ASSE 1017 listed for high flow point-of-distribution applications such as water heaters.
- 521 & 5213 Series valves certified by IAPMO to meet lead free standards.



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