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JOURNAL OF DESIGN INNOVATION FOR HYDRONIC AND PLUMBING PROFESSIONALS

CALEFFI
Hydronic Solutions

36
Fall 2025

Hydronic Zoning Options

FROM THE CEO

Dear Plumbing and Hydronic Professional,

Is it possible to balance comfort and energy efficiency? In many cases, finding this balance can be difficult. A perfect solution prioritizes occupant comfort without being wasteful. Finding this balance in a hydronic system is not hard. A hydronic system design that enhances performance, benefits the environment, and provides a better quality of life is realistic and achievable.

Modern zoning techniques are crucial for designers and installers to make the best use of energy in the pursuit of comfort. This issue of idronics™ discusses the best way to evaluate zoning options to help you select the best option to precisely deliver energy to the areas of the building that need it, while keeping energy waste to a minimum.

Additional topics within our collection of idronics can be found at caleffi.com. We appreciate your continued support of the industry and encourage you to share any feedback by emailing us at marketing.na@caleffi.com.

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1. INTRODUCTION

The purpose of any heating system is to provide comfort in all areas of a building throughout the heating season. Likewise, cooling systems are expected to establish and maintain comfortable interior conditions based on air temperature and humidity.

Accomplishing these objectives requires systems that can adapt to the lifestyle and activities of the building occupants, as well as constantly changing thermal conditions inside and outside of a building.

Figure 1-1

Imagine a building in which all rooms have the same floor area and the same wall height. Someone not familiar with heating systems might assume that, because all the rooms are the same size, they require the same rate of heat input at all times. Although that assumption is reasonable, it doesn't account for differences in the thermal characteristics of the rooms. Some rooms may have only one exposed wall, while other rooms might have two or three exposed walls. Some rooms might have a large window area, while other rooms have no windows. The air leakage, and potential for sunlight to enter through windows, could also vary from one room to another.

Figure 1-2

Beyond these differences are conditions imposed by occupants. One person may prefer to sleep in a room maintained at 65ºF, while another feels chilled if their bedroom is anything less than 72ºF. Someone might prefer a living room temperature of 70ºF while relaxed and reading, but they may also expect the temperature in an exercise room to be 62ºF during a workout.

The combination of room thermal characteristics, weather conditions, inside activities, internal heat gains from equipment and lights, and occupant expectations presents a complex and dynamic challenge for building heating and cooling systems as they attempt to maintain the desired comfort level.

One technique that helps heating and cooling systems adapt to changing conditions and occupant expectations is dividing the system into multiple zones.

WHAT IS A ZONE?

A zone is any area of a building for which indoor air temperature is regulated by a thermostat or other temperature sensing control device.

Figure 1-3

A zone can be as small as a single room or as large as an entire building. The number of zones in a building can range from one to as many as the number of rooms in the building. The latter scenario is called room-by-room zoning.

The greater the number of zones, the more flexibility the occupants have in selecting comfort levels well suited to the activities and other imposed conditions occurring within the building. However, the quality and performance of a zoned heating or cooling system is not determined *solely* by the number of zones it has.

Zoning has been used in hydronic heating and cooling systems for decades. Even early systems without circulators or electrical controls allowed for zoning through use of manually operated valves at each radiator. By adjusting these valves, it was possible to change the flow rates, and thus the heat outputs, from each radiator.

Figure 1-4a

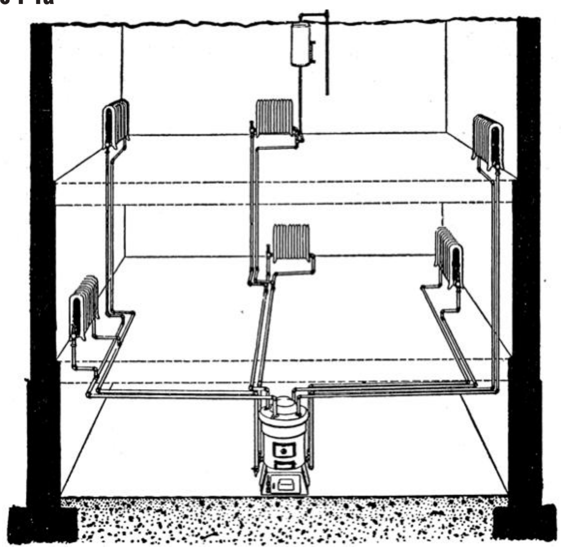


Figure 1-4b

Although these early systems were rudimentary compared to what is possible using modern hydronics technology, they recognized and addressed the need for varying the rate of heat delivery to different areas of a building to accommodate changing conditions and occupant preferences.

WHY IS ZONING BENEFICIAL?

The two most-recognized benefits of zoning are:

1. Allowing occupants to remain comfortable in different areas of a building while accommodating individual or group comfort preferences, activity levels, and continuously varying sources of internal heat generation or other conditions that affect heating or cooling loads.

2. Allowing different internal spaces to be set at comfort levels that, at times, reduce the energy input to heating or cooling systems, and thus lower operating costs. Setting a heating thermostat in a particular zone to a lower temperature during an unoccupied period is an example.

Other benefits include enhancing human productivity in commercial buildings, improved sleeping comfort, and reduced pumping energy in hydronic systems.

ZONE PLANNING CONSIDERATIONS:

When planning a hydronic heating or cooling system, it is important to consider how best to divide the building space into zones, as well as how best to control heat output or cooling delivery within each zone. The goal is to achieve the previously stated benefits without creating systems that are overly complex, expensive or difficult to control.

There is no “standard” approach for zoning design. Every project has nuances that need to be considered. Fortunately, modern hydronics technology provides the flexibility to accommodate a wide range of possibilities.

Given the extensive amount of hardware now available for hydronic zoning, one might assume that the more zones a system has, the better that system was designed. This isn’t necessarily true. Just because it is easy to design a system in which every room is controlled as a separate zone does not mean it’s always the wisest choice. “Over-zoning” can add expense without returning tangible benefits. It can also lead to issues such as short cycling of the system’s heating or cooling source, reduced efficiency and increased maintenance costs.

The following considerations all play a part in planning a zoned system.

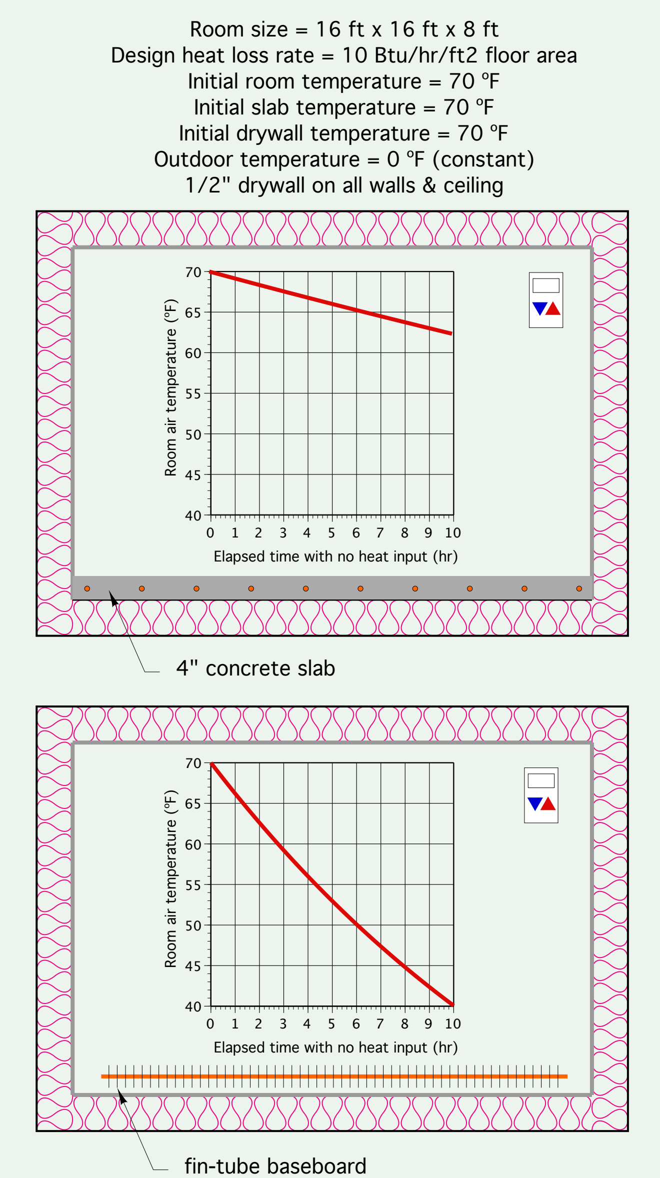
THE EFFECT OF THERMAL MASS

People sometimes assume that a zoned heating system should be able to reduce the temperature within a given space *as soon as the thermostat setting is lowered*, or increase that temperature *as soon as a thermostat setting is increased*. This is not possible because of the thermal mass of the building materials and heating system components.

Thermal mass is the ability of materials to store heat. All materials have some amount of thermal mass, depending on their specific heat and density. Concrete, masonry and drywall have higher thermal mass per unit of volume compared to materials such as wood, plastic, insulation or fabric.

The greater the total thermal mass within a given building space, the slower the air temperature will change when the thermostat setting is increased or decreased. This is illustrated in figure 1-5, which charts the decrease in room temperature over several hours, assuming there is no heat input from the heating system.

Figure 1-5 Room air temperature vs. time



The upper curve is for a room with a 4-inch-thick concrete slab. With no heat input from the heating system, all heat lost from the room is replaced from the thermal mass of the slab and the drywall on the walls and ceiling, all of which had an initial temperature of 70ºF. Over the course of 10 hours, during which the outdoor temperature remains at 0ºF, the room temperature decreases from 70ºF to approximately 62.5ºF.

The lower curve also shows how the air temperature in the room decreases, but in this case, the room doesn't have the concrete floor slab. All heat lost from the room is replaced from the thermal mass of the drywall and stationary water within 16 feet of the residential fin-tube baseboard. Over the same 10-hour period, and with the same outdoor conditions (i.e., 0ºF outdoor temperature), the room's air temperature would drop to about 40ºF.

It's important to remember that most thermostats are simply *temperature-operated switches*. Lowering the thermostat setting several degrees simply opens an electrical circuit running through the thermostat that prevents further heat input from the heat emitters in that space.

Consider the room represented by the assumptions and graph in figure 1-5. Assume that the occupants turn the thermostat setting from 70ºF to 60ºF at bedtime (e.g., when the elapsed time shown in figure 1-5 begins).

The temperature in the room containing the concrete floor slab doesn't drop to 60ºF, even after 10 hours. However, the room without the floor slab has much lower thermal mass. Its temperature drops to the 60ºF setpoint in less than three hours. At that point, the thermostat would turn the heating system on to prevent further temperature drop.

Figure 1-6

Because the room with the lower thermal mass would undergo more elapsed time at an interior temperature of 60ºF, and because the rate of heat loss from the room decreases at lower interior temperatures, the energy savings associated with the thermostat setback would be greater compared to that of the room with the floor slab.

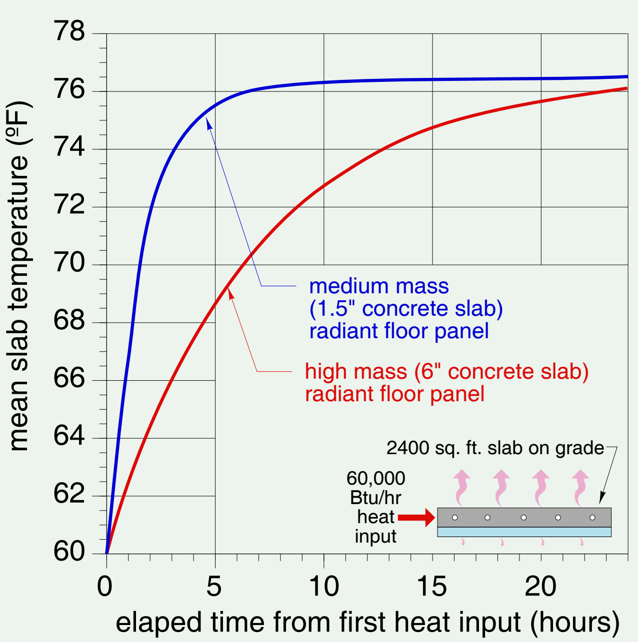
The potential energy savings associated with thermostat setbacks are highly dependent on the heat loss and thermal mass characteristics of the space in which the thermostat is located. Spaces having well-insulated and tightly sealed thermal envelopes, as well as high thermal mass construction, will experience minimal energy savings from daily thermostat setbacks.

Thermal mass also affects the rate at which a space at some initial temperature can be warmed to a higher temperature. Spaces with high thermal mass heat emitters, such as a heated floor slab, warm significantly slower compared to spaces with low thermal mass heat emitters. Figure 1-7 shows the latter effect by charting the time required for a 2,400-square-foot floor slab to be warmed from an initial temperature of 60ºF, while absorbing heat at a constant rate of 60,000 Btu/hr.

The 1.5-inch-thick "thin slab" approaches its steady state condition after about 8 hours of heat input. However, the 6-inch-thick slab is still increasing temperature after 24 hours of steady heat input.

If rooms with significantly different thermal mass are combined on the same zone (e.g., controlled from the same thermostat), their temperature responses can be very different. The space with low thermal mass will reach the desired temperature much quicker than the space with high thermal mass. It's likely that this difference in response will lead to complaints, especially if thermostat setbacks or other frequent thermostat setting changes occur.

Figure 1-7



When two or more rooms are being considered to operate as a single zone, it's important that they have similar thermal mass in both their interior materials as well as their heat emitters.

HEAT TRANSFER BETWEEN ZONES

In an ideal scenario, each zone within a building would act as if it were an isolated "compartment," completely separated from other zones in the building. In such a scenario, it would be possible to set the desired air temperature of one zone at 70ºF and the desired temperature of an adjacent zone at 60ºF. The heat emitter(s) within each zone would release heat at the rates needed to maintain those set temperatures. Occupants would also be able to walk between these zones without disturbing those temperatures.

In reality, such a scenario doesn't exist. In many buildings, the separation between adjacent zones is an *uninsulated* partition. Interior doorways from rooms on different zones often lead to common spaces such as hallways. Even in situations where adjacent zones are separated by *closed* interior doors, those doors are typically not insulated and offer minimal resistance to heat transfer.

The relatively weak thermal separation of adjacent interior zones can result in significant inter-zone heat transfer. A room maintained at 70ºF will transfer heat through an uninsulated interior partition or open doorway to an adjoining room that's at a lower temperature. This effect is especially pronounced in buildings with well-insulated thermal envelopes.

Inter-zone heat transfer might be viewed as beneficial because it tends to equalize interior temperatures between spaces where heat emitter outputs are not well matched to loads, or where unanticipated internal heat gains occur. However, inter-zone heat transfer makes it difficult to maintain temperature differences of more than about 5ºF between rooms in well-insulated buildings, even when the interior doors in those rooms are kept shut. This effect partially defeats one of the often-intended goals of zoning.

When it's desirable to maintain higher temperature differences between adjacent zones, interior partitions need to be insulated. Interior doors between those zones should also provide a relatively tight seal against interior air flows and remain closed. Although this is all possible, it is not commonly implemented in modern residential or commercial construction.

INTERNAL HEAT GAINS

All buildings experience unscheduled heat input from sources *other than* their heating system. Building spaces with minimal windows, low occupancy and minimal if any electrical load, usually have low internal heat gain. Spaces with large window areas on east, south or west walls, or skylights can experience large solar heat gains based on the time of day and weather conditions. Spaces where people gather, or where lots of electrically powered equipment operates, can also experience high internal heat gains.

These gains can significantly affect thermal comfort, and as such should be considered when planning zones. In general, building spaces with the potential for high internal heat gains should not be on the same zone as spaces with minimal internal heat gains.

Figure 1-8

An example would be a building with significant window area on the east, south or west sides. As the sun moves across the sky on a clear day, rooms with east-facing glass will warm first due to morning sunlight. Next to warm will be rooms with south-facing windows. During the afternoon, rooms with west-facing glass will experience solar heat gains. During this same time, rooms with north-facing glass will experience minimal if any solar heat gain. Setting these different rooms up as separate zones would help in maintaining comfort by allowing heat input to vary based on solar heat gains. Equally important would be using heat emitters with low thermal mass that can quickly adjust heat output to compensate for the heat gains.

Internal heat gains from occupants depend on the number of people present and their activity level. A sedentary adult will typically generate 350 to 400 Btu/hr of metabolic heat output. The same person engaged in a strenuous or highly athletic activity could generate close to 2,000 Btu/hr.

Internal heat gain from electrically operated devices within a space is relatively easy to estimate once the wattage of the device(s) is determined. Use formula 1-1 to convert watts to Btu/hr.

Formula 1-1:

$$\frac{Btu}{hr} = watts \times 3.413$$

OCCUPANCY SCHEDULE

Zoning allows for reduced temperatures in spaces when they are unoccupied, resulting in reduced heat loss. Leveraging this potential benefit requires planning that separates spaces that can operate at reduced temperatures from spaces where temperature setback is unlikely or undesired.

Bedrooms are often zoned separately from spaces that are occupied during daytime hours. It's also good to put bathrooms and bedrooms on separate zones. This allows the bathrooms to be brought to a comfortable temperature for morning showers, while bedrooms remain at lower temperatures.

Figure 1-9

Rooms that are only occasionally occupied are also good candidates for separate zoning. Examples include a guest room, workshop area or a recreation room. When such areas are zoned separately, it's important to consider the time required to bring them from a reduced temperature to the desired comfort level. Areas maintained 10ºF or more below normal occupancy temperature, and having high thermal mass, can take several hours to warm back to the desired occupancy temperature. If this is unacceptable, those spaces should be equipped with low thermal mass heat emitters.

Areas with significantly different occupancy schedules should not be on the same zone.

ROOM-BY-ROOM ZONING

There are several ways to make every room in a building a separate zone. In some situations, this can be done at minimal additional cost. In other circumstances, it can add thousands of dollars to the installed cost of the system.

Given the zone planning considerations just discussed, room-by-room zoning provides the greatest flexibility for factors such as differences in thermal mass, internal heat gain or occupancy schedules.

The decision to use room-by-room zoning depends on several factors:

1. The piping method and materials required to allow flow adjustments through the heat emitter(s) in each room.

2. Any added cost compared to combining some rooms onto a single zone.

3. The likelihood that the temperature in different rooms *will need to be changed on a regular basis.*

4. The likelihood of significantly different internal heat gains from one room to another.

Piping and control methods for room-by-room zoning are necessarily more complex than those needed for minimally zoned systems. These methods will be discussed in later sections.

The cost to implement room-by-room zoning depends on the hardware used. Electronic thermostats, along with the associated low voltage wiring and electrically operated valves, often cost more than using non-electric thermostatic valves. However, modern thermostats offer more features, such as WiFi accessibility, setback schedules and the ability to “learn” occupant preferences over time.

Keeping different rooms in a building at different *but consistent* temperatures is possible without the need for room-by-room zoning. It can be done using techniques such as flow adjustment, mixing devices that create multiple supply water temperatures, or by varying tube spacing within site-built radiant panels. These techniques don’t require a separate thermostat (or other temperature-sensing control device) in each room.

Room-by-room zoning is ideal when there’s *a need to make recurring changes* in the temperature of some rooms with minimal impact on the temperature in other rooms. It’s well-suited to situations where occupants want the possibility of setting different temperatures for sleeping rooms, bathrooms, exercise areas, rooms for growing certain types of plants, or rooms for people with medical conditions that favor warmer temperatures. It’s also a good choice in situations where rooms have widely varying potential for solar or other internal heat gains.

Not all buildings need room-by-room zoning. Buildings with large open spaces or passages between adjoining rooms tend to defeat the purpose of room-by-room zoning due to ease of natural heat flow between spaces. This is especially true if the thermal envelope surrounding these adjoining spaces presents high resistance to heat loss. While it’s certainly possible to install expensive thermostats in every room of a large house, and to install wiring from all those thermostats to associated controls in the mechanical room, doing so can add significant cost without producing significant performance benefits.

The sections that follow describe several approaches to creating zoned hydronic systems. They vary based on the hardware and control methods used. When properly designed and installed, all these methods can provide accurate control of heat delivery or cooling effect when and where it’s needed within a building.

2. ZONING WITH CIRCULATORS

One common approach for zoning a hydronic heating or cooling system is based on using a separate circulator for each zone circuit. The circulator is turned on when a thermostat located within the zoned space calls for heat or cooling. When the thermostat reaches its setpoint temperature, the circulator is turned off.

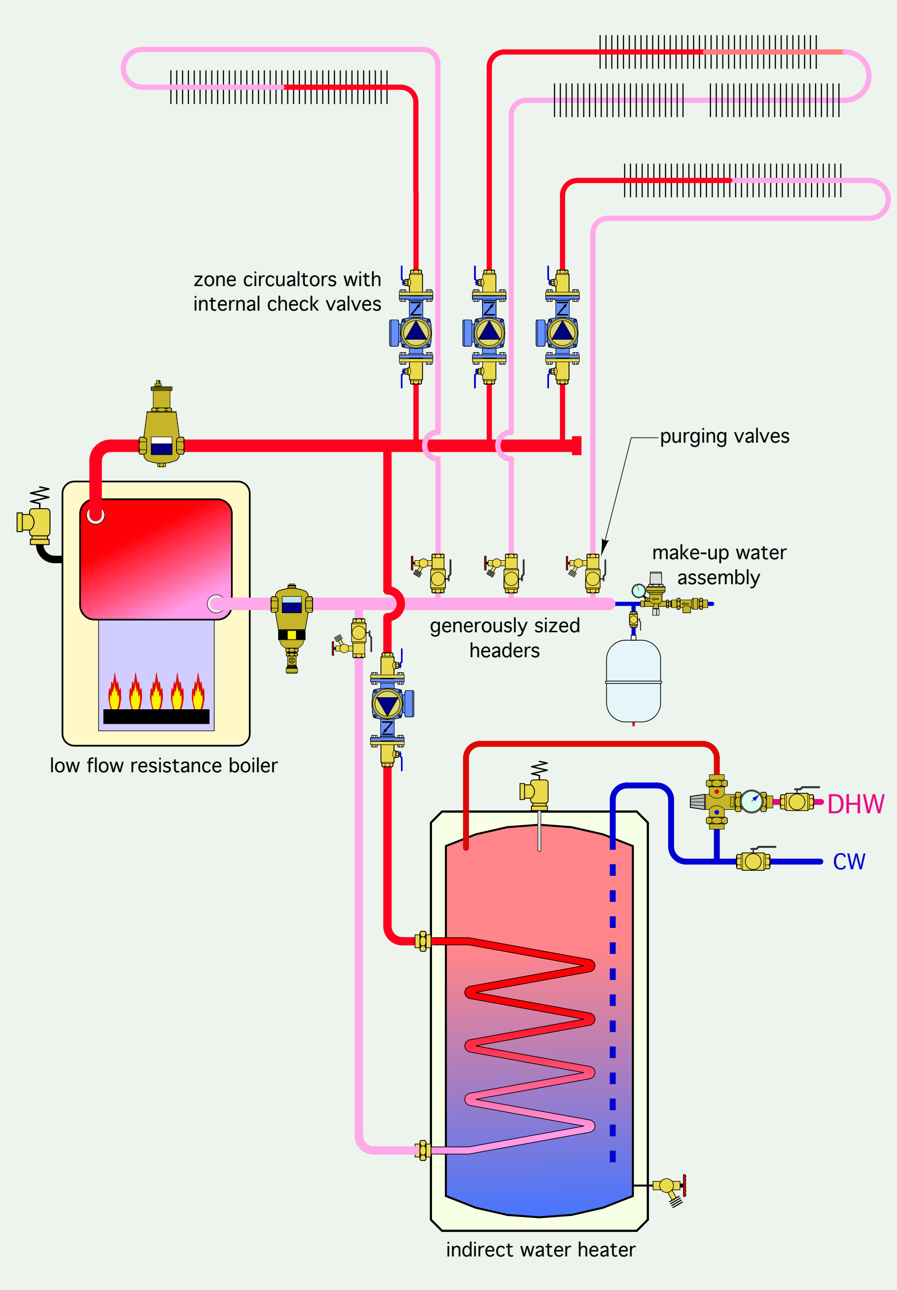
Figure 2-1 shows two common piping arrangements for a four-zone system.

The system in figure 2-1a assumes that the heat source has very low flow resistance. A cast iron boiler is an example of such a heat source. A buffer tank that temporarily stores heat from some other source is another. In such systems, all zone circuits begin and end at headers that connect directly to the heat source or buffer tank.

The system in figure 2-1b assumes a heat source with high flow resistance, such as certain modulating/condensing boilers, or a hydronic heat pump. The headers connect to a hydraulic separator. The heat source has its own dedicated circulator.

In both systems, three of the four zone circuits supply space heating, while the fourth zone supplies an indirect water heater.

Figure 2-1a



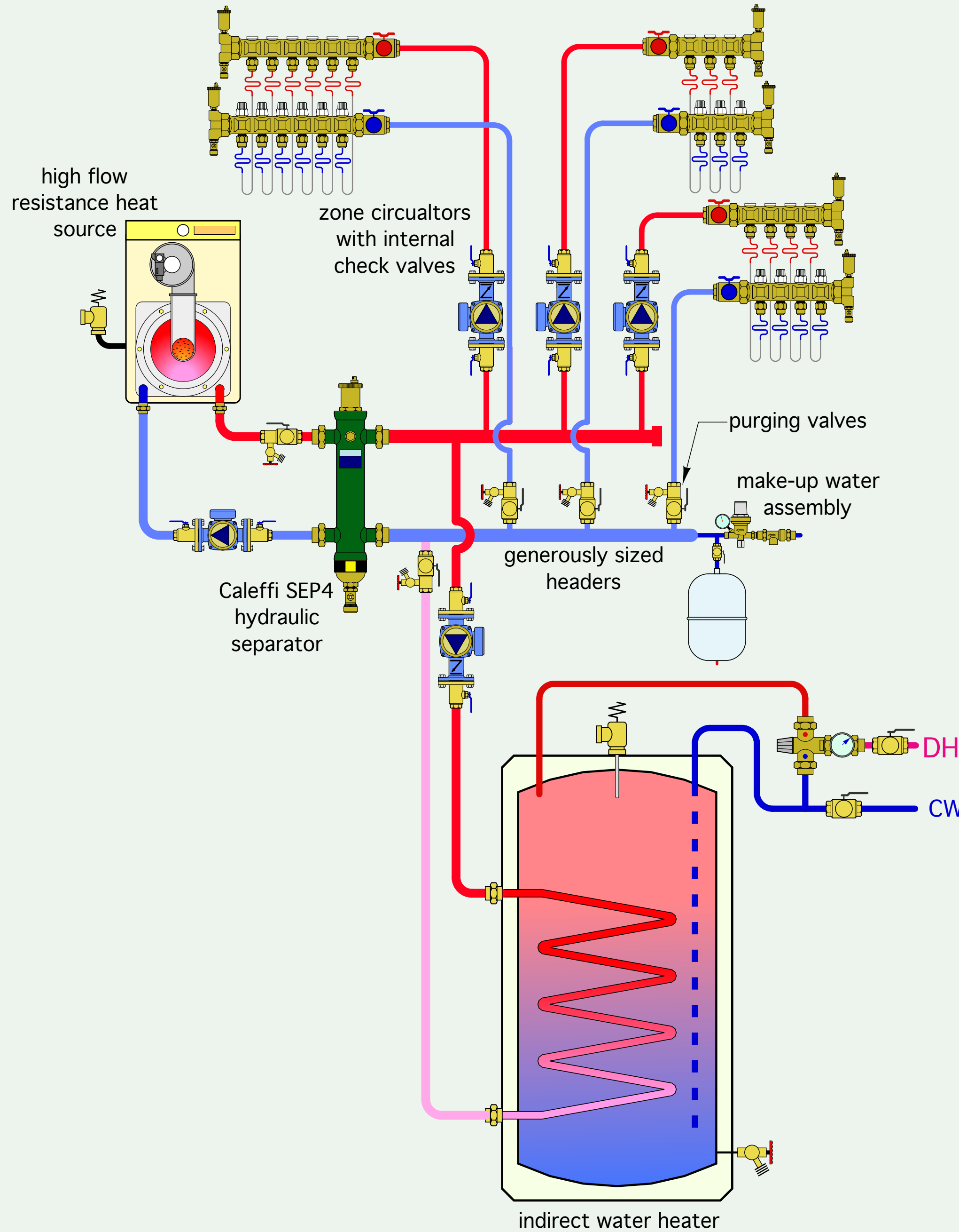
ADVANTAGES AND DISADVANTAGES ASSOCIATED WITH ZONE CIRCULATORS

One advantage of using zone circulators is that the failure of one circulator doesn't interrupt heat delivery to the other zones. If the circulator that failed was installed with valves on both its inlet and outlet, it can be quickly isolated, removed and replaced within a few minutes.

Another advantage of zoning with circulators is the ability to size each circulator to the flow and head requirements of its associated zone circuit. Contrary to what is often assumed, *all the zone circulators in a system don't have to be the same make or model.* Multi-speed circulators can be set for lower flow and head requirements in small or short zone circuits. They can also be set for higher flow and head requirements in large or long zone circuits. If the speed settings available on a multi-speed circulator are unable to provide the hydraulic needs of a given zone, a different circulator can be used.

One major *disadvantage* of zoning with circulators is that the electrical power required, especially with all zones operating, typically exceeds that required for an equivalent system

Figure 2-1b



using valve-based zoning. This can be demonstrated by calculating the distribution efficiency of a system with zone circulators to that of an equivalent system using zone valves.

Distribution efficiency is defined as follows:

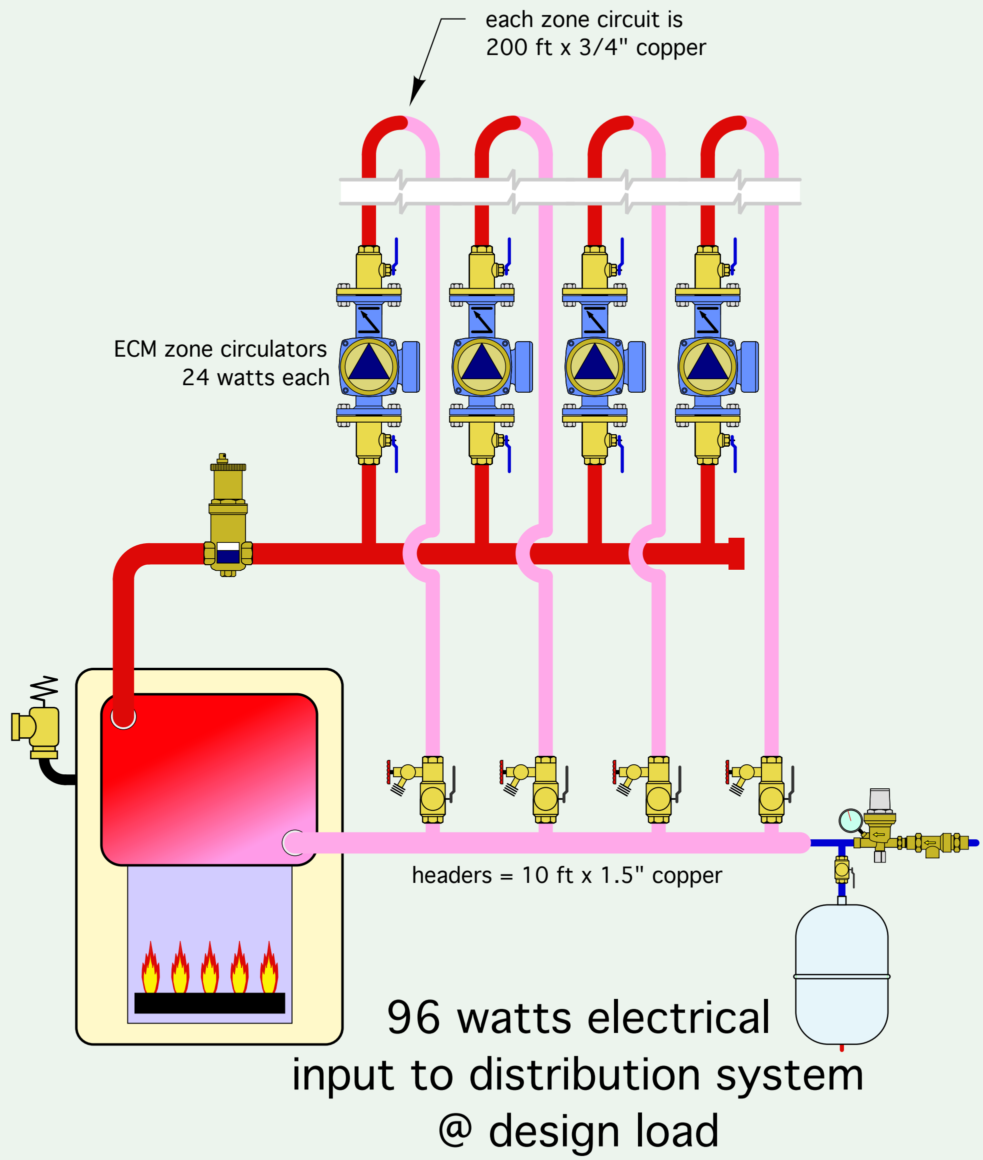
$$n_d = \frac{q_d}{w_d}$$

Where:
n_d = distribution efficiency
q_d = rate of heat delivery at design load (Btu/hr)
w_d = wattage required to operate the distribution system at design load (watts)

The higher the distribution efficiency, the greater the rate of heat delivery per watt of input power to operate the distribution system.

Distribution efficiency is not, in any

Figure 2-2a



way, related to the *thermal* efficiency of the system's heat source. It is solely determined by the design and components used in the distribution system.

Consider a four-zone system where each zone circuit is powered by a modern zone circulator with an ECM motor, as shown in figure 2-2a.

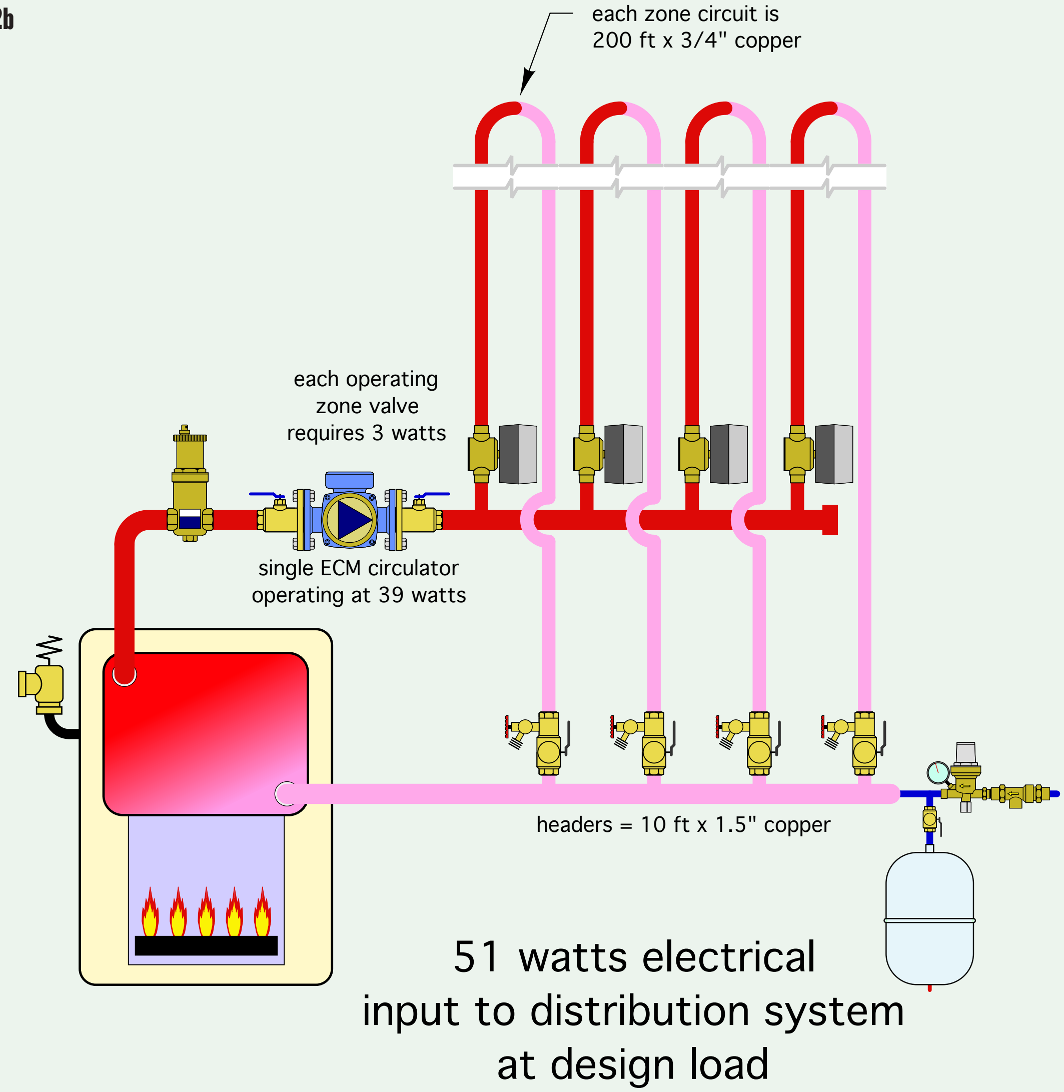
Assume that each zone circuit has the equivalent length of 200 feet of 3/4-inch copper tubing and operates with water supplied at 130ºF. Each zone delivers 5,000 Btu/hr at design load. Under these conditions, the estimated power input to each zone circulator when it's operating is 24 watts. With all four zones operating, the total estimated power input to the distribution system is 96 watts.

The distribution efficiency of this system would be:

$$n_d = \frac{q_d}{w_d} = \frac{4(5{,}000)\dfrac{Btu}{hr}}{4(24\,watt)} = 208\,\frac{Btu/hr}{watt}$$

The calculated value of distribution efficiency (e.g., 208 Btu/hr/watt) can be interpreted as follows: For each watt of electrical power supplied to operate this distribution system, it delivers 208 Btu/hr where it needs to go in the building.

Figure 2-2b

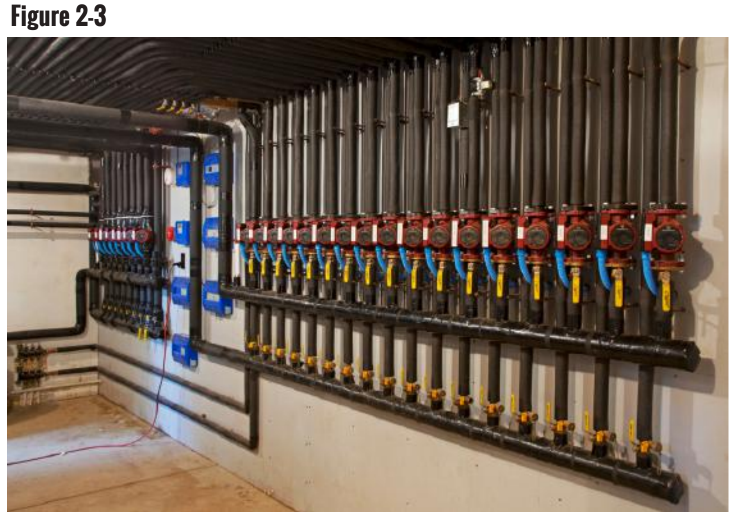


If these four zone circuits were instead supplied by a *single* circulator *of the same make and model* as the four zone circulators, along with valve-based zoning, the estimated power input to that circulator with all zones operating is 39 watts. Adding another three watts each for four operating zone valves brings the total wattage for the distribution system at design load to 51 watts (figure 2-2b).

The distribution efficiency of the zone valve system would be:

$$n_d = \frac{q_d}{w_d} = \frac{4(5{,}000)\dfrac{Btu}{hr}}{51 watt} = 392\frac{Btu/hr}{watt}$$

Figure 2-3



Courtesy of Radiant Professionals Alliance

In this comparison, the system using valve-based zoning delivers about 88% more heat per watt of electrical input, compared to the system using zone circulators.

Systems using circulator zoning, but with a very high number of zones, can have low distribution efficiency. This is especially true if the zone circulators have permanent split capacitor (PSC) motors.

Consider a system similar the one shown in figure 2-3.

Although the workmanship appears excellent, this system has 26 zone circulators with PSC motors. Each circulator has an estimated input power of 75 watts. Assume that the distribution system delivers 240,000 Btu/hr at design load conditions with all 25 circulators operating. It's distribution efficiency would then be:

$$n_d = \frac{q_d}{w_d} = \frac{240{,}000\frac{Btu}{hr}}{26(75watt)} = 123\frac{Btu/hr}{watt}$$

This distribution efficiency is significantly lower than either of the previous examples.

Converting the circulators to new models with ECM rather than PSC motors would improve the distribution efficiency, but it's likely to remain well below that of a similar system using zone valves and a single ECM circulator, especially if that single circulator has pressure-based variable-speed control.

Another potential disadvantage of zoning with circulators is the need for line voltage wiring to each circulator. Some building or electrical codes may require that wiring to be routed through conduit and installed by a licensed electrician. In contrast, most electrically operated zone valves only require 24 VAC wiring, which typically doesn't have to be run through conduit or installed by a licensed electrician. This helps reduce installation cost.

DETAILS WHEN ZONING WITH CIRCULATORS

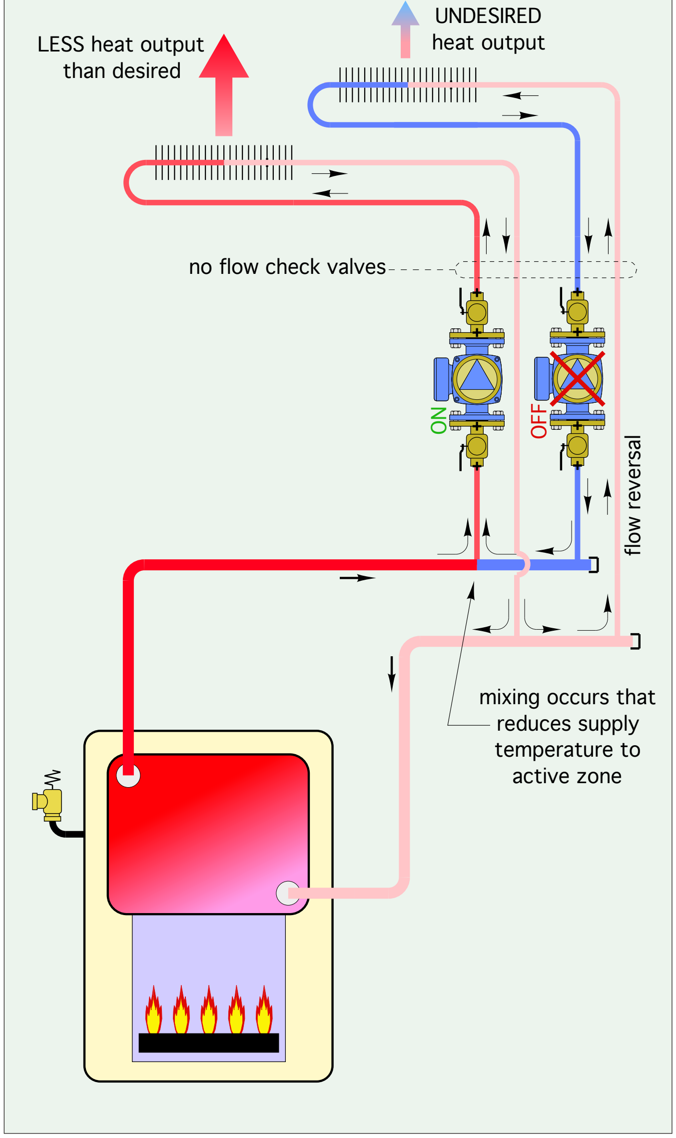
There are several design and installation details that help ensure reliable and efficient performance of systems using zone circulators.

One is the use of spring-loaded or weighted-plug check valves in each zone circuit. These valves serve two purposes:

1. They prevent hot water from migrating into inactive zone circuits. Without this provision, hot water will thermosiphon upward into zone circuits when the associated zone circulator is off. This effect is caused by the difference in density between "hot" water in the heat source and adjacent piping, and cooler water on the return side of the circuit. *__A typical swing check valve cannot prevent this undesirable effect__.* However, a spring-loaded check valve, such as shown in figure 2-4, or the weight of the plug in an older style "Flo Control" valve, both provide approximately 0.5 psi forward opening resistance. This is typically sufficient to prevent thermosiphon flow.

Figure 2-4

Figure 2-5



2. They prevent flow reversal through inactive zone circuits when other zones are operating. Figure 2-5 shows how such flow reversal would otherwise occur if check valves were not present in each zone circuit.

Flow reversal through inactive zone circuits creates undesirable heat output in spaces that don't need that heat. It also causes a mixing effect in the supply header that reduces the water temperature supplied to the active zone circuits, which reduces heat output from the heat emitters in those circuits.

Many of the wet-rotor circulators currently sold for zoning in residential and light commercial hydronic systems come with spring-loaded check valves that fit into the discharge port of the circulator's volute. If a circulator with an integral check valve is installed in vertical pipe with upward flow, it is essential to thoroughly purge the circuit to prevent air from being trapped within the circulator's volute.

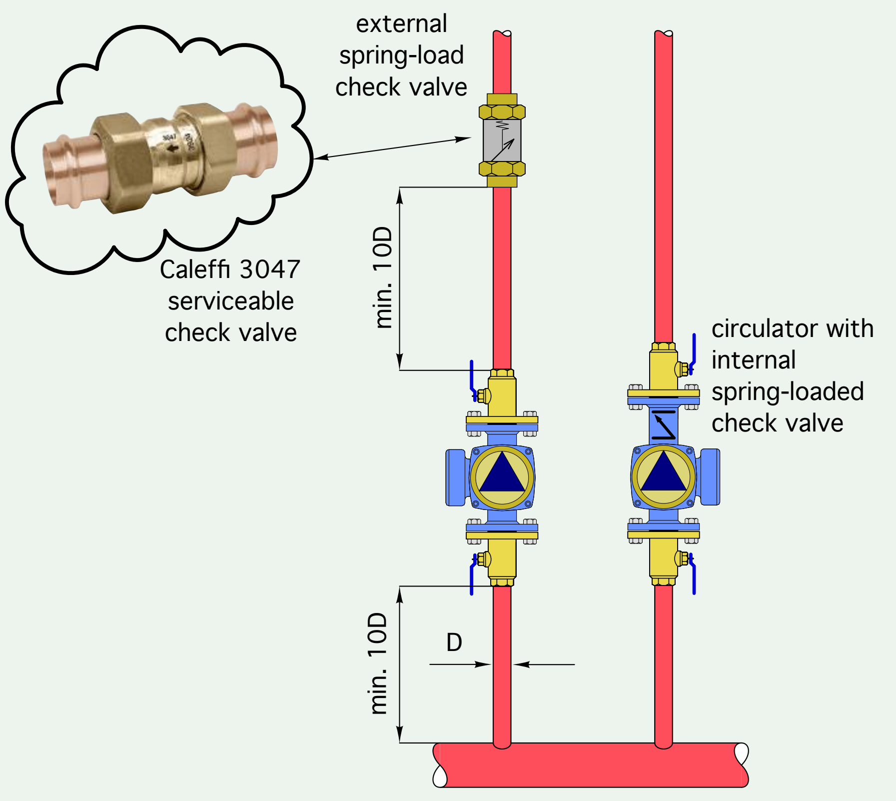
It's also possible to install a spring-loaded check valve downstream of the circulator, as shown in figure 2-6.

When installing circulators, it's important to plan for a minimum length of straight pipe on the inlet side of the circulator. The suggested minimum length is 10 times the nominal diameter of the pipe. This reduces turbulence in the flow stream before it enters the circulator, suppressing flow noise and reducing the possibility of cavitation under certain conditions.

The same minimum straight pipe length of 10 times the pipe diameter should be present *upstream* of any check valve. This reduces the potential for oscillations in the check mechanism. It also allows air bubbles to rise up and out of the circulator's volute, reducing the possibility that the circulator cannot clear itself of air.

It is possible for dirt, solder balls, pieces of teflon tape or other debris to get entangled with the spring assembly or the seat in a check valve. This can prevent full closure of the valve and partially negate its intended functions. Caleffi offers a *serviceable* spring check valve which can be easily disassembled to clear any such debris. Figure 2-4 shows an example of this valve, which is available in pipe sizes up to 2-inch and with several types of pipe connections (e.g., solder, press, FPT threaded or PEX).

Figure 2-6



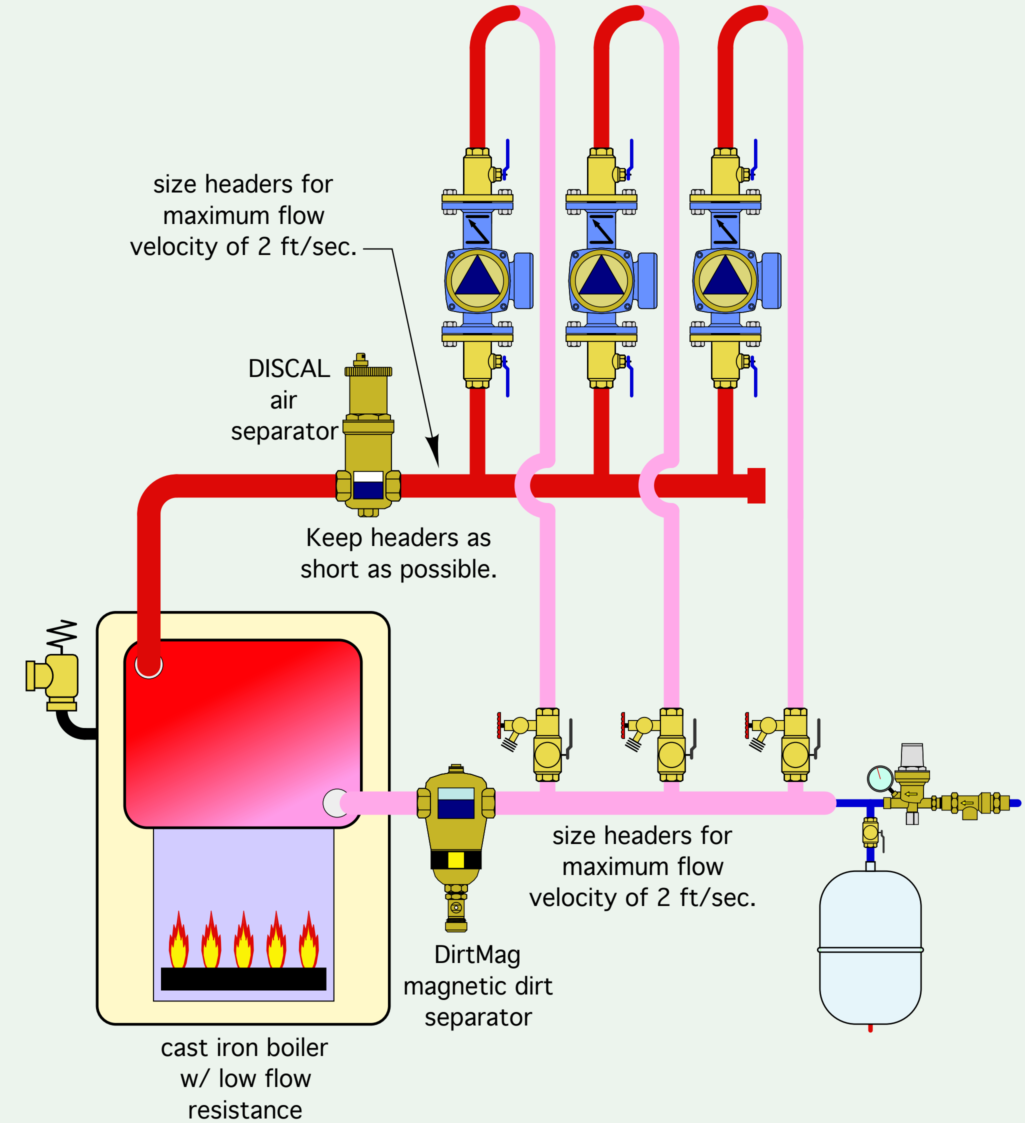
IMPORTANCE OF HYDRAULIC SEPARATION

Systems with circulator-based zoning have at least two circulators. Depending on the size of the building and how it is divided into zones, there can be four, six, even 12 or more zones, each powered by a separate independently controlled circulator.

Designers often plan for each zone to operate at some target flow rate. Those flows are usually calculated independently for each zone, based on the load, the desired temperature drop under design conditions, and the type of heat emitters used.

In an ideal scenario, the intended flow rate for each zone would remain unaffected by the on/off status of other zones in the system. If the target flow rate for zone 1 is four gpm, that flow rate should be maintained in zone 1 when it's the only zone operating, *and* when any one or more of the other zone circulators are operating.

Figure 2-7



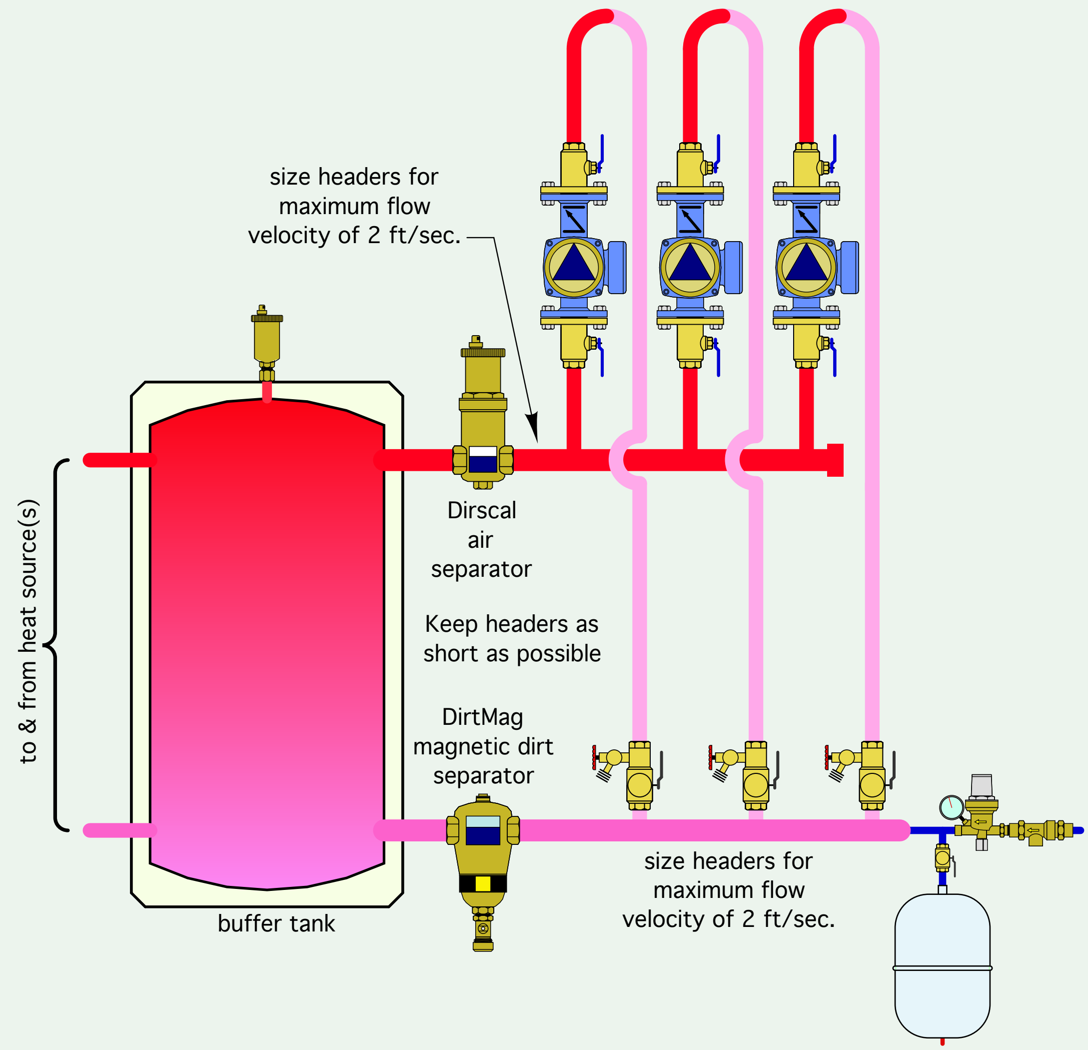
Whenever two or more circulators are used in the same system and are capable of operating at the same time, it's important that the pressure dynamics created by one circulator do not interfere with those created by another circulator. This effect, when achieved, is called hydraulic separation. *Understanding the concept of hydraulic separation is an essential prerequisite to designing hydronic systems that perform as expected.*

Achieving hydraulic separation starts by first identifying the piping and components that are "common" or "shared" by all circuits having circulators. This portion of the system will be called the "common piping." Once identified, *the design goal is to make the head loss of the common piping as low as possible.*

There are several design techniques and component options that can be used to establish hydraulic separation. In systems using zone circulators and low-flow-resistance heat sources, such as cast iron boilers, hydraulic separation can be achieved by keeping the headers supplying the zone circuits generously sized and as short as possible, as shown in figure 2-7.

The headers should be sized for a maximum flow velocity of two feet per second, assuming that all zones are operating. This, along with keeping the headers as short as possible, creates minimal head

Figure 2-8



loss. Most cast iron boilers have very low flow resistance due to the large open flow chambers in the cast iron sections. The headers combined with the boiler represent the piping that is *common* to all three zone circuits. Since the flow resistance of that common piping is low, hydraulic separation is achieved.

Hydraulic separation can also be achieved when the headers supplying the zone circuits connect to a buffer tank, as shown in figure 2-8.

The flow resistance through the buffer tank is extremely low. The buffer tank, combined with short and generously sized headers, provides a low-flow-resistance common piping path for all the zone circuits, and thus, hydraulic separation is achieved.

Another possibility is to use a pair of closely spaced tees along with the short and generously sized headers to achieve hydraulic separation of the zone circulators, as shown in figure 2-9.

A modern method for achieving hydraulic separation of the zone circuits is to install a hydraulic separator along the short and generously sized headers, as shown in figure 2-10.

The system in Figure 2-10 uses a Caleffi SEP4™ hydraulic separator. In addition to providing hydraulic separation of the circulators, the SEP4 provides microbubble air separation, dirt separation and magnetic particle separation. It eliminates the need to install multiple components for these separation functions, allowing for compact and faster installation.

Figure 2-9

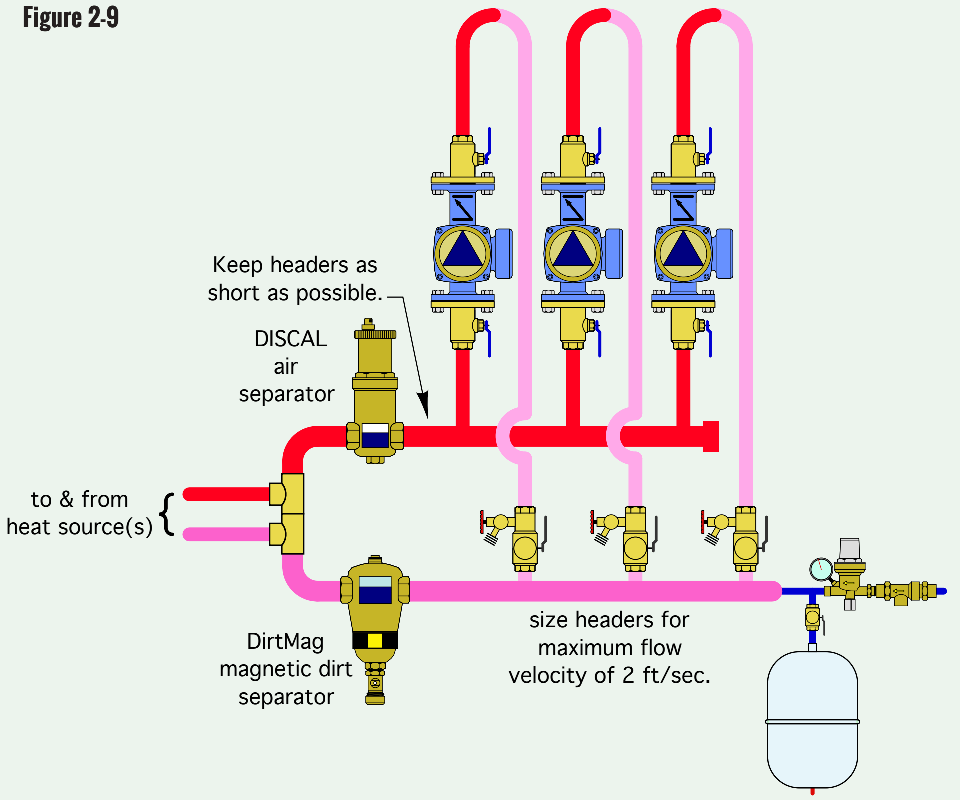
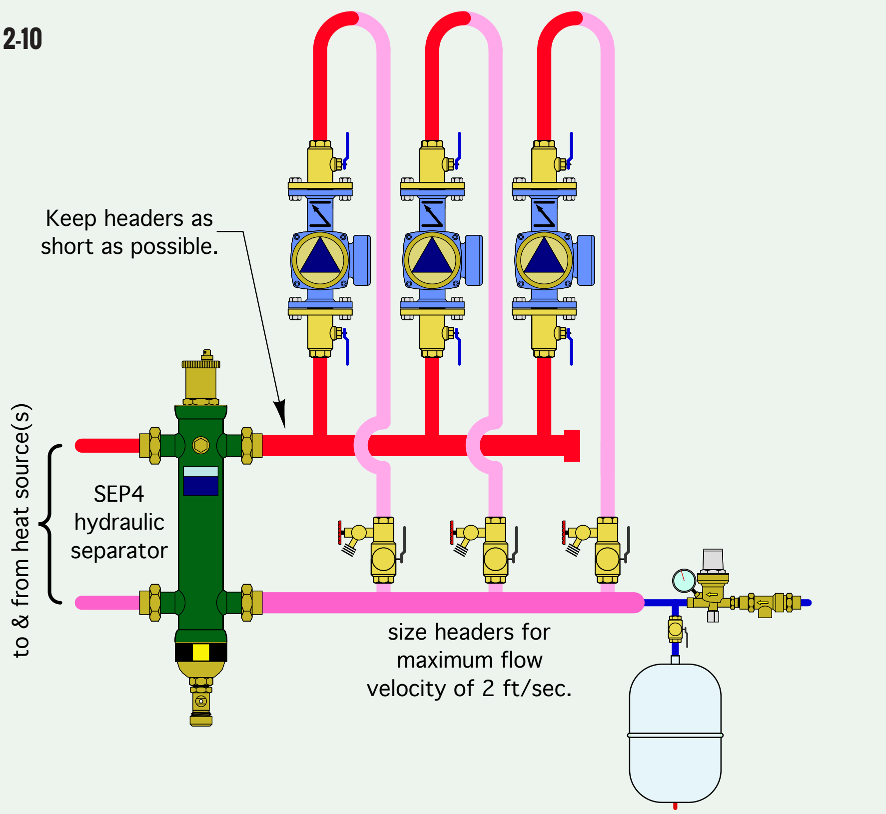


Figure 2-10



PURGING PROVISIONS

Whenever zoning is used, some means for efficiently filling each circuit and purging it of air should be provided. Figures 2-7 though 2-10 all show purging valves on the *return side* of each zone circuit. These valves combine an inline ball valve with another "side port" valve that can be connected to a hose. The same functionality can also be provided by installing two separate valves, one in line with the zone circuit and another fitted to the side port of a tee installed just upstream of the inline valve. The latter option is more suitable in systems that use larger piping. Both options are shown in figure 2-11.

Figure 2-12 shows an efficient method for filling a system with water and purging it of "bulk air."

In this example, a hose is connected to the outlet port of the purge valve on one zone. The inline ball of the purge valve in that circuit is closed, and the outlet valve is opened. The purge valves and isolation flanges on the circulators in the other zones are all closed. Cold water is fed into the system through the (manually opened) pressure-reducing valve. This flow is forced through the boiler, the headers, and the one open circuit. The cold water feed pressure needs to be high enough to create a strong flow rate through the open flow path. Air in the piping path is pushed ahead of the water and eventually exits through the outlet valve on the circuit.

Figure 2-11

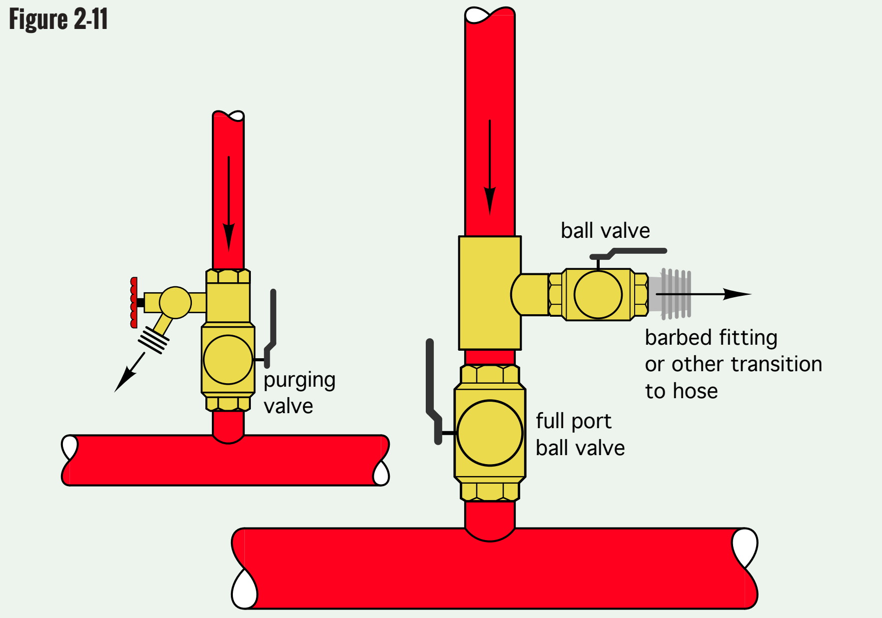
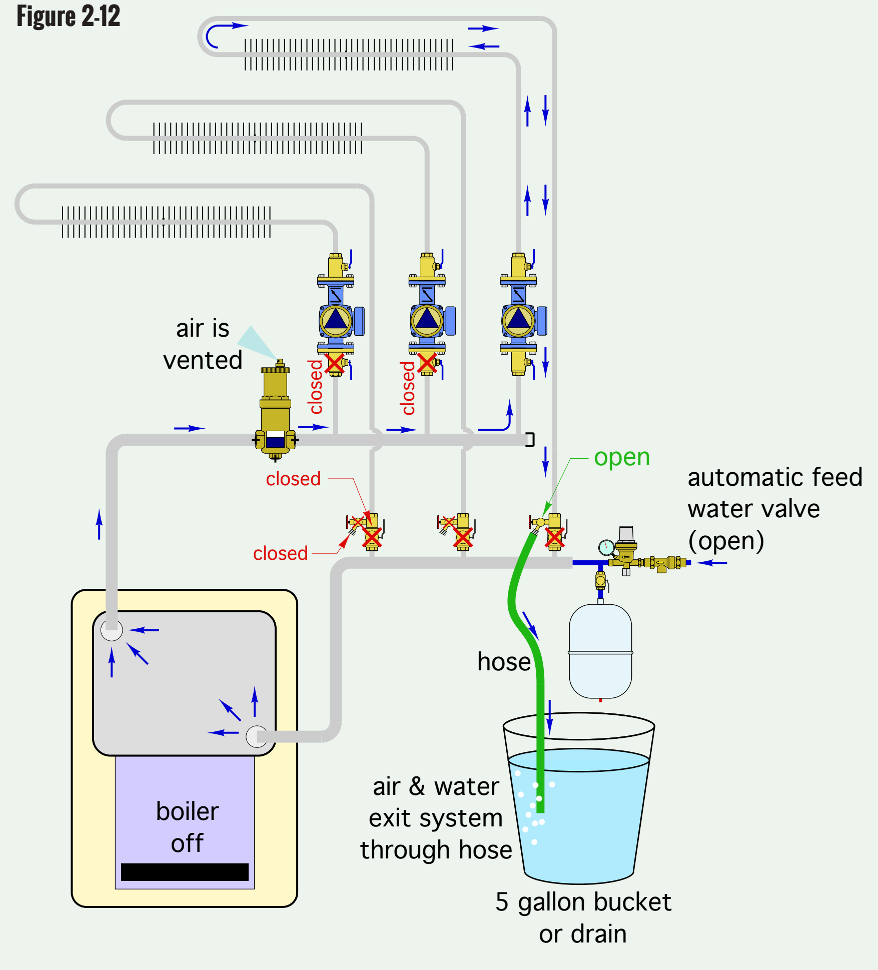


Figure 2-12



The hose should be held or secured over a bucket or drain. The purging flow should be maintained until the stream leaving the purge valve is free of any visible bubbles. The circuit that was just filled and purged should then be isolated, the hose moved to another purge valve, and the process repeated for the remaining circuits. Purging each zone circuit independently expedites bulk air removal, compared to purging all zone circuits simultaneously.

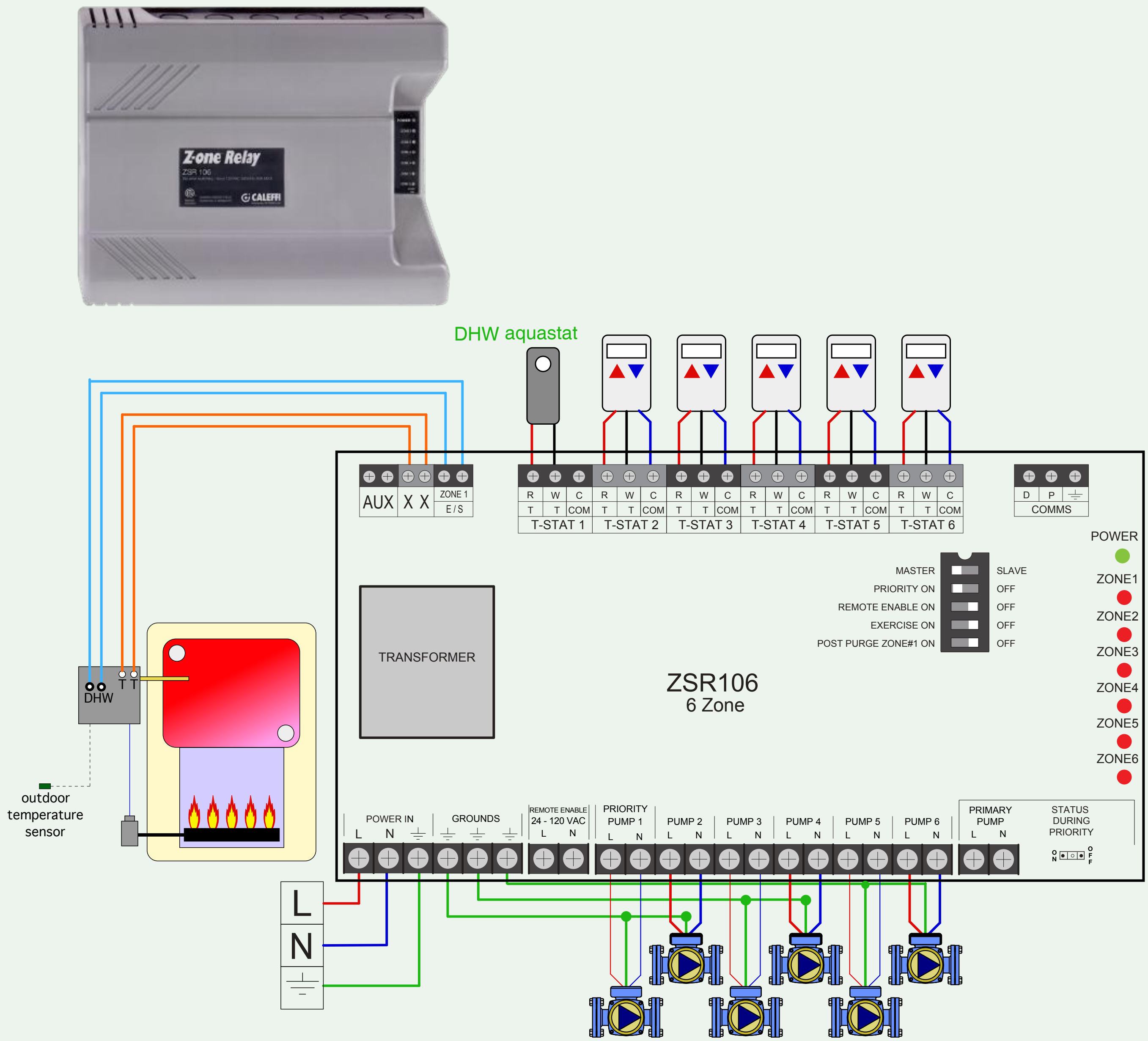
After all zone circuits are purged of "bulk air," there are still *molecules* of oxygen, nitrogen and other air gases dissolved in the cold water. A high-efficiency microbubble air separator, such as the Caleffi Discal®, will capture and eject this dissolved air soon after the system is put into operation.

MULTI-ZONE CONTROLLERS FOR ZONE CIRCULATORS

Systems using zone circulators typically use a low-voltage (24 VAC) thermostat in each zone to signal when a line voltage circulator should turn on or off in response to changes in room temperature. These systems also require that the heat source is enabled to operate whenever one or more zone thermostats are calling for heat. Some systems also require one zone to have "priority" over other zones. When the priority zone is active, the other zones are temporarily turned off, at least for some predetermined time interval. In many systems, domestic water heating using an indirect water heater is treated as the priority zone.

The most convenient, simplest and most cost-effective approach to accomplishing these control functions is by using a Multi-Zone Pump Control. Figure 2-13 shows an example of the Caleffi ZSR106 Multi-Zone Pump Control.

Figure 2-13



The Caleffi ZSR106 Multi-Zone Pump Control provides wire “landing” terminals for up to six zone thermostats. When a heating call is received from a specific thermostat, the relay center turns on the associated zone circulator and signals the heat source to operate.

Similar multi-zone pump controls are available for systems with motorized zone valves. These are discussed in the next section.

See *idronics* 14 for more information on Caleffi multi-zone controllers.

3. ZONING WITH MOTORIZED VALVES

Another common method for zoning hydronic heating and cooling systems is based on a single circulator combined with an electrically operated zone valve in each circuit. A thermostat in each zone signals its associated zone valve to open when heating (or cooling) is needed. In most systems, the circulator and the heat source (or the chiller) are also enabled to operate whenever one or more zones are calling for heating or cooling.

Figures 3-1a and 3-1b shows two common piping arrangements for a four-zone heating system.

Each of these systems uses a single variable-speed pressure-regulated circulator to create flow through any active zone circuit(s).

The system in figure 3-1a is based on a low-flow-resistance

Figure 3-1a

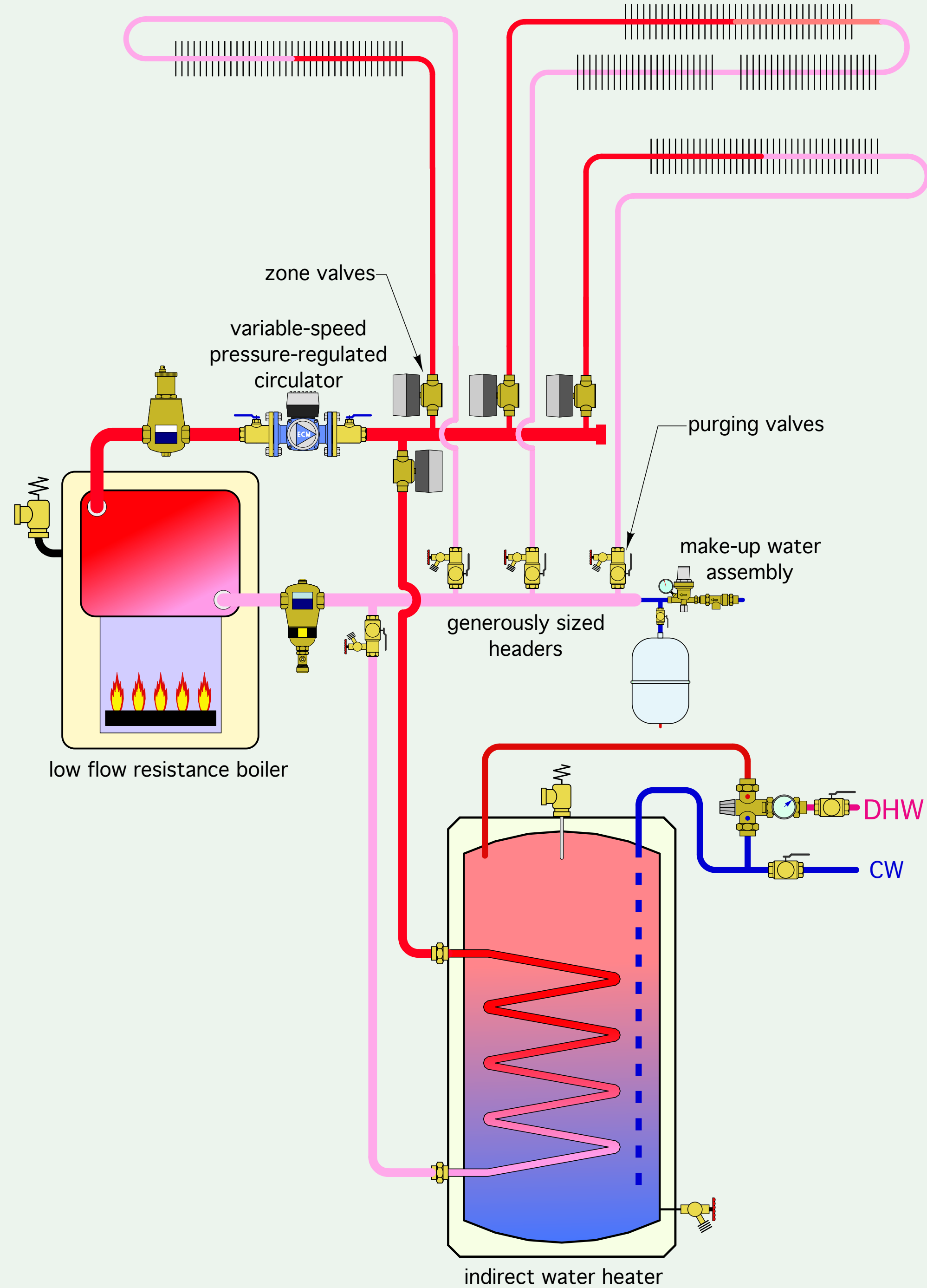
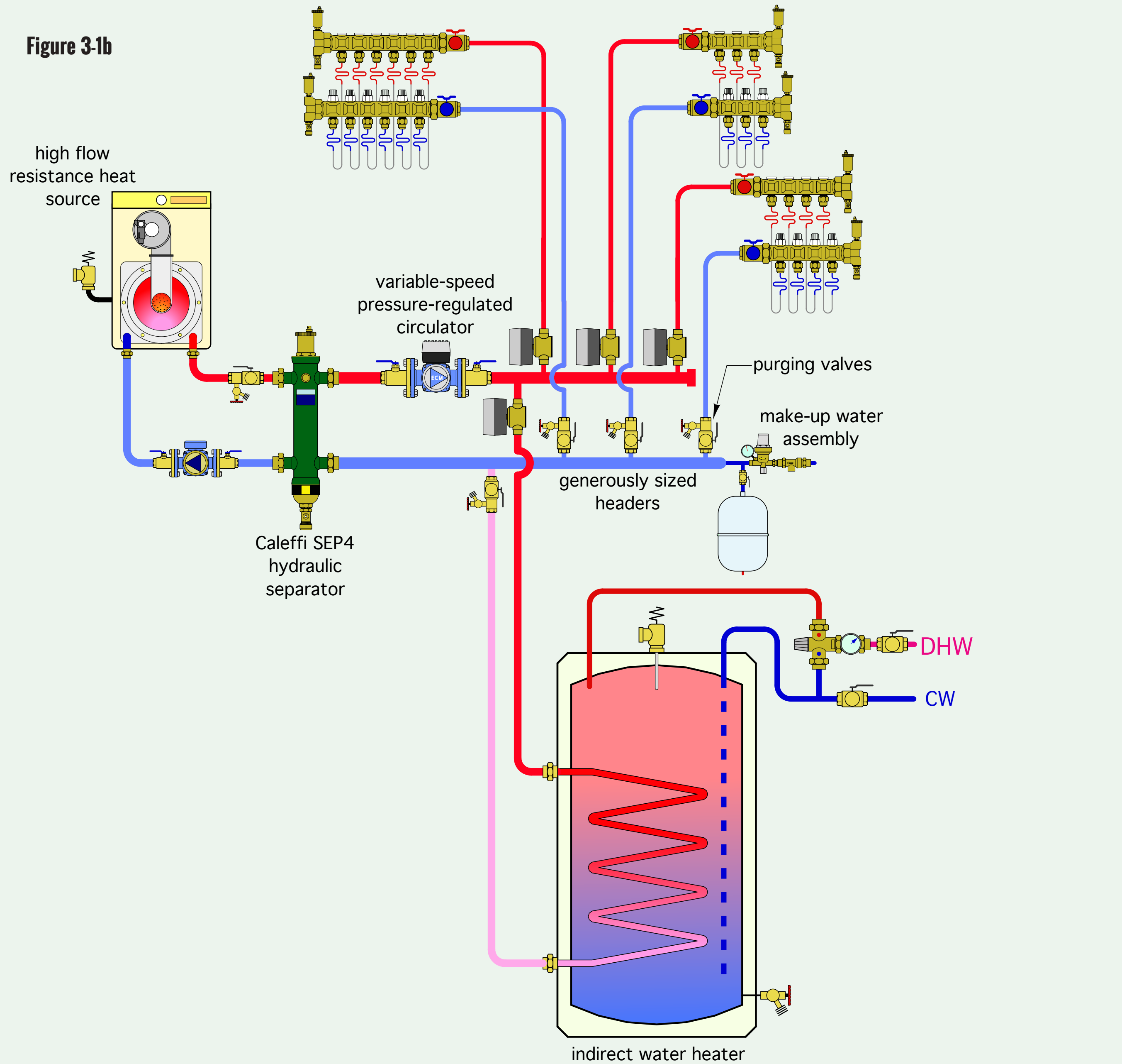


Figure 3-1b



heat source, such as a cast iron boiler. The headers connect directly to this heat source.

The system in figure 3-1b is based on a high-flow-resistance heat source, such as certain modulating/condensing boilers or a hydronic heat pump. Due to its high flow resistance, the heat source has its own circulator. The headers connect to a Caleffi SEP4 hydraulic separator, which prevents undesirable interaction (e.g., hydraulic separation) between the boiler circulator and the variable-speed distribution circulator.

There are many similarities between figure 3-1a, b and figure 2-1a, b. All four piping configurations provide purging valves on the return side of each zone circuit. All of them have components that provide air, dirt and magnetic particle separation. All of them use short and generously sized headers.

ADVANTAGES & DISADVANTAGES OF ZONING WITH MOTORIZED ZONE VALVES

One advantage of valve-based zoning is that it only requires a single circulator. When properly sized, selected and configured, that circulator can operate on lower input power relative to a similar system using zone circulators. This was demonstrated in the previous section by calculating and comparing the distribution efficiency of a system with zone valves versus an equivalent system with electrically operated zone valves.

Many modern circulators have variable-speed pressure-regulated circulators with electronically commutated motors (ECM). *These circulators are ideal for systems using zone valves.* They can be set to automatically vary their motor speed based on changes in operating conditions as zones valves open and close. Under partial load conditions, which are present most of the time in a typical heating season, these circulators can operate at reduced input power, resulting in substantial energy cost savings relative to fixed-speed circulators.

Valve-based zoning is well suited to circuits that need to operate at low flow rates. Examples include circuits serving individual panel radiators or fan coils. In some cases, these heat emitters only require flow rates in the range of 0.5 to 2 gallons per minute. Zone circulators may not have motor speed adjustments low enough to meet these flow rates. In that case, some type of balancing valve would be required to throttle the flow. This approach, while possible, is not as energy efficient as valve-based zoning combined with a variable-speed pressure-regulated circulator.

When properly selected, motorized zone valves provide much higher resistance to unintentional forward differential pressure compared to the nominal 0.5 psi forward opening resistance of a typical spring-loaded check valve in a zone circulator. This unintentional forward differential pressure can be caused by poor system design, such as the lack of hydraulic separation between circulators. The ability to resist forward differential pressure is based on the zone valve's close-off pressure rating, which is discussed later in this section.

Another advantage is that most zone valves operate on low voltage (24 VAC). Most codes do not require this low-voltage wiring to be installed in conduit or by a licensed electrician.

One disadvantage of zoning with valves is that the failure of the circulator would prevent flow in all zones. Although possible, modern circulators, when properly selected and installed, have an excellent record for reliable operation over many years.

Figure 3-2a

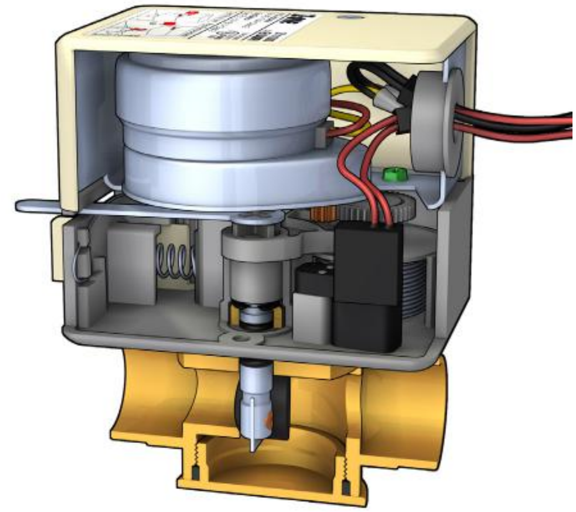
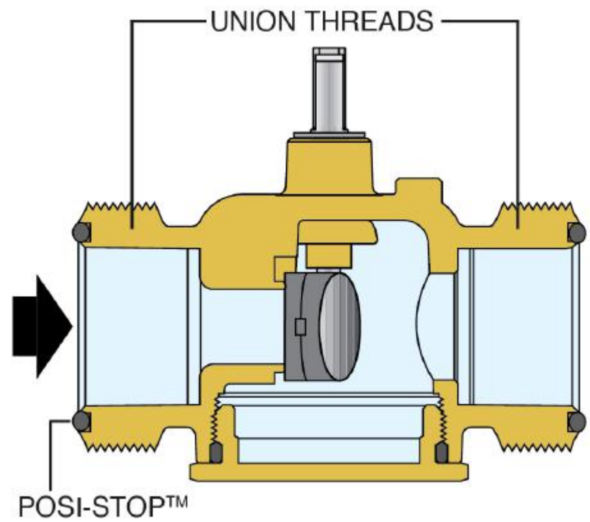


Figure 3-2b



INTERNAL DESIGN OF MOTORIZED ZONE VALVES

The most common type of electric zone valve uses an actuator in which a small AC motor turns a gear assembly that rotates the valve's shaft. That rotation moves a paddle away from the valve's seat, allowing flow through the valve. As the valve opens, a spring assembly inside the actuator is wound under tension. When the paddle reaches its fully open position, the motor stops, and a very low electrical power input holds the motor in that position. When power is removed, the spring assembly unwinds, rotating the shaft backward to close the paddle against the valve's seat. This spring also creates the force that opposes the pressure created by the system's circulator, keeping the unpowered valve closed while other zones are operating.

Figure 3-2 shows two cut-away illustrations of the Caleffi Z-one™ zone valve.

Figure 3-2a shows the actuator mounted to the brass valve body. The motor/gear assembly is seen at the top of the actuator. The shaft and paddle are seen inside the valve body. Figure 3-2b shows the currently shipping version of this valve with Posi-Stop™ connections on both valve ports. Posi-Stop connections allow the valve body to be fitted with several tailpieces that connect to soldered copper tubing, NPT threaded fittings, press fittings or PEX compression fittings. An embedded O-ring provides the pressure-tight seal between these tailpieces and the valve body.

CONTROLLING DIFFERENTIAL PRESSURE IN SYSTEMS WITH ZONE VALVES

The operating condition of the circulator in a system with zone valves can vary widely, depending on how many zone circuits are present and how many zones are active.

Consider the simple four-zone system shown in figure 3-3.

Assume that this system has a *fixed-speed* circulator. The pump curve for that circulator is shown (in red) in the graph below the piping schematic.

When all four zone valves are open, the flow resistance of the distribution system — as a whole — is relatively low and is represented by the dark blue curve. This curve crosses over the red pump curve at a point that corresponds to a flow rate of approximately nine gpm. This is the flow rate through the circulator under this condition.

When one of the zone valves closes, the head loss of the distribution system — as a whole — increases,

Figure 3-3

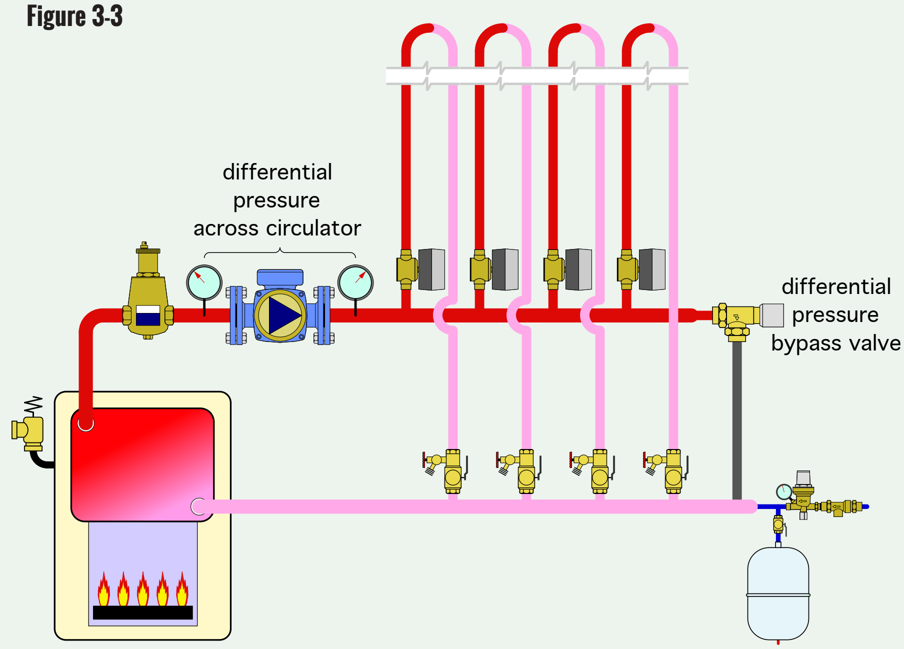
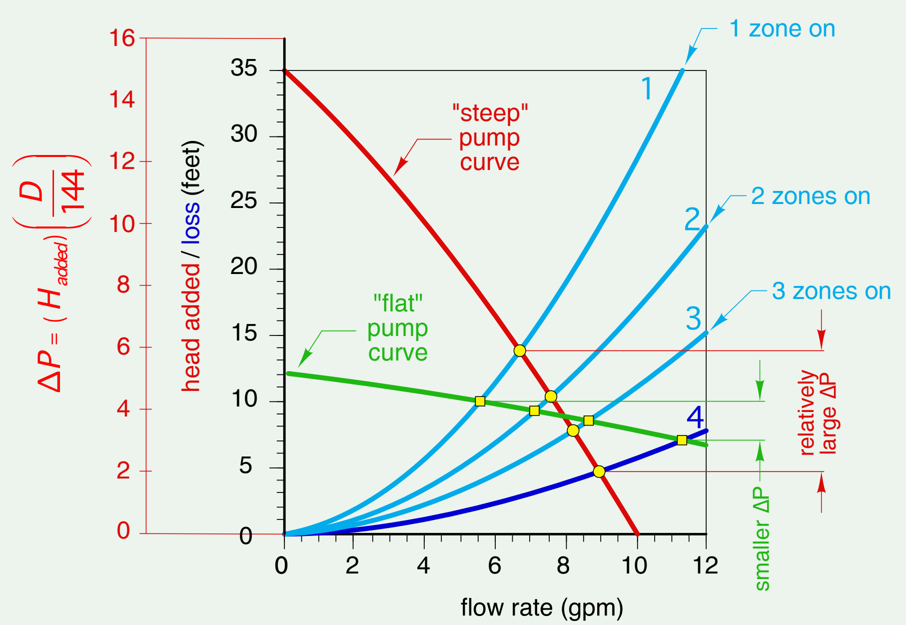


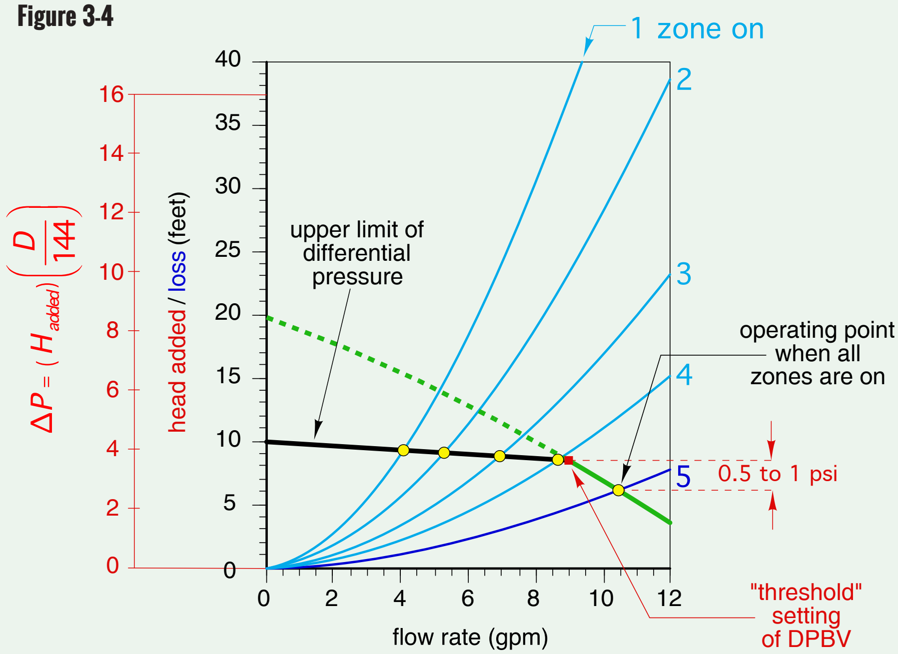
Figure 3-4



as represented by the light blue curve labelled "3 zones on" in figure 3-3. The intersection between this curve and the circulator's pump curve has moved to the left and upward relative to the previous condition when all four zones are operating.

The movement to the left implies that the flow rate through the circulator has

Figure 3-4



decreased. The upward movement indicates that the head at which the circulator operates has increased, which also implies that the differential pressure across the circulator has increased. That higher differential pressure is exerted on the three active zones. *This causes an increase in flow rate through each active zone.*

A similar response occurs when another zone valve closes, as represented by the light blue curve labelled "2 zone on" in figure 3-4. The differential pressure across the circulator increases more, and so does the flow rate in each of the two active zones.

When only one zone is active, the differential pressure across the circulator is even higher.

These increases in differential pressure as zone valves close can lead to problems, including:

• Increased flow noise in the active zone circuits due to high flow velocity.

• Potential erosion of the metal in pipe fittings or valves due to high flow velocity.

• The possibility that the spring within any *inactive* zone valve cannot hold the valve's paddle fully closed, and thus, allows some flow through zones that are supposed to be off.

• Potential cavitation of the circulator depending upon system static pressure, water temperature and the location of the expansion tank relative to the circulator.

In an ideal system, there would be no change in differential pressure across the circulator as the number of active zone circuits changes. Systems using a fixed-speed circulator can be designed to "approach" this ideal condition. Systems using a properly set variable-speed pressure-regulated circulator can achieve this ideal condition.

One way to limit the undesirable increases in differential pressure as zone circuits turn off is to select a fixed-speed circulator with a relatively "flat" pump curve, as shown in figure 3-3.

Although the operating points still climb upward as zone valves close, the vertical shift is much less for the circulator with the "flatter" (green) pump curve compared to the shift experienced with the previous circulator with the (red) pump curve. This demonstrates that fixed-speed circulators with flatter pump curves are better suited for systems using zone valves. *Fixed-speed circulators with "steep" pump curves should not be used in systems with zone valves.*

DIFFERENTIAL PRESSURE BYPASS VALVES

Another way to limit differential pressure increase in systems using zone valves and a fixed-speed circulator is to install a differential

Figure 3-5a

Figure 3-5b

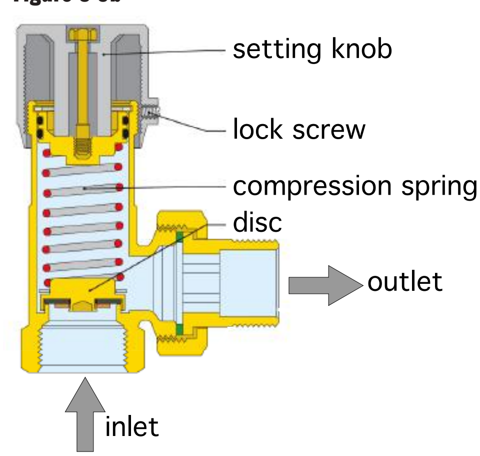
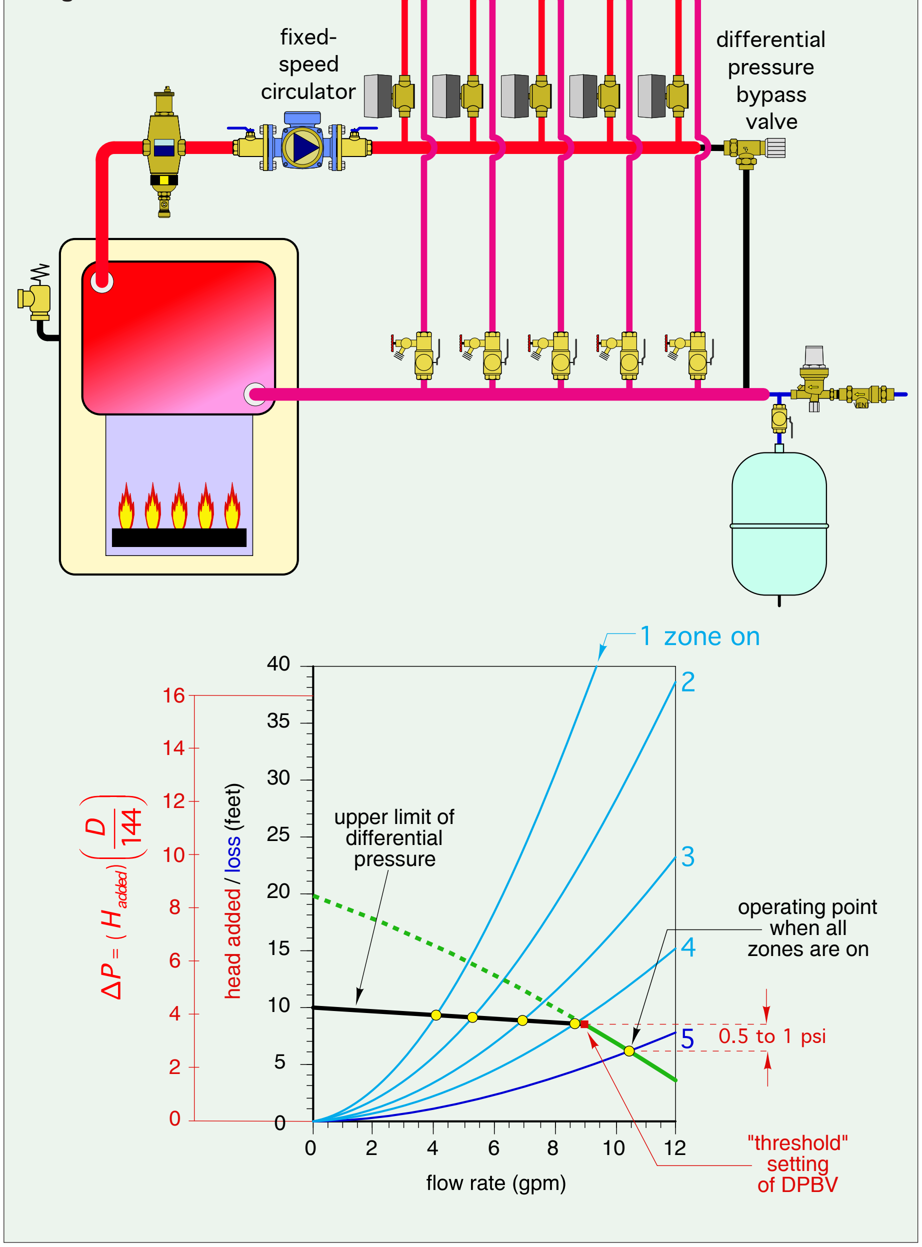


Figure 3-6



pressure bypass valve (DPBV). An example of such a valve, along with its cross section is shown in figure 3-5.

A differential pressure bypass valve has a disc that's held against the valve's seat by a spring. The knob adjusts the force exerted by the spring on the disc. This force, in combination with the diameter of the disc, determines the differential pressure at which the disc begins to move away from the seat. This pressure is called the "threshold" pressure setting. If conditions in the system attempt to further increase the differential pressure across the valve, the disc begins moving away from the seat. This allows increased flow through the valve, while maintaining minimal variation in the differential pressure between its inlet and outlet ports.

An example of a five-zone system with a fixed-speed circulator and a DPBV installed across the headers is shown in figure 3-6

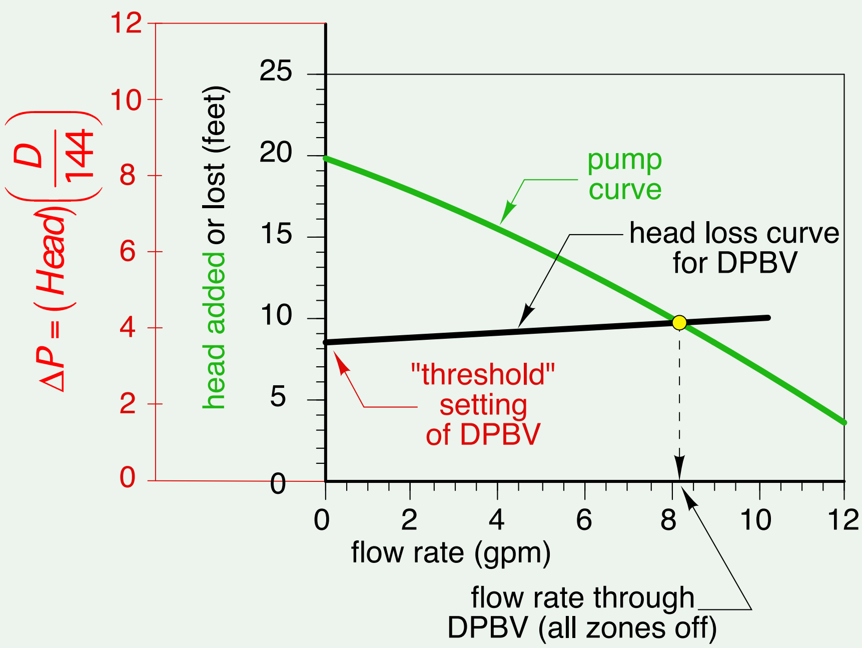
The dark blue head loss curve represents a condition in which all five zone circuits are operating. Under this condition, the differential pressure exerted on the DPBV is below its threshold setting. Under this condition, the DPBV remains fully closed and has no effect on the system.

As the number of active zone circuits decreases, represented by the "steeper" light blue curves, the differential pressure across the circulator and across the headers attempts to increase. For the setting represented in figure 3-6, the DPBV begins to open when the differential pressure across it reaches 0.5 to 1 psi above the differential pressure present when all five zones are active. At that point, flow begins to pass through the DPBV, and further upward movement of the operating point is significantly limited, as shown by the yellow points along the black line. The slight upward slope of the black line is caused by increasing head loss through the DPBV as the number of active zones decreases. The net effect of the DPBV in this system is too "approximate" the ideal scenario where there would be no change in differential pressure across the headers as zone valves open or close.

SIZING DIFFERENTIAL PRESSURE BYPASS VALVES

To properly size a DPBV, it's necessary to estimate the flow through it assuming all zone circuits are closed. Under this condition, it's possible to estimate the flow rate through the DPBV by plotting the head loss curve for the DPBV along with the pump curve for the fixed-speed circulator and find where they intersect, as illustrated in figure 3-7.

Figure 3-7



A vertical line drawn downward from this point indicates the flow rate through the DPBV when all the zone valves are closed. A properly sized DPBV can now be selected based on the maximum recommended flow rate for a given valve size.

VARIABLE-SPEED, PRESSURE-REGULATED CIRCULATORS

Circulator technology has evolved significantly over the last several years. The common wet-rotor circulator with a permanent split capacitor (PSC) has largely been replaced by variable-speed circulators using electronically commutated motors (ECM). Most of these circulators have pre-programmed operating modes that are ideally suited for systems with valve-based zoning. Those modes include:

- Constant differential pressure control
- Proportional differential pressure control

Constant differential pressure control can be thought of as "cruise control" for differential pressure. The circulator is set for a specific differential pressure. While operating, it continually monitors the speed of its rotor, the slip of the rotor relative to the rotating magnetic field created by the motor's stator poles, and current draw. It uses these measurements, along with its firmware, to *infer* the differential pressure between its inlet and outlet. This inferred differential pressure is compared to the differential pressure setpoint. If the inferred differential pressure is higher than the setpoint, motor speed is reduced, and vice versa. This allows the circulator to maintain a stable differential pressure setting over a wide range of flow rates.

Figure 3-8 shows how a variable-speed circulator configured for constant differential pressure responds when a one of the system's zone valves closes.

Point A is the initial operation point (e.g., where the gray pump curve crosses the gray system head loss curve). This is the operating condition when all four zone valves in the system are open. The head added by the circulator is about 6.5 feet, and the flow rate through the circulator is about 11 gpm. When one of the zone valves closes, the system head loss curve steepens (e.g., the gray head loss curve transitions to the blue head loss curve). The circulator's internal electronics sense this change and respond by reducing motor speed, which causes the gray pump curve to transition to the red pump curve. The net effect is that the operating point moves from point A to point B. The flow rate has reduced from approximately 11 gpm to 7.8 gpm, but the head added by the circulator (6.5 feet), and thus, the differential pressure across the circulator, remains constant.

Constant differential pressure control is ideal for systems in which the pressure drop through the common piping is very small in comparison to the pressure drop through the zone circuits. The system in figure 3-9 is a good example.

The total pressure drop through the SEP4 hydraulic separator, the short headers, and the manifolds is low compared to the pressure drop through the 1/2" PEX circuits supplying the panel radiators.

Another operating mode for variable-speed pressure-regulated circulators is called *proportional* differential pressure control. When set for this mode, the circulator's internal electronics establish a mathematical line that begins at some set value of head that corresponds to the circulator operating at full speed. The line slopes downward as flow rate decreases and ends at a point corresponding to zero flow rate and

Figure 3-8

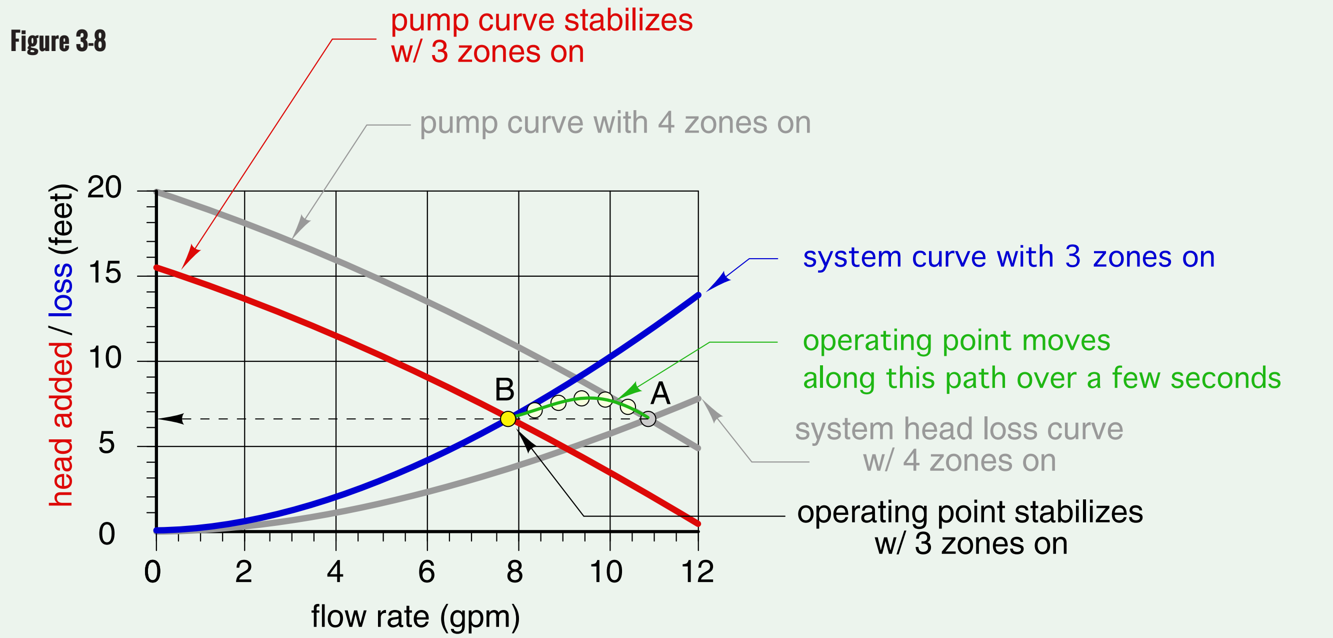


Figure 3-9

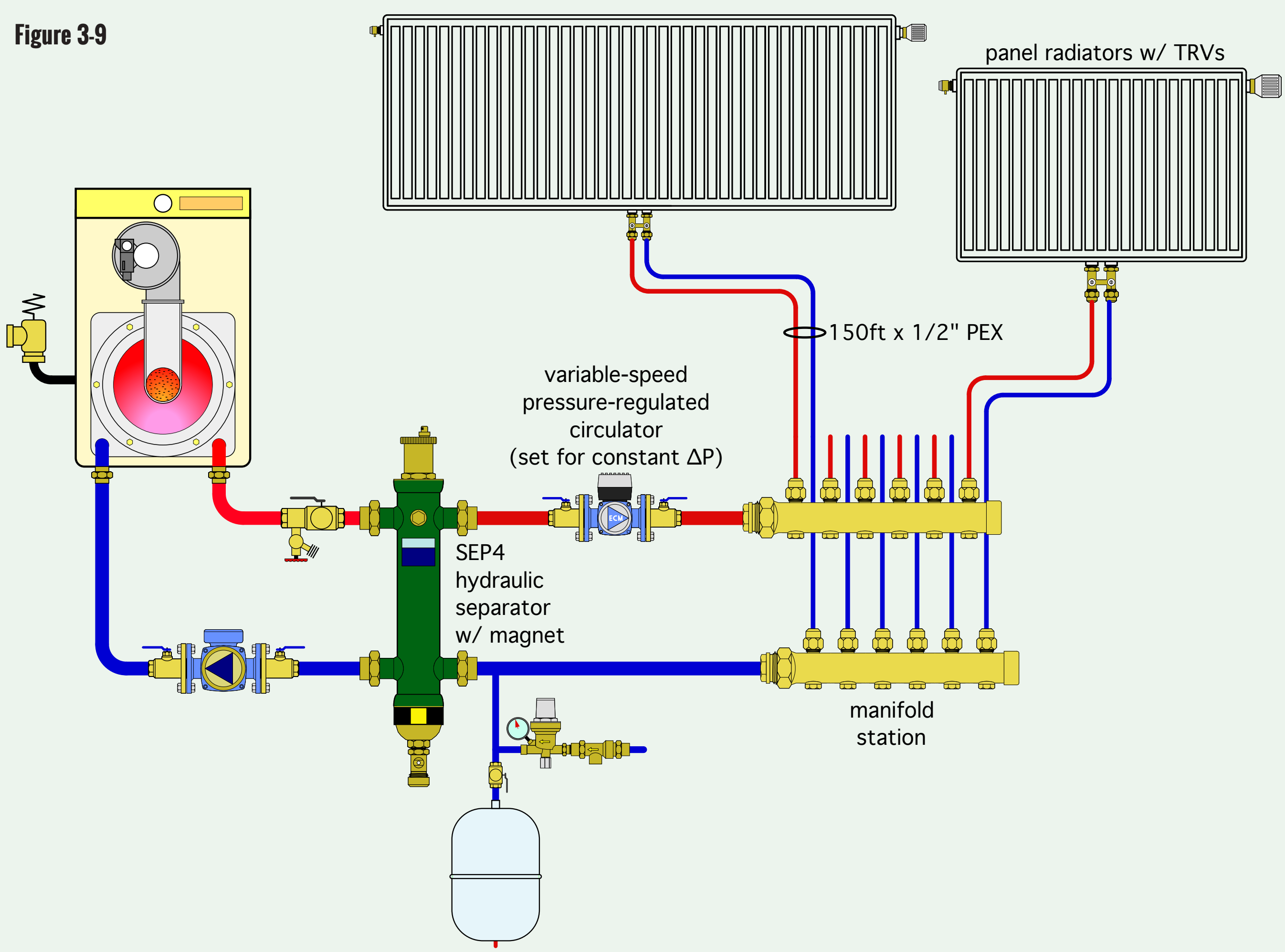


Figure 3-10

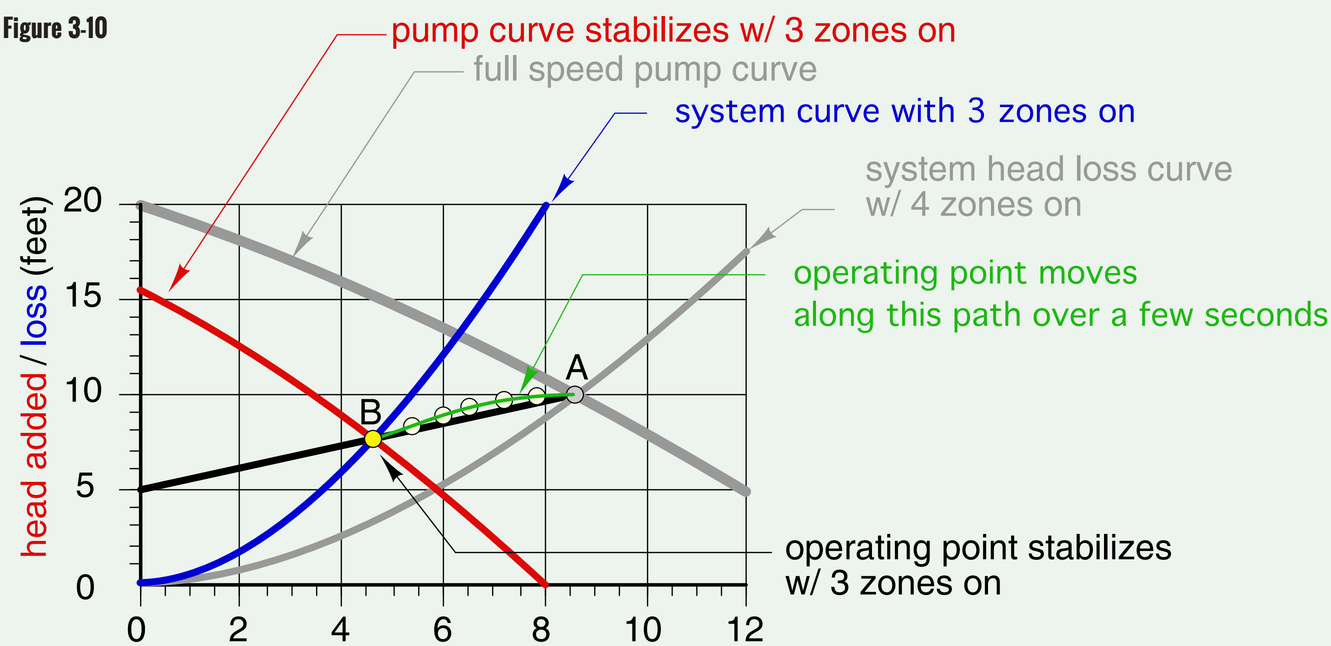
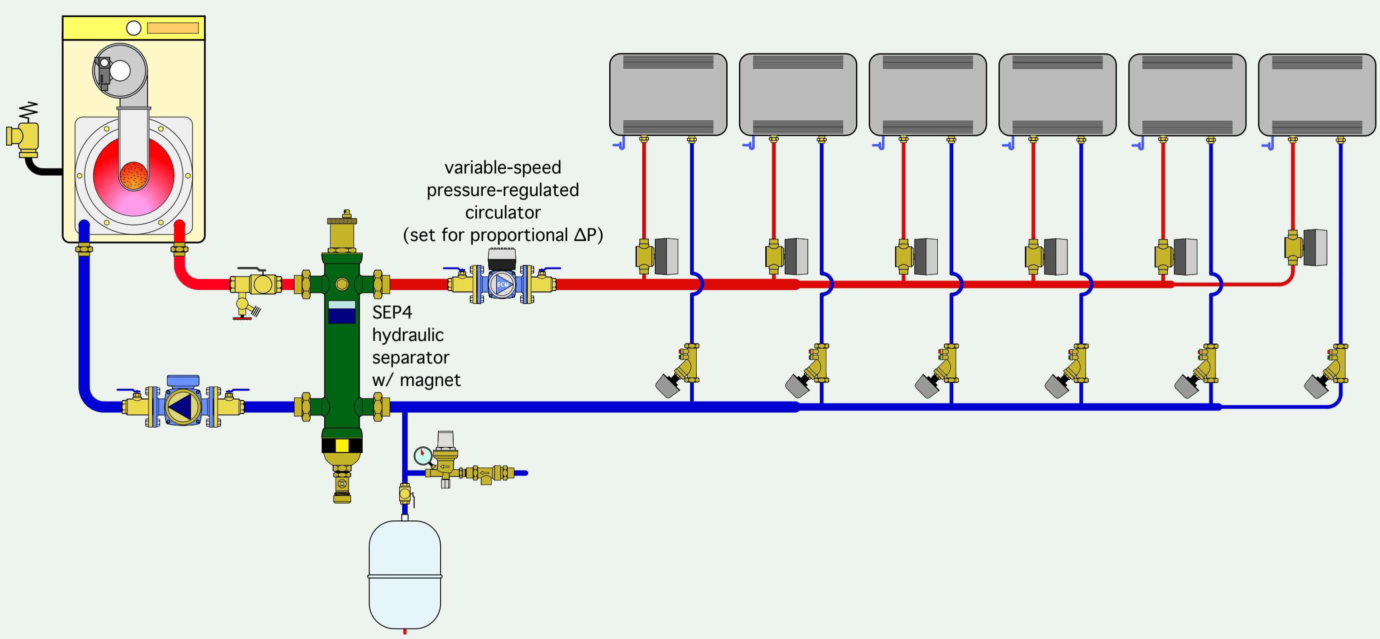


Figure 3-11



a head value that's 50% of the full speed head setpoint.

Figure 3-10 shows how a circulator set for proportional differential pressure control responds when one of the zone valves in a four-zone system closes. The circulator has been set to a head value of 10 feet, corresponding to a condition where its motor is running at full speed. The black line on the graph shows how head decreases as flow decreases. This relationship is created by reducing the motor speed. The black line ends at zero flow rate and a head of 5 feet.

This control mode is intended for systems that have significant head loss in the supply and return mains that serve parallel "crossover" zone circuits. The two-pipe direct return piping system shown in figure 3-11 is one example.

Proportional differential pressure minimizes variations in differential pressure across the active zone circuits as other zones turn on and off. It compensates for the head loss across the parallel zone crossovers, as well as along the supply and return mains.

SELECTING ELECTRICALLY OPERATED ZONE VALVES

Zone valves are typically available in pipe sizes ranging from 1/2-inch to 1-1/4 inch. However, *proper selection involves more than simply matching the valve's pipe size to the pipe it will be installed in.* Two other criteria should always be evaluated when selecting zone valves:

- The valve's Cv rating
- The valve's close-off pressure rating

The valve's Cv rating is the flow rate (in gallons per minute) of 60ºF water that creates a pressure drop of one psi across the valve.

The relationship between the flow rate through the valve and the resulting pressure drop is based on formula 3-1.

Formula 3-1:

$$\Delta P = \left(\frac{D}{62.4}\right)\left(\frac{f}{C_v}\right)^2$$

Where:
ΔP = pressure drop through valve (psi)
D = density of fluid flow through valve (lb/ft^3)
F = flow rate through valve (gpm)

The Cv of a zone valve is partially determined by the *diameter of the orifice within the valve* through which all flow passes. The larger the diameter of this orifice, the higher the Cv of the valve. Figure 3-12 shows several Caleffi zone valves having the *same pipe size*, but with different internal orifice diameters that affect the valve's Cv rating.

Figure 3-13 shows how several Caleffi zone valves, all with the same nominal 3/4-inch pipe size, have significantly different orifice diameters, and thus, have different Cv values.

Higher Cv ratings are beneficial because they reduce pressure drop through the valve. Lower pressure drop implies lower head loss, and thus, lower pumping power. *However, as the Cv rating increases, the valve's ability to close off against a differential pressure trying to push flow through it decreases.* Figure 3-13 also shows this inverse relationship between the valve's Cv rating and its rated close-off pressure.

The close-off pressure rating is the maximum differential pressure across the valve under which it can close and remain closed. If a differential pressure higher than the close-off pressure is exerted on the valve, the hydraulic force against the paddle inside the valve becomes greater than the spring force trying to hold the paddle against the valve's seat. This allows some flow through the valve. This undesirable condition can

Figure 3-12

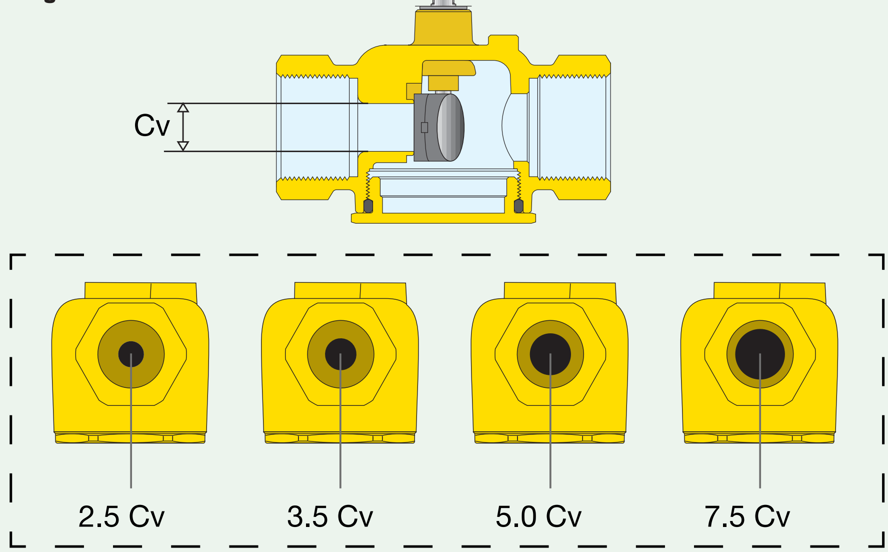


Figure 3-13

3/4" valve model #	Cv rating	close-off pressure
Z300512	2.5	50 psi
Z300513	3.5	30 psi
Z300515	5.0	25 psi
Z300516	7.5	20 psi

be avoided by *selecting zone valves with close-off pressures slightly higher than the maximum differential pressure they could be subject to in a given system*.

The maximum pressure differential a zone valve would experience can be conservatively estimated based on the "shut-off" differential pressure of the system's circulator. That differential pressure occurs when the circulator is operating at full speed but with zero flow rate. This pressure is found by converting the maximum head the circulator can create to a corresponding differential pressure using formula 3-2.

Formula 3-2:

$$\Delta P = H_{max}\left(\frac{D}{144}\right)$$

Where:
ΔP = differential pressure across circulator (psi)
H_{max} = maximum head of circulator (at 0 flow rate) (feet of head)
D = fluid density (lb/ft^3) (See figure 3-14)
144 = units conversion factor

The maximum head occurs at the high point of the pump curve. For most circulators, this corresponds to zero flow rate. However, some circulators may have pump curves where maximum head occurs at low but non-zero flow rates, as shown in figure 3-15.

This maximum differential pressure would only occur when the circulator is operating at its maximum speed *and all zone valves in the system are closed*. This condition, although possible, is uncommon, since most systems using electric zone valves do not operate the circulator unless at least one zone is active. In most systems with zone valves, the close-off pressure differential will be less

Figure 3-14

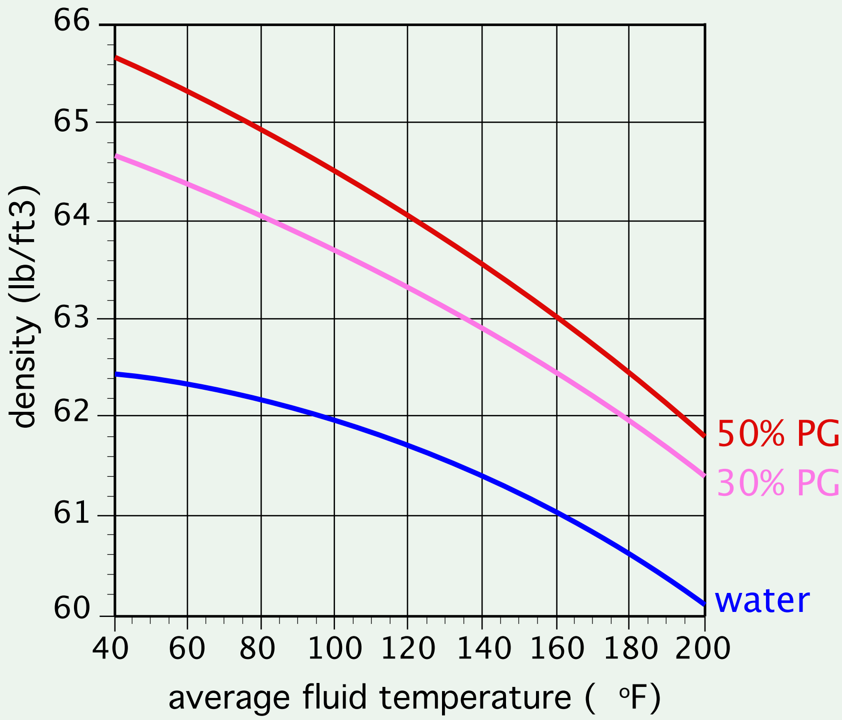
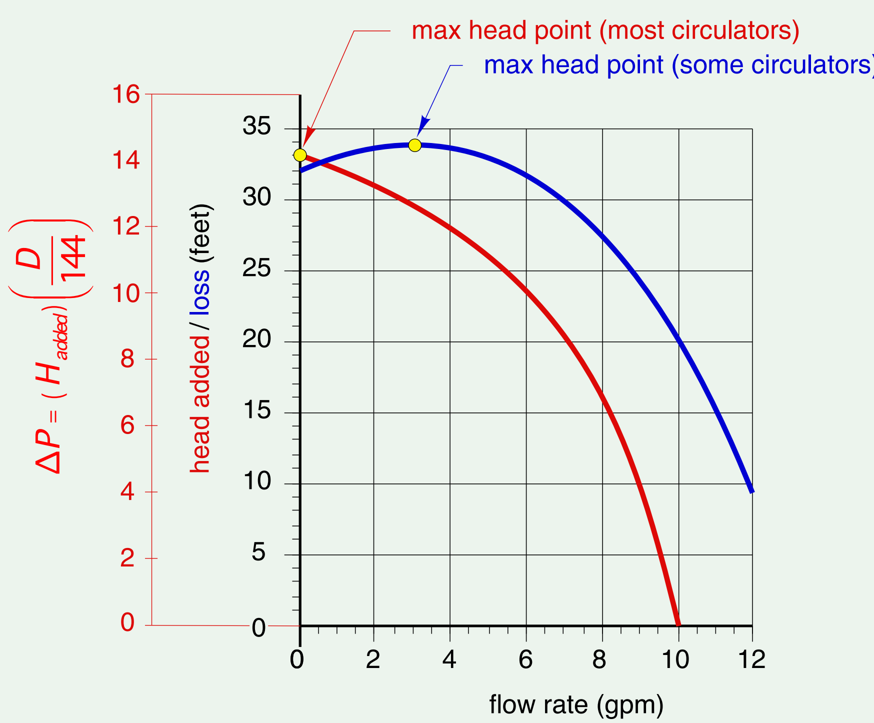
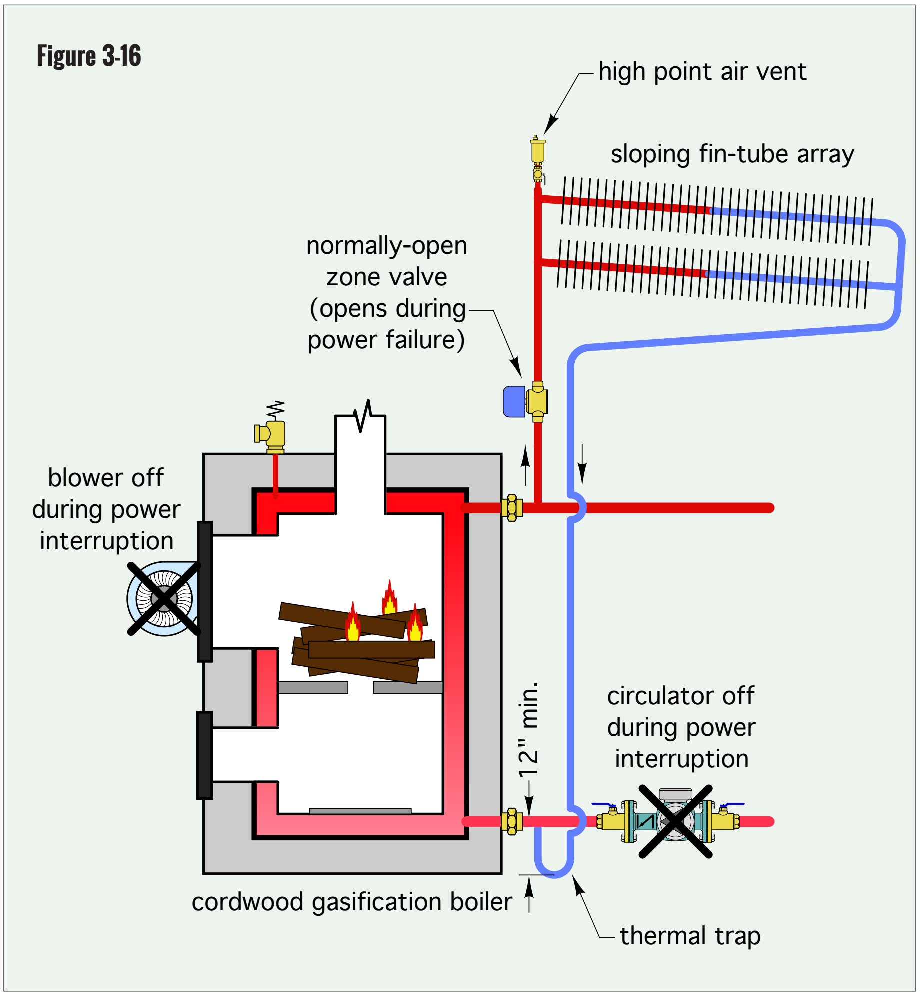


Figure 3-15





than the maximum differential the circulator can create. This is especially true if a variable-speed pressure-regulated circulator is used. It's also true for systems with a properly set differential pressure bypass valve and a fixed-speed circulator.

ELECTRICAL DETAILS FOR SYSTEMS WITH ELECTRIC ZONE VALVES

Electrically powered zone valves are available with operating voltages of 24, 120 and sometimes 240 VAC. Of these, the 24 VAC configuration is the most common in hydronic heating and cooling systems. The electrical details to be discussed are based on 24 VAC zone valves. However, some of these details also apply to zone valves powered by 120 and 240 VAC.

NORMALLY OPEN VS. NORMALLY CLOSED ZONE VALVES

Most zone valves are configured so they are closed when the actuator is unpowered and open when powered. These are specifically called "normally closed" zone valves. However, there are some applications in which the opposite action is required (e.g., the valve is open when the actuator is unpowered and closed when the actuator is powered). These are called "normally open" zone valves. The latter may be used in applications where it's desirable to allow flow through the valve during a power outage. One example would be a subsystem that dissipates heat from an active wood-burning boiler during a power outage. Figure 3-16 shows an example of one such application.

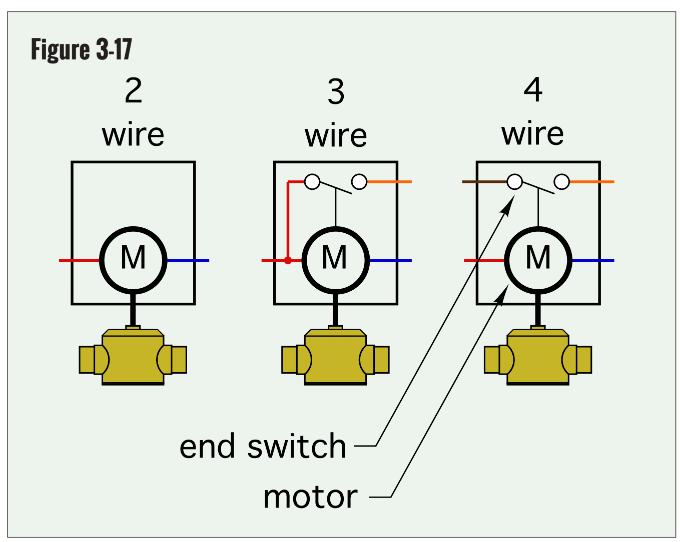
END SWITCHES

Some zone valves can be ordered with an *end switch* that closes its contacts when the zone valve is fully open. The usual purpose for this switch is to signal other equipment to operate whenever the zone valve is fully open. Examples include turning on the system's circulator and enabling its heat source or cooling source to operate.

Figure 3-17 show three internal wiring configurations for zone valves.

A two-wire zone valve has no end switch. The two terminals or wire leads on a two-wire zone valve are only used for powering the spring-return motor assembly.

A three-wire zone valve has an end switch. One contact in that end switch is connected in parallel with one power wire for the motor. The end switch closes when the valve reaches



its fully open position. The internal wiring implies that the circuit connected to the end switch must be powered by the same source as the valve's motor. This is possible, but far less versatile in terms of how the end switch is used. Three-wire zone valves have limited availability at present and are primarily used to replace older or failed three-wire zone valves.

A four-wire zone valve allows the end switch to be *electrically isolated* from the circuit that power's the valve's motor. This isolation allows the end switch to "signal" equipment that is powered by sources separate from the power source for the valve's motor. This greatly expands possible applications, while preserving the basic function of an end switch.

The electrical power that can be passed through a typical end switch is limited. Typical ratings are for a maximum current of 0.4 amp in a 24 VAC circuit. This is sufficient for common low-voltage switching applications for which the end switch is intended. It is not adequate for any type of line voltage switching.

See *idronics* 14 for more information on wiring for electrical zone valves.

Figure 3-18

CHILLED WATER APPLICATIONS

Caleffi Z-One zone valves are rated to work with fluid temperatures down to 32ºF. When applied in chilled water cooling systems, the fluid temperatures are usually in the range of 45 to 55ºF. When operating at these temperatures, the valve body is typically below the dewpoint temperature of surrounding air. This creates the potential for condensation to form on the valve body. To avoid this, the body of the valve should be wrapped with insulating foam tape. However, *the valve's actuator should not be insulated*. Figure 3-18 shows an example of chilled water piping where the piping and valve body are wrapped with elastomeric foam insulation, but the valve actuator is not insulated.

MULTI-ZONE VALVE CONTROLS FOR ELECTRICALLY OPERATED ZONE VALVES

Systems using zone valves typically use a low-voltage (24 VAC) thermostat in each zone to signal when a zone valve should open or close. A line voltage circulator must also be turned on whenever one or more thermostats call for heating or cooling. The heat source or chilled water source must also be enabled to operate whenever one or more zone thermostats are calling for heating or cooling. Some systems also require one zone to have "priority" over other zones. When the priority zone is active, the other zones are temporarily turned off, at least for some predetermined time.

The most convenient, simplest and most cost-effective approach to accomplishing these control functions is by using a Multi-Zone Valve Control. Figure 3-19 shows one of several wiring configurations for on a Caleffi ZVR106 Multi-Zone Valve Control.

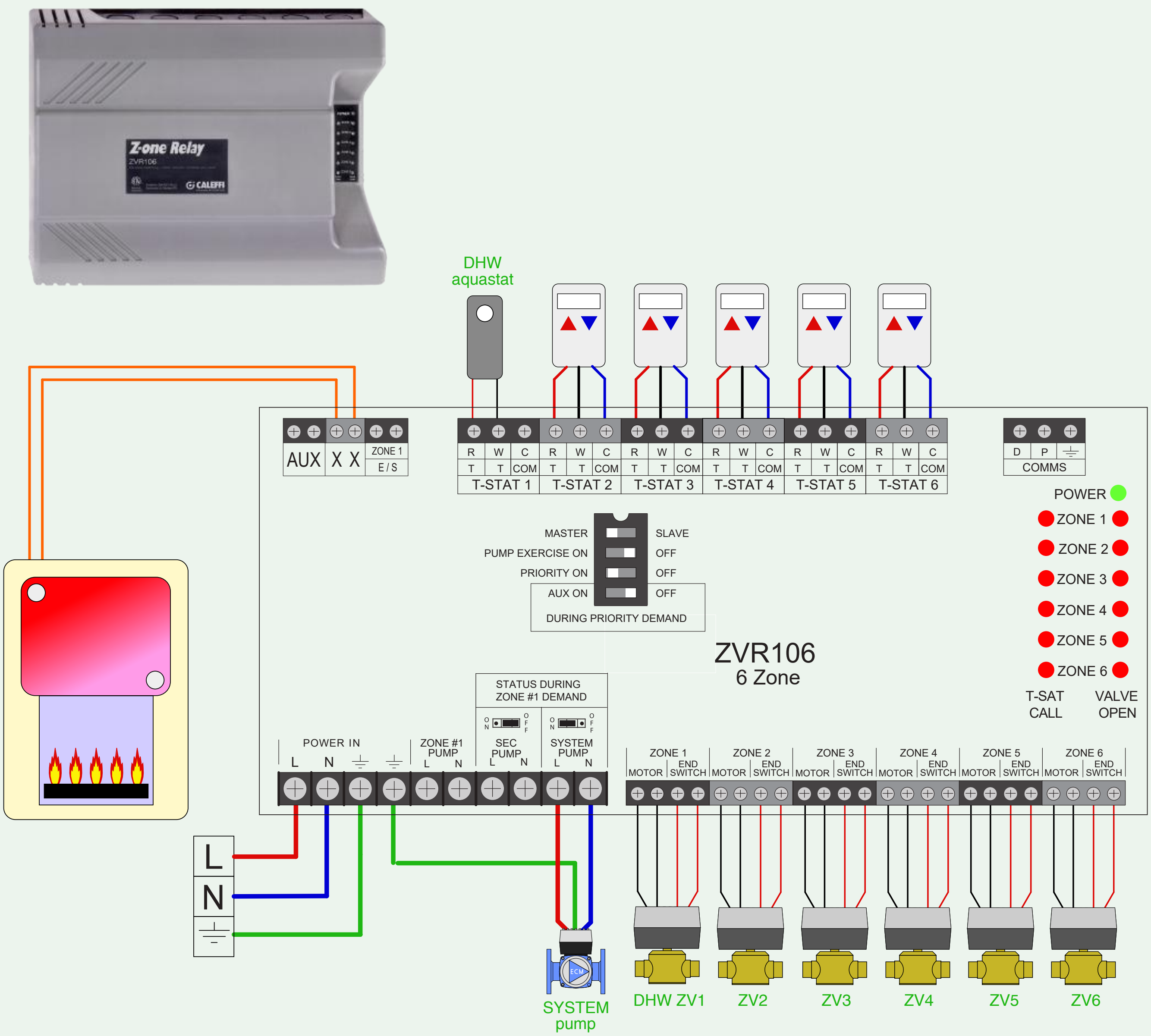
The Caleffi ZVR106 Multi-Zone Valve Control provides wire "landing" terminals for up to six zone thermostats. When a heating call is received from a specific thermostat, the control powers on the associated zone valve and signals the heat source to operate.

See *idronics* 14 for more information on Caleffi multi-zone controls.

MOTORIZED BALL ZONE VALVES

The previously discussed electric zone valves have actuators with small AC motors that turn a gear train to rotate the valve's shaft. When power is removed from a normally closed actuator, a spring assembly unwinds to rotate the shaft in the opposite direction to close the valve. This type of valve is sometimes referred to as *power open/spring closed*.

Figure 3-19



In some applications, the valve controlling flow through a zone circuit needs to have a higher Cv rating than what might be available with a typical power open/spring closed zone valve. The valve might also need to close against a higher differential pressure than is possible with a spring return valve. In these situations, a motorized ball valve with a power open/power close actuator can provide both requirements.

Figure 3-20 shows an example of a Caleffi 6442 motorized ball valve that has a power open/power close actuator.

Figure 3-20

Figure 3-21

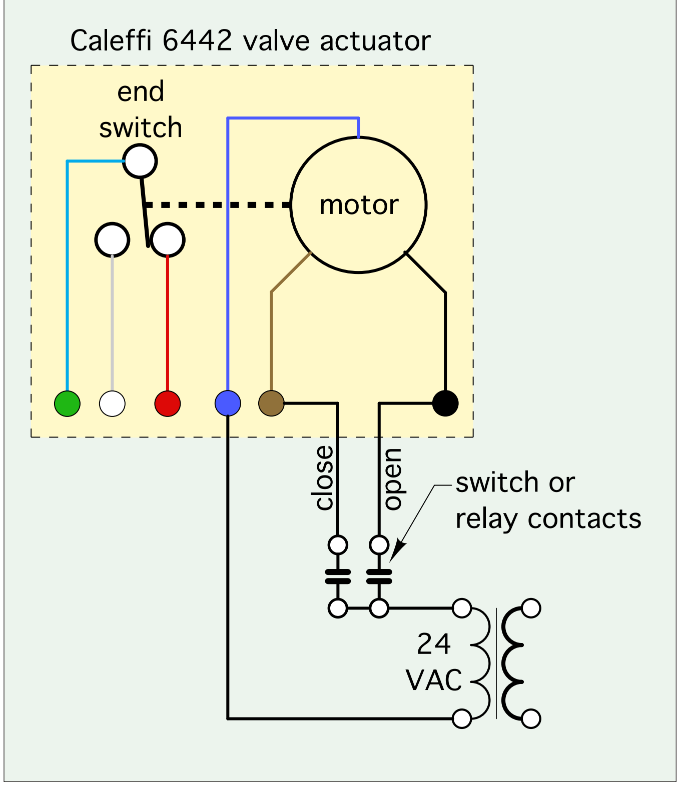


Figure 3-21 shows how external 24 VAC wiring connects to the valve.

The **blue** lead from the 6442 actuator connects to one side of a transformer that provides 24 VAC secondary voltage to operate the valve's motor. When the other side of the transformer is connected to the **brown** lead of the actuator through a switch or relay contact, the motor closes the ball valve. When this same side of the transformer is connected to the **black** lead of the actuator through a switch or relay contact, the ball valve opens. When neither the **brown** nor black lead is powered, the valve holds its current position.

These valves require approximately 40 seconds to rotate the ball valve through 90º between fully open and fully closed, or vice versa. During this operation, the valve motor requires about four watts of power input. When the ball valve reaches its fully open or fully closed position, an internal microswitch stops further power input. Thus, unlike a spring-return zone valve, *no power is required to hold the valve in its fully open position.*

The actuator on the Caleffi 6442 valve also has an internal single pole double throw (SPDT) switch. The **green** lead on the cable connects to the common terminal of this switch. The **red** lead connects to the normally closed contact. There is electrical continuity from the **red** to the **green** lead when the valve is fully closed. The **white** lead connects to the switch's normal open contact. There is electrical continuity from the **white** to the **green** lead when the valve is fully open. These switch contacts can be wired to other controls in the system to verify the open versus closed status of the valve. They can also be left unconnected if there is no need for open versus closed verification. These switch contacts are rated for a maximum current of 5 amps in a 24 VAC circuit.

The Caleffi 6442 has a Cv rating of 13 and can close against a differential pressure of up to 150 psi.

These valves are ideal for applications where high close off pressure, high Cv and low electrical power demand are needed.

The Caleffi 638 valve, shown in figure 3-22, is also a motorized ball valve with the same type of wiring as the 6442. It's available in pipe sizes from 3/4-inch up to 2-inch. The latter has a Cv rating of 162. The 638 valve is also configured with a Posi-Stop™ body, which allows it to be matched with union tailpieces that connect to sweat copper, MPT or press copper. These valves are ideal for higher flow rate applications in heating or cooling systems.

Figure 3-22

4. ZONING WITH THERMOSTATIC VALVES

The preceding section described valves that use electric motors to open and close the valve. Although such valves are common in residential and commercial zoning applications, they are not the only type of valve that can be used for zoning.

Another category of control valves is based on thermostatic (rather than motorized) actuators. These actuators use *heat* to produce the motion that moves the valve's shaft. The source of the heat varies depending on the application.

THERMO-ELECTRIC ZONE VALVES

In some applications, the heat needed to operate the valve comes from an electrical resistor inside the valve's actuator. This type of actuator is more specifically called a *thermo-electric actuator*. A cross section of the Caleffi 6564 thermo-electric TwisTop™ actuator attached to a Caleffi 6762 2-way valve body is shown in figure 4-1.

When an electrical current supplied from a 24 VAC source passes through the resistor, it heats a small piston/cylinder assembly (2) containing a specially formulated wax. Heating causes the wax to expand, which moves the piston several millimeters. That motion is transferred to the valve's shaft to lift the disc (1) off the valve seat. When electrical power is removed, the wax shrinks back to its original volume. A spring assists in closing the valve, holding it closed to its rated close-off pressure.

Caleffi 6563 thermo-electric actuators are available with an isolated end switch that allows them to be wired the same way as a four-wire motorized zone valve. A small "pop-up" disc at the top of the actuator shows when the actuator shaft is fully extended and the valve is open. These actuators also have a TwisTop feature that allows the actuator to be manually operated to open the valve during a power outage, during system commissioning or whenever needed.

Thermo-electric actuators have slower response characteristics relative to motorized valve actuators. The 6563 actuator requires 120-180 seconds to fully open. The upper end of this time range applies to situations where the actuator is surrounded by cold air prior to being powered. Closing time also varies between 120 and 180 seconds, depending on the temperature of the actuator when power is removed and the surrounding air temperature. These longer opening and closing times are typically not an issue when the valves are used for zoning. They also reduce the potential for water hammer as the valve disc closes over its seat. Thermo-electric actuators are completely silent as they open and close, making them ideal for situations where zone valves need to be installed in noise-sensitive areas.

Figure 4-1a

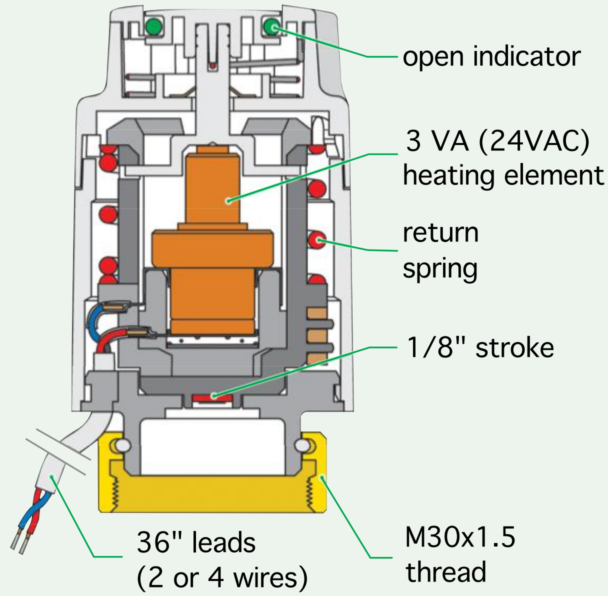
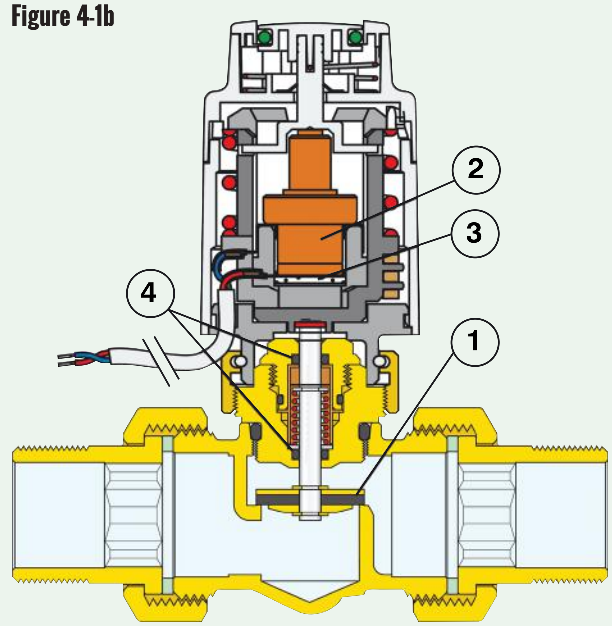


Figure 4-1b



Caleffi 6563 thermo-electric actuators have an initial power draw of about six watts but stabilize to a continuous power draw of about three watts when fully open.

Caleffi 6762 valves fitted with 6365 thermo-electric actuators have a Cv rating of 4.0, and a close-off pressure rating of 20 psi. Caleffi 6765 valves fitted with the same

Figure 4-2

Figure 4-3

Figure 4-4

actuator have a Cv rating of 5.6, and a close-off pressure rating of 35 psi.

Thermo-electric actuators should not be used in systems where the zone valve is located within an enclosed heat emitter, such as a fin-tube baseboard housing or the cabinet of a wall convector. The internal temperature of such emitters can, under some circumstances, slow or prevent full closure of the valve when power is removed.

These Caleffi thermo-electric zone valves are available in nominal pipe sizes from 1/2-inch to 1-inch. Connection options include press copper, cold expansion PEX and solder copper, as shown in figure 4-2.

ZONING WITH THERMO-ELECTRIC MANIFOLD VALVE ACTUATORS

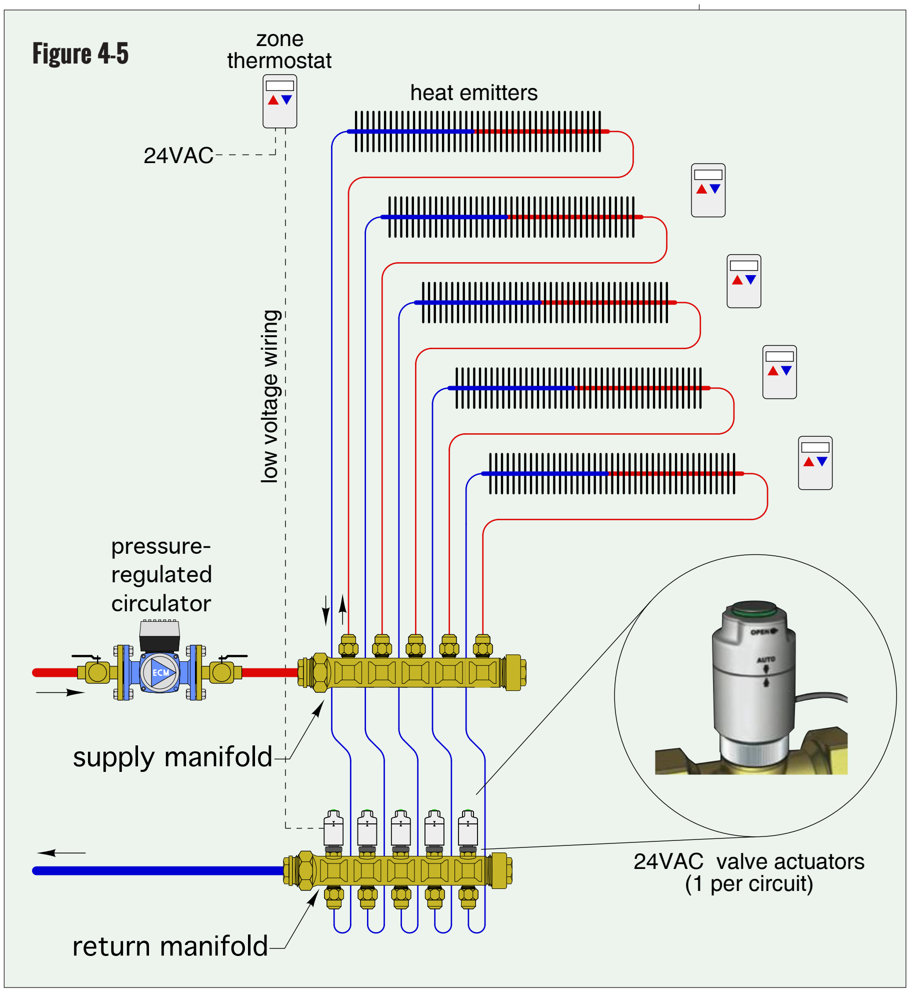
Thermo-electric valve actuators can also be combined with valved manifolds to create multi-zone systems. Functionally, this approach is equivalent to using several individual valves, each with its own thermo-electric actuator. However, all valving hardware is now integrated into a single preassembled component. This "homerun" approach also makes use of flexible PEX, PERT or PEX-AL-PEX tubing, rather than traditional rigid piping, to supply each of the system's heat emitters.

Figure 4-3 shows an example of a circuit valve built into the return manifold. These valves are opened and closed with a linear (versus rotational) movement of their shaft. The valves are also spring loaded. The spring force maintains the valve in its fully open position. A manifold valve can be manually adjusted by rotating the plastic knob that covers each valve stem.

The operation of manifold valves can be automated by adding a Caleffi 6563 thermo-electric actuator to each valve, as shown in figure 4-4. The actuator simply screws onto the valve, pushing the valve's stem to the closed position as it is mounted.

An example of a homerun distribution subsystem using a manifold station with valve actuators is shown in figure 4-5.

In a homerun distribution system, each heat emitter is connected to the supply and return manifolds using separate runs of small diameter PEX, PERT or PEX-AL-PEX tubing. Each heat emitter, along with its associated thermostat, constitutes an independent zone. When any thermostat calls for heat, 24 VAC is applied to the associated thermo-



electric valve actuator. After a short time, the actuator retracts its shaft and the spring-loaded manifold valve opens, allowing flow through its associated heat emitter.

NON-ELECTRIC THERMOSTATIC VALVE OPERATORS

Several types of valves can also be combined with *non-electric* thermostatic operators. The most common application for these operators is in combination with small spring-loaded valves that control flow through heat emitters, such as panel radiators or fin-tube baseboard. Figure 4-6 shows an example of how a non-electric thermostatic operator is matched with a radiator valve.

The thermostatic operator screws onto the valve's bonnet. When mounted, it pushes the valve's stem down, closing the valve. From this initial status, the position of the valve's stem is regulated based on the setting of the operator's knob and the surrounding air temperature. This action is created by the internal design of the operator, as shown in figure 4-7.

The thermostatic operator contains a bellows filled with a working fluid that expands and contracts when its temperature changes. This movement is transferred to the valve spindle and ultimately to the valve's disc.

When the air temperature surrounding the thermostatic operator increases, the valve stem is pushed down, moving the disc closer to its seat and reducing flow through the valve.

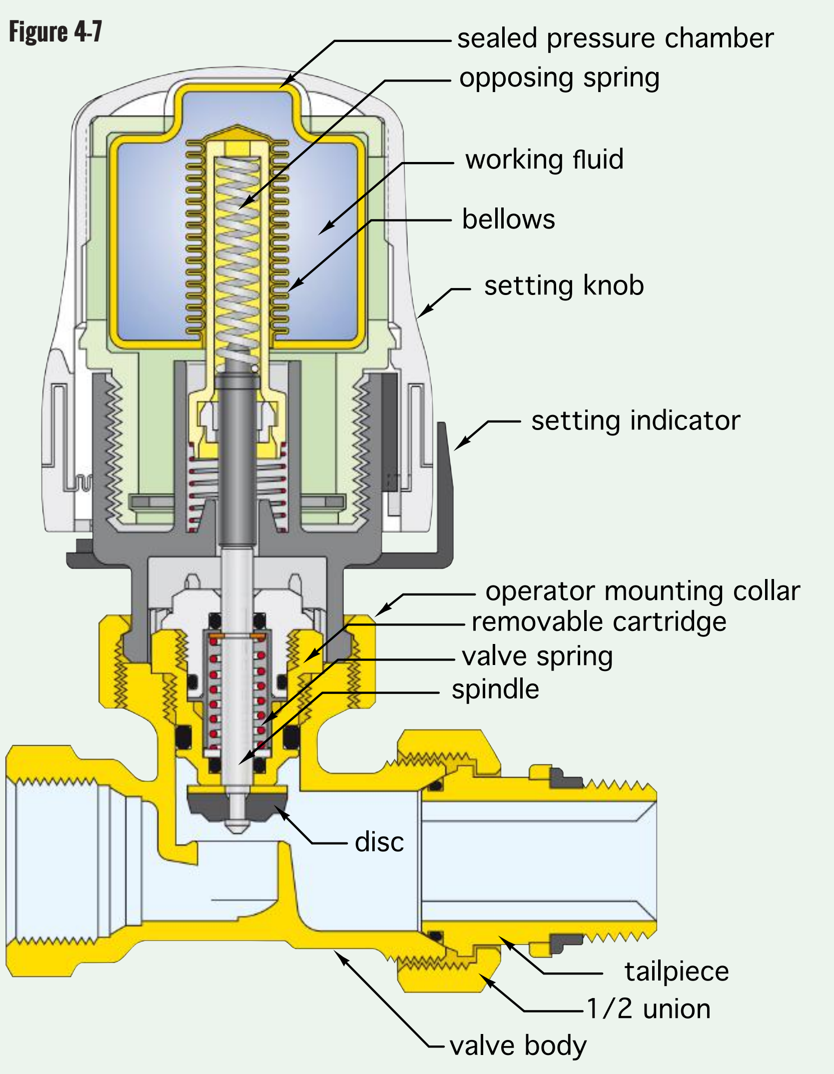
When the air temperature decreases, the valve's stem rises, allowing the spring-loaded valve shaft to rise, increasing flow through the valve. This "feedback" between air temperature changes and flow through the valve can provide stable interior temperature control. It's a technique that has been used in tens of millions of hydronic heating systems around the world for many decades.

The "comfort setting" of a thermostatic valve operator is adjusted by rotating the outer knob. Rather than temperature settings, the knob has numbers from 1 to 5 as relative indicators of comfort. This encourages occupants not to associate comfort with a specific room temperature. The correlation between the numbers on the knob of the Caleffi 200 thermostatic operator and the corresponding room temperature setting are shown in figure 4-8.

The setting of (*) provides freeze protection in unoccupied spaces.

Unlike thermo-electric actuators or motorized zone valves which

Figure 4-7



function as fully open or fully closed, non-electric thermostatic operators can *modulate* the flow through a heat emitter over a wide range. This ability to continually fine-tune flow through each heat emitter helps minimize room temperature variations.

Radiator valves equipped with thermostatic operators are typically mounted close to or directly to the inlet port of a heat emitter, as shown in figure 4-9.

The flow direction through the valve is indicated by an arrow on the valve body. *It's important that flow passes upward through the valve's seat and against the valve's disc.* Piping the valve in reverse can lead to chatter, water hammer or other undesirable sounds when the valve's disc is close to its seat.

Care must be taken not to mount the operator so that warm air rising from the heat emitter goes directly over the operator. This will cause the operator to close the valve very shortly after hot water begins flowing through the heat emitter. Keeping the long axis of the operator in a horizontal position and pointing away from the heat emitter is ideal.

Thermostatic operators can also be mounted to a "straight" pattern or

Figure 4-8

knob setting	temperature setting (ºF)	temperature setting (ºC)
0	32	0
*	45	7
1	54	12
2	61	16
3	68	20
4	75	24
5	82	28

Figure 4-9

Figure 4-10a

Figure 4-10b

"angle" pattern valve. The latter is shown in figure 4-10b, where the valve body provides a 90-degree angle between the valve's inlet and outlet ports.

Thermostatic valve operators can also be fitted directly to panel radiators that have *integral* valves, as shown in figure 4-11.

The thermostatic operator is simply screwed onto the threaded portion of the integral valve. However, it's important to verify that the radiator valve stem projection is compatible with the thermostatic operator. In some cases, it may be necessary to use an adapter between the valve body and thermostatic operator, as shown in figure 4-12.

Radiators with integral valves place the thermostat operator at a convenient height for adjustment, as shown in figure 4-13.

Figure 4-11a

Figure 4-11b

Figure 4-12a

Figure 4-12b

Figure 4-12c

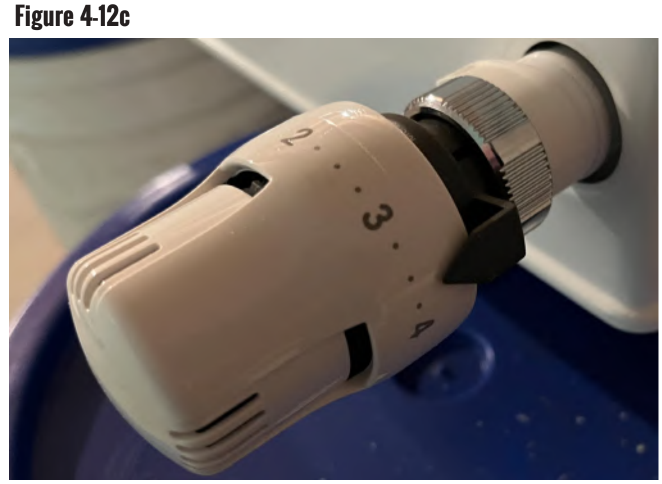


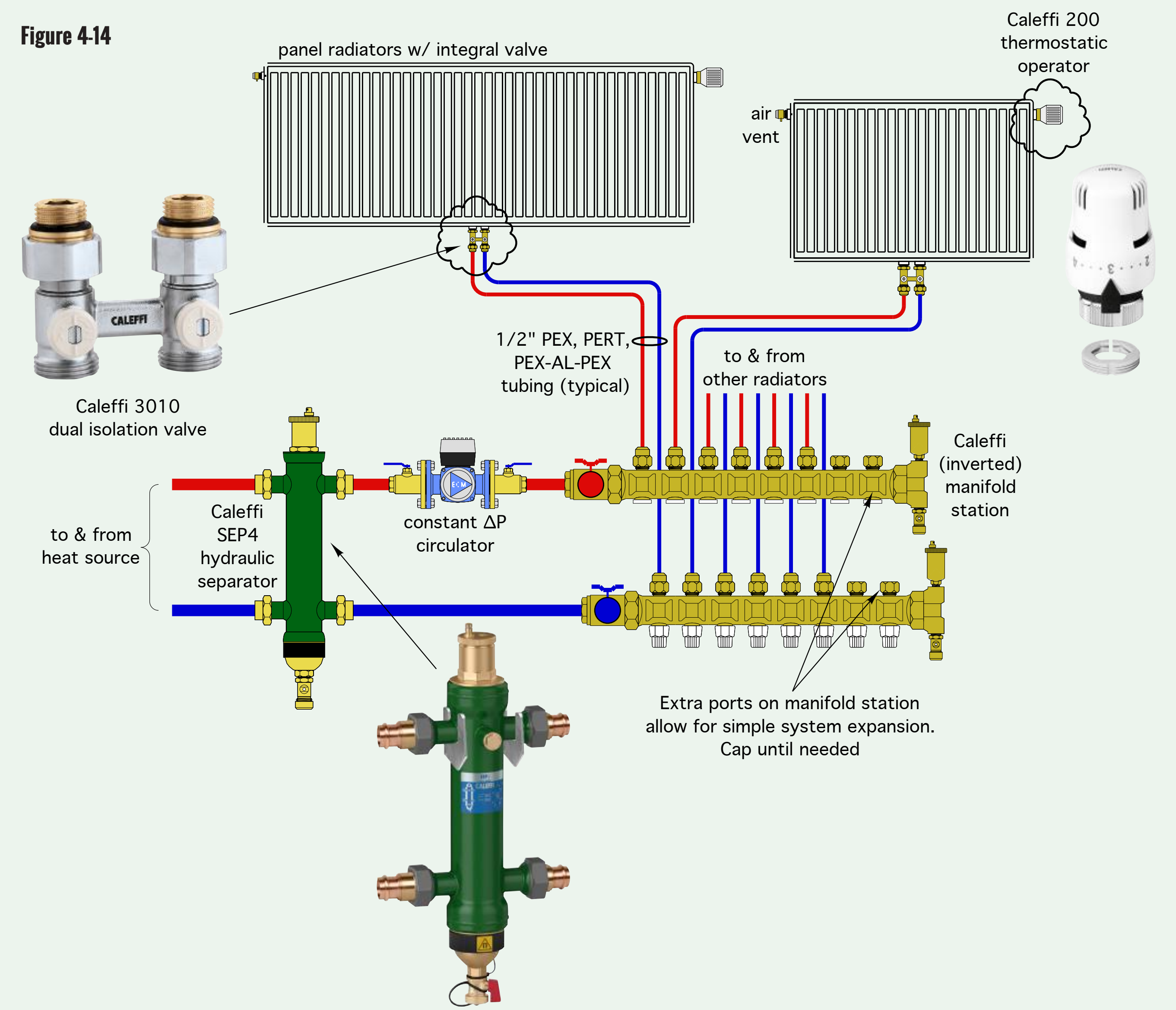
Figure 4-13

When multiple panel radiators with integral valves are served by a homerun distribution system, as shown in figure 4-14, each radiator can be independently controlled, and thus, becomes a zone.

The concept shown in figure 4-14 is simple but elegant. Each panel radiator functions as an independent zone, both hydraulically and thermally.

Flexible 1/2-inch size PEX, PERT or PEX-AL-PEX tubing is ideal for connecting panel radiators to the manifold station. It's easily routed along floor framing or through wall cavities, making this approach well suited to retrofit applications.

Figure 4-14



The transition between the tubing and the radiator is made using a Caleffi 3010 dual isolation valve. This component contains two independent ball valves that can be opened or closed using a screwdriver. When these ball valves are closed, the panel radiator is isolated from the remainder of the system, and can be removed, if necessary, without affecting the other radiators in the system.

Figure 4-15

Figure 4-15 shows a closeup of the area where the 1/2-inch PEX-AL-PEX tubing supplying a "compact" style panel radiator rises through the floor and attaches to the Caleffi 3010 dual isolation valve.

For this style of panel radiator, the holes through the floor should be drilled 2 inches on-center, and slightly larger than the tubing to allow for expansion and contraction without noise or stress. When several radiators of the same style are being installed, it's convenient to make a plywood jig to locate the holes at the proper center-to-center spacing, as well as the proper distance from the wall, as shown in figure 4-16.

After flooring is installed, the holes are covered by an escutcheon plate for a finished appearance, as seen in figure 4-17. Snap-on plastic sleeves are installed over the tubing to give a finished appearance and protect the tubing.

The variable-speed pressure-regulated circulator used for a homerun distribution system, such as shown in

Figure 4-16

Figure 4-14, should be set for constant differential pressure mode and operate 24/7 during the heating season. The speed of the circulator automatically adjusts as the thermostatic valve operators open, close or modulate flow through their associated radiators.

In an average residential system with perhaps 8-10 panel radiators, a variable-speed circulator with a low power input (under 50 watts at full speed) is often sufficient. The power input to the circulator is typically even lower under partial load conditions. The cost of operating the circulator in an area where electricity costs $0.20/kWh is often under 20 *cents* per day.

The Caleffi SEP4™ hydraulic separator shown in figure 4-14 decouples the pressure dynamics of the variable-

Figure 4-17a

Figure 4-17b

speed circulator from those of other circulators in the system. It also provides high performance air, dirt and magnetic particle separation.

See *idronics* 15 for more information on separation in hydronic systems.

When connecting the tubing to the radiators, *be careful to observe the correct flow direction through the radiators.* Flow should always be against the disc within the radiator's integral valve. Reversing the flow direction can create chatter and water hammer when the valve's disc is close to its seat.

Flow balancing of the homerun circuits can be done using the balancing features of the integral radiator valves. Many of these valves have an adjustable "shutter" that can be set to create a specific Cv. The higher the Cv setting of the integral valve, the lower the flow resistance through the radiator. Flow balancing can also be done using the balancing valves built into some manifold stations.

It's also possible to incorporate radiant panel heating circuits along with panel radiators, all supplied from the same manifold station. Since the manifold station supplies all circuits at the same, it's important to size the radiant panel circuits based on the supply temperature for the panel radiators or vice versa.

Another recommended detail is to use a manifold station with one or two extra ports beyond those needed for the initial installation. This allows for simple expansion of the system in the future. The unused ports should be capped until they are needed.

In systems where several panel radiators are supplied by a fixed output heat source, a buffer tank can be used in place of the SEP4 hydraulic separator. An example of this system configuration is shown in figure 4-18.

Figure 4-18

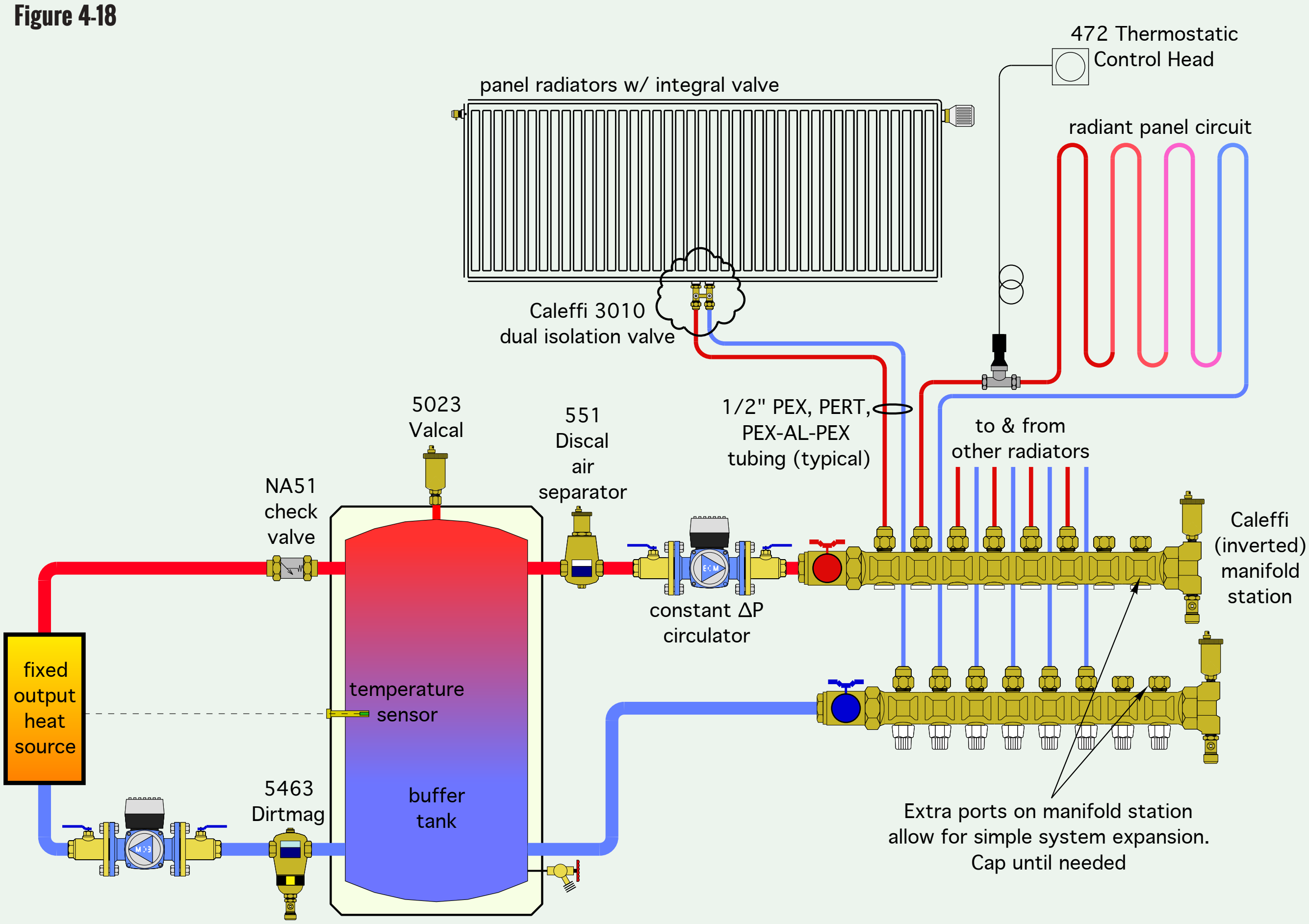
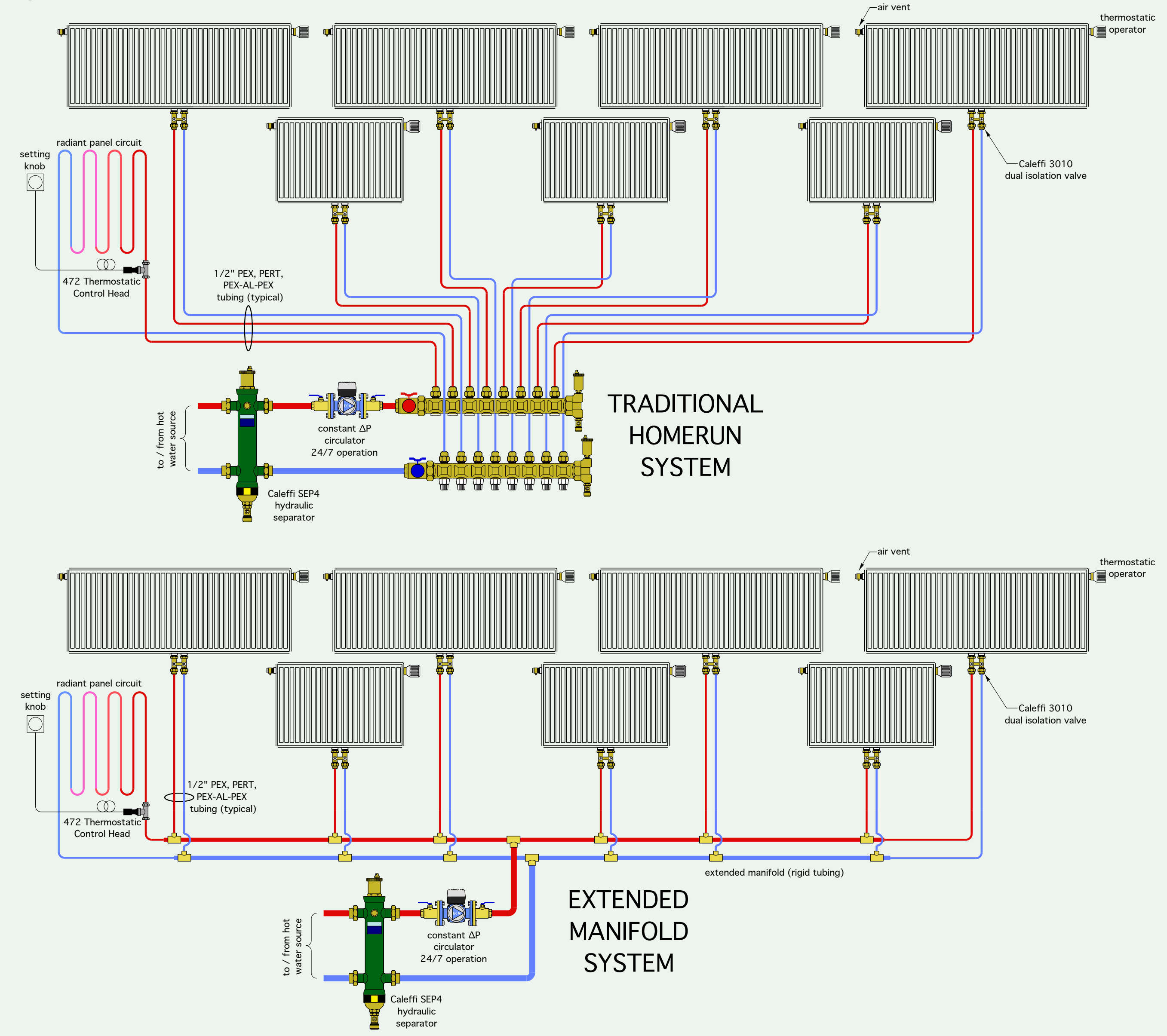


Figure 4-19



The thermal mass of the buffer tank protects the fixed-output heat source from short cycling when only one or perhaps two panel radiators are active. The buffer tank also provides hydraulic separation between the heat source circulator and the variable-speed pressure-regulated distribution circulator.

In the system shown in figure 4-18 the heat source monitors the temperature in the buffer tank and operates as necessary to maintain that temperature within a suitable range for the heat emitters. That range could be a setpoint combined with a differential. It could also be based on outdoor reset control. The latter usually improves the efficiency of the heat source.

See *idronics* 15 for more information on buffer tanks.

The variable-speed pressure-regulated circulator operates 24/7, just as it did in the system shown in figure 4-14.

This system includes a Caleffi DISCAL® air separator and DIRTMAG® PRO dirt and magnetic particle separator. The latter ensures that the internal components in the heat source remain as clean as possible. It also helps protect the ECM circulators from magnetite accumulation.

The homerun distribution system serves both panel radiators and radiant panel circuits. The heat output of the panel radiators is regulated by thermostatic valve operators attached to the integral valves in the radiators. The output of the radiant panel circuit is also controlled by a thermostatic operator that combines the valve actuator with a wall-mounted adjustment dial, connected to the actuator by a capillary tube. These types of thermostatic devices are discussed later in this section.

EXTENDED MANIFOLD SYSTEMS

In some situations, the amount of tubing needed to facilitate "homerun" circuits from a single manifold station to each panel radiator, or other heat emitters, becomes inconvenient. Doing so could require many holes to be drilled through floor joists, which might have structural consequences. This approach might also require substantial amounts of tubing, which increases system volume and adds to heat loss if routed through partially heated spaces.

A variation on traditional homerun piping is the "extended manifold" piping configuration. It uses longer lengths of rigid tubing (typically copper), along with tees and transition fittings as a replacement for a central manifold station. Figure 4-19 shows a traditional homerun distribution system and an equivalent extended manifold system.

The extended manifold approach is especially helpful in situations where the heat emitters are spread out over long distances within the building. It's also a good option when the extended manifold can be routed along a straight path, such as along the main girder supporting the center of the floor framing.

Both systems use a variable-speed pressure-regulated circulator that operates 24/7 during the heating season. The heat emitters can be any combination of panel radiators and radiant floor, wall or ceiling panels. However, all the heat emitters should be sized to operate at the same nominal supply water temperature.

Figure 4-20 shows a "branching point" from an extended manifold made of 3/4" copper tubing routed along a girder that supports floor framing. The support clips allow tubing to expand and contract without developing stress or creating noise. The 3/4" x 3/4" x 1/2" reducer tees transition to connectors for 1/2" PEX-AL-PEX tubing, which leads to a panel radiator.

Figure 4-21 shows the end of the same extended manifold system where the 3/4" copper manifold transitions to three branches, each piped with 1/2" PEX-AL-PEX tubing. Two of those branches lead to panel radiators. The other branch leads to a floor heating circuit. Flow through the latter is controlled by a Caleffi 472 actuator attached to a Caleffi 221 radiator valve.

Figure 4-20

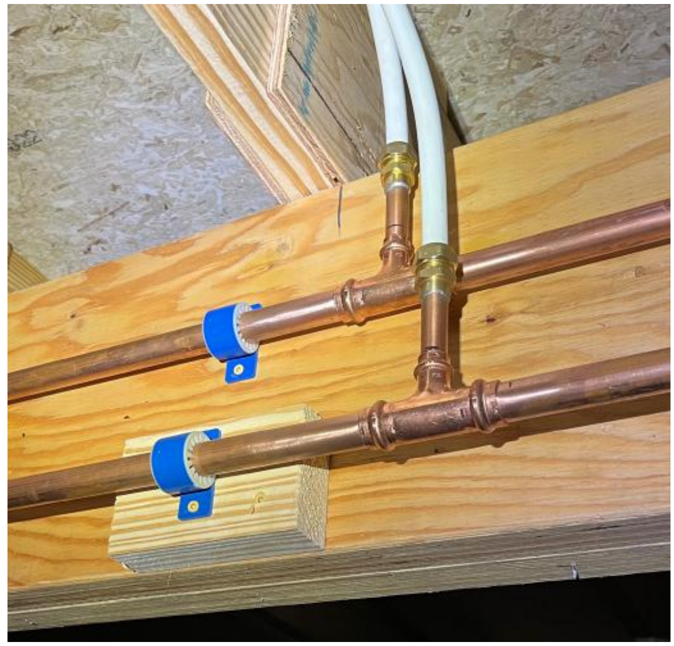


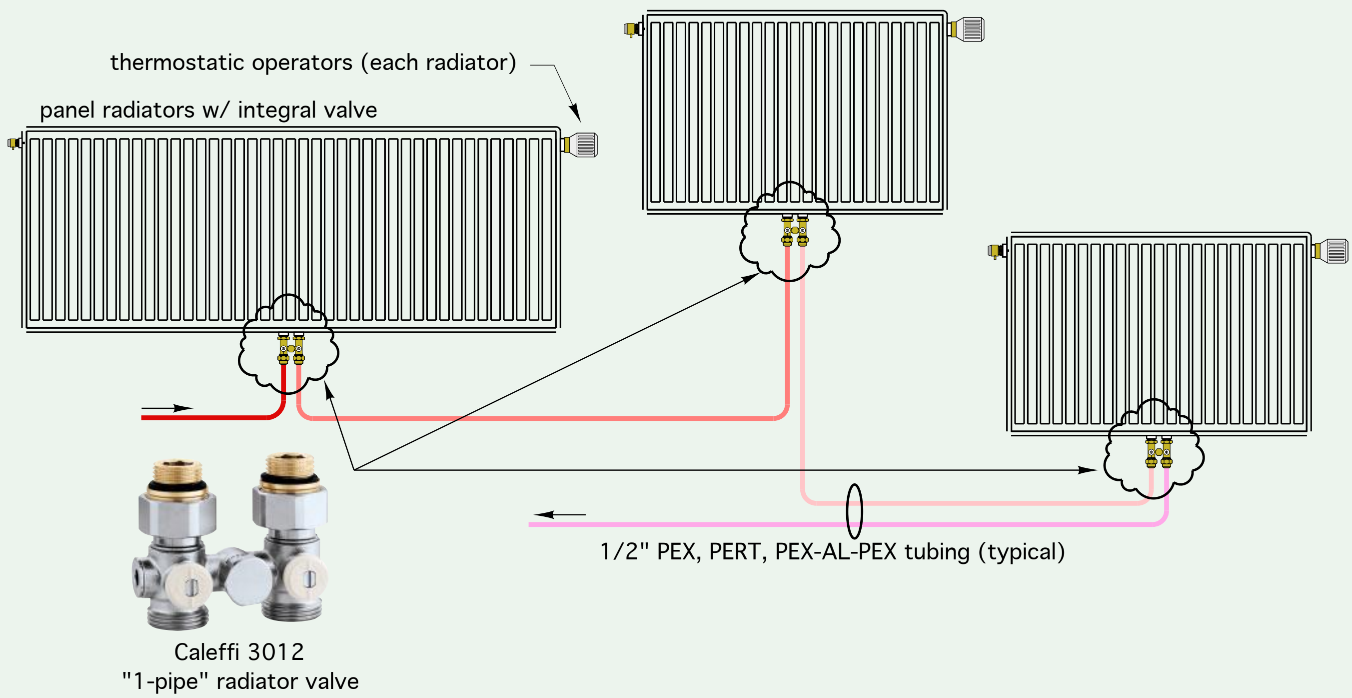
Figure 4-21

1-PIPE PANEL RADIATOR SYSTEMS USING THERMOSTATIC OPERATORS

The piping configurations shown in figures 4-14 through 4-21 *connect all the heat emitters in parallel.* Each heat emitter has its own supply and return tube that originates at a manifold station or extended manifold. This approach allows each heat emitter to receive essentially the same supply water temperature.

Another approach that can significantly reduce tubing lengths is to connect *two or three* panel radiators into

Figure 4-22



a “1-pipe” configuration using specially designed bypass valves that also provide for panel isolation. Figure 4-22 shows three panel radiators connected in a “1-pipe” configuration.

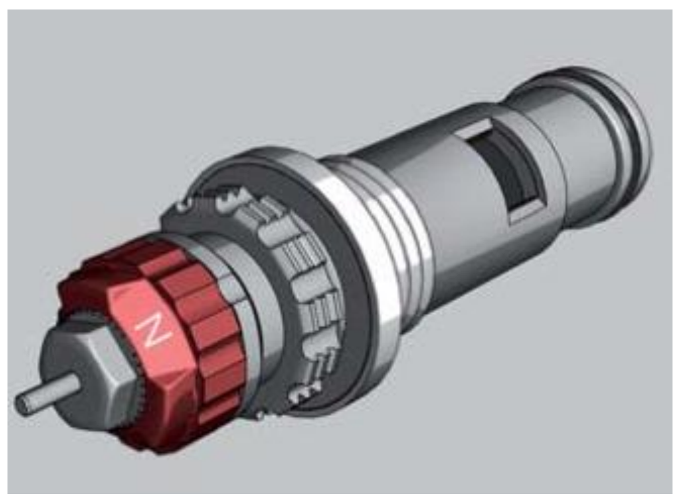
Flow entering each Caleffi 3012 valve is divided. One portion passes through the radiator and the remainder passes through the horizontal bypass valve connecting the left and right sides of the valve body.

These valves also have a small side port for draining water from the radiator if it has to be removed from its mounting. The side drainage port can be opened with a 6mm Allen wrench.

ESTIMATING FLOW USING 1-PIPE RADIATOR CONNECTION VALVES

The Caleffi 3012 and 3013 valves are designed for use with “compact style” panel radiators. These radiators have bottom inlet and out connections spaced at 50mm (2”) apart. Incoming flow enters the left side port and passes up through a tube inside the radiator that leads to the seat of an integral valve assembly. That valve assembly has a spring-loaded shaft. When the shaft is fully extended by the spring, the valve’s disc is fully open. When the shaft is fully pushed in against the spring, the valve is closed. Figure 4-23 shows a typical integral valve assembly.

Figure 4-23

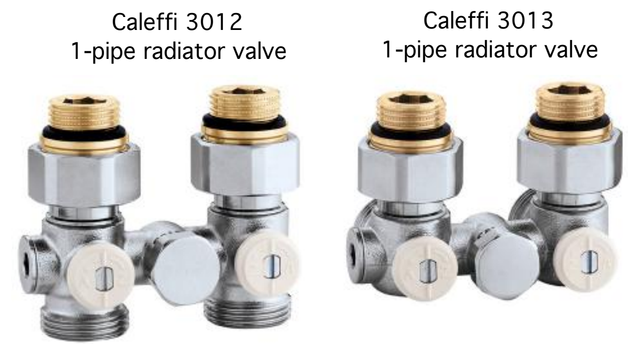


Courtesy of Purmo Group

The integral valve assembly has a ring with numbers 1-7, and the letter N. These correspond to Cv values ranging — approximately linearly — from Cv = 0.15 at a setting of 1, to Cv = 0.7 at a setting of 7. The Cv at the “N” setting, where the shutter in the valve is fully open, is Cv = 0.83. The Cv of the valve can be set by turning the ring to align one of these numbers or the letter “N” with the groove on the valve body. In Figure 4-23, the letter “N” on the red ring is aligned with the grove on the valve body, meaning that the valve shutter, seen at the rear of the assembly, is fully open.

When a compact-style panel radiator with an integral valve is installed in a "1-pipe" arrangement, its supply and return connections are fitted with a "1-pipe" valve, such as the Caleffi 3012 and 3013 valves shown in figure 4-24.

Figure 4-24



These specialty valves combine *three* valves into a single assembly. The two outer valves are for isolating the radiator from the remainder of the system if it has to be serviced or removed. These two valves are meant to be fully open (normal operation) or fully closed (to isolate the radiator).

The center valve is a bypass valve. It can be adjusted by removing the cap and using a 6mm Allen wrench to turn the stem. The setting of this center bypass valve determines the hydraulic resistance between the inlet and outlet sides of the valve. The greater this resistance, the higher the percentage of entering flow that passes through the radiator.

Figure 4-25 shows the Cv range of the center bypass valve in the Caleffi 3012 and 3013 1-pipe radiator valves.

The flow passing through the panel radiator depends on the Cv of the radiator valve, as well as the Cv setting of the bypass valve. It can be calculated as a fraction of the flow entering the valve using formula 4-1.

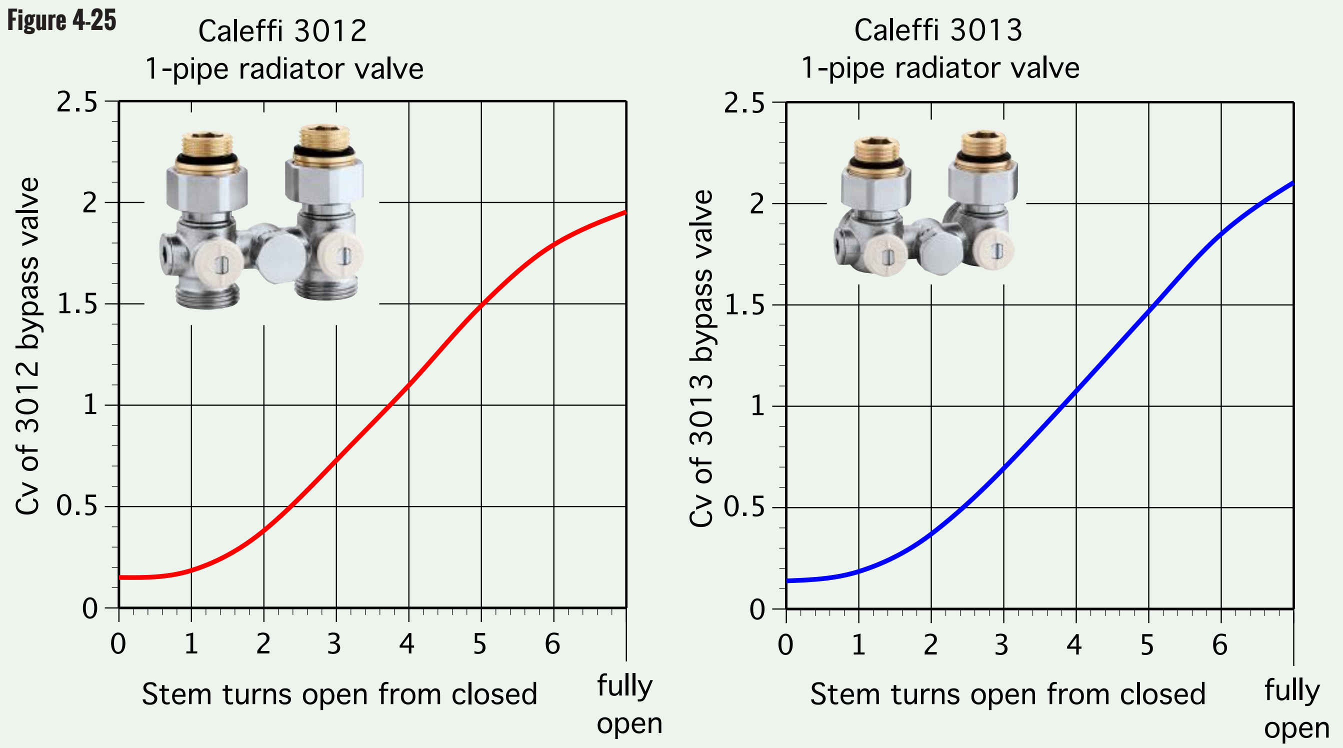
Formula 4-1:

$$f_{rad} = f_{total}\left[\frac{\left(\frac{Cv_{rad}}{Cv_{bypass}}\right)}{\left(1+\frac{Cv_{rad}}{Cv_{bypass}}\right)}\right]$$

Where:

f_{rad} = flow rate through the radiator (gpm)
f_{total} = total flow entering the valve's left side port (gpm)
Cv_{rad} = Cv setting of the integral radiator valve
Cv_{bypass} = Cv setting of the bypass valve

Figure 4-25



The value of the terms shown in red in formula 4-1 can be thought of as the *decimal percentage of total flow entering the 1-pipe valve that passes through the radiator*.

For example, if the Cv of the integral radiator valve is the same as that of the center bypass valve (2.0 for example), the red portion of Formula 4-1 becomes 0.5:

$$f_{rad} = f_{total}\left[\frac{\left(\frac{Cv_{rad}}{Cv_{bypass}}\right)}{\left(1+\frac{Cv_{rad}}{Cv_{bypass}}\right)}\right] = f_{total}\left[\frac{\left(\frac{2}{2}\right)}{\left(1+\frac{2}{2}\right)}\right] = f_{total}\left[\frac{1}{(1+1)}\right] = f_{total}[0.5]$$

This implies that 50% of the flow rate entering the 1-pipe valve passes through the radiator, and the remaining 50% passes through the bypass valve.

If the Cv of the radiator valve was 0.25, and the Cv of the bypass valve was 1, formula 4-1 would be as follows:

$$f_{rad} = f_{total}\left[\frac{\left(\frac{Cv_{rad}}{Cv_{bypass}}\right)}{\left(1+\frac{Cv_{rad}}{Cv_{bypass}}\right)}\right] = f_{total}\left[\frac{\left(\frac{0.25}{1}\right)}{\left(1+\frac{0.25}{1}\right)}\right] = f_{total}\left[\frac{0.25}{(1.25)}\right] = f_{total}[0.2]$$

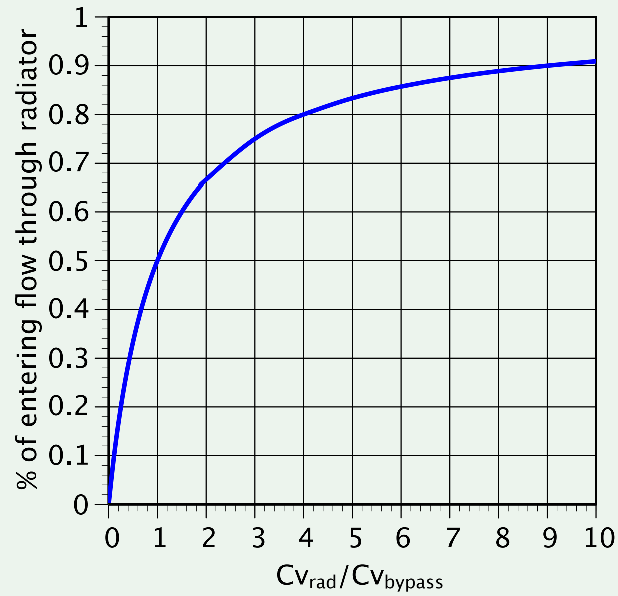
The result implies that 20% of the total flow entering the valve passes through the radiator, while the remaining 80% passes through the center bypass valve.

Figure 4-26 shows a plot of the percentage of entering flow that passes through the radiator as a function of the ratio (Cv_{rad}/Cv_{bypass}).

Caleffi 1-pipe radiator valves come preset so that *approximately* 35% of the flow entering the valve passes through the radiator, while the remaining 65% passes through the bypass valve. This default setting is usually acceptable when three identical panel radiators are piped as shown in figure 4-22. However, *when radiators of different sizes are connected in a 1-pipe arrangement, the percentage of the total flow that passes through a given radiator should be approximately proportional to the design heat output of that radiator as a percentage of the total design heat output of all radiators in the 1-pipe circuit.*

For example: Consider a 1-pipe circuit with two panel radiators. One radiator is sized for a design heat output of 5,000 Btu/hr and the other is sized for a design heat output of 8,000 Btu/hr. The total heat output of the string would be 5,000 + 8,000 = 13,000 Btu/hr. The percentage of total flow through the 5,000 Btu/hr radiator would be 5,000/13,000 = 0.38 or 38% of the total flow. The remaining 62% of total flow would pass through the other radiator.

Figure 4-26



Assuming that the integral valve assembly in both radiators was set to “N”, the Cv of the integral radiator valves would be 0.83. To find the Cv setting of the bypass valve, set up a slightly rearranged form of formula 4-1, knowing that the fraction of entering flow that needs to pass through the radiator is 0.38 (e.g., 38%) of the circuit flow.

$$\frac{f_{rad}}{f_{total}} = 0.38 = \left[\frac{\left(\frac{0.83}{Cv_{bypass}}\right)}{\left(1+\frac{0.83}{Cv_{bypass}}\right)}\right]$$

This rearranged form of formula 4-1 can be solved to get the value of Cv_{bypass}:

$$0.38+\frac{0.38(0.83)}{Cv_{bypass}} = \frac{(0.83}{Cv_{bypass}}$$

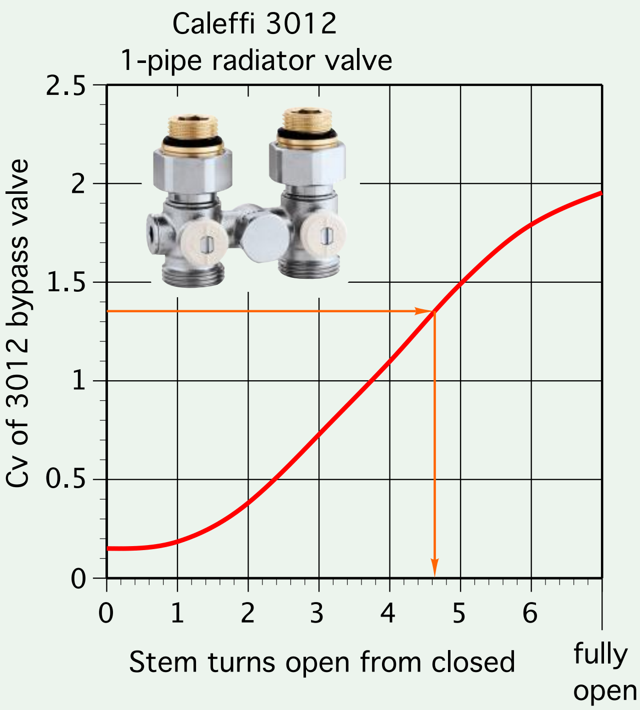
$$0.38 = \frac{1}{Cv_{bypass}}\left(0.83-.38(0.83)\right)$$

$$\frac{0.38}{\left(0.83-.38(0.83)\right)} = \frac{1}{Cv_{bypass}}$$

$$Cv_{bypass} = 1.35$$

Referencing figure 4-25 shows that opening the plug of the Caleffi 3012 bypass valve 4.6 turns would yield a Cv of 1.35 for the bypass valve, as shown in figure 4-27.

Figure 4-27



The temperature drop of the flow stream passing through a 1-pipe radiator valve can be calculated using formula 4-2.

Formula 4-2:

$$\Delta T = \frac{q_{rad}}{(8.01cD)f}$$

Where:
ΔT = temperature drop of fluid from inlet to outlet of dual isolation valve (ºF)
q_{rad} = heat output of radiator (Btu/hr)
8.01 = a constant need for units
c = specific heat of fluid (Btu/lb/ºF)
D = density of fluid (lb/ft^3)
f = circuit flow rate (gpm)

For example: Assume that a panel radiator releases 5,000 Btu/hr when supplied with 120ºF water and operating in a room with a 70ºF air temperature. Also assume that flow rate in the 1-pipe circuit is 1.5 gpm. Determine the outlet temperature from the 1-pipe valve.

Solution: The density of water at 120ºF is 61.6 lb/ft^3. The specific heat of water at 120ºF is 1.00 Btu/lb/ºF. Putting these fluid properties and the given values into formula 4-2 yields the temperature drop across the radiator.

$$\Delta T = \frac{q_{rad}}{(8.01cD)f} = \frac{5000}{(8.01)(1.00)(61.6)1.5} = 6.76^{\circ}F$$

The outlet temperature from the dual isolation valve — which typically is assumed to be the inlet temperature for the next radiator in the 1-pipe circuit — is 120 - 6.76 = 113.2ºF.

Note that it is not necessary to know how the circuit flow entering the 1-pipe valve divides between the radiator and the bypass valve to make this calculation. The flow passing through the bypass valve would mix with the water leaving the panel radiator to produce a "net" temperature drop of 6.76ºF.

In a 1-pipe configuration, each active radiator, other than the first one on the supply side of the circuit, receives water at a temperature lower than the radiator upstream of it. Because of this sequential temperature drop, the radiator "string" should be limited to three radiators, and the maximum design load output for the string should be limited to about 34,000 Btu/hr (10 kW), *assuming a high supply water temperature to the first radiator in the range of 180 to 190ºF.* When lower supply water temperatures are used, it's prudent to limit the string to two radiators.

ALTERNATIVE APPLICATIONS FOR NON-ELECTRIC THERMOSTATIC OPERATORS

The thermostatic radiator valves (such as shown in figure 4-7), and thermostatic operators fitted to radiators with integral valves (shown in figure 4-11), both regulate flow based on the *air temperature near the heat emitter*. It's also possible to use non-electric thermostatic operators to regulate flow based on other temperatures in the system.

Figure 4-28 shows a radiator valve body, such as a Caleffi 221 or 220 valve, fitted with a Caleffi 472 thermostatic actuator assembly.

This assembly allows the space comfort level to be set using a dial located on a wall, typically about five feet above the floor, as shown in figure 4-29.

This assembly is ideal for situations where occupants may not have the willingness or the mobility to reach thermostatic operators located on low-profile radiators near the floor.

Figure 4-28a

Figure 4-28b

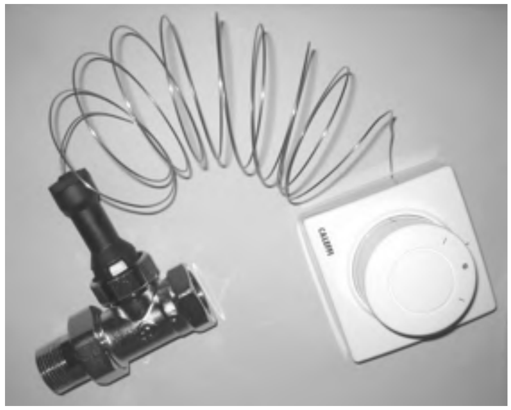


Figure 4-29

When using this assembly, it's important to remember that it's a capillary tube — not a wire — connecting the valve actuator to the setting dial. *The capillary tube cannot be cut or extended*. It needs to be routed from the setting dial location to the valve. Any holes needed for this routing need to be large enough for the actuator head to pass through (e.g., the black cylindrical part of the assembly seen screwed to the valve in figure 4-28).

It's also important to mount the valve body in an accessible location. If mounted within a wall or ceiling cavity that will eventually be covered with drywall or other materials, an access panel should be provided.

Figure 4-30 shows an application that uses a thermostatic valve to regulate flow in a circuit that supplies a towel warmer and floor heating in the same bathroom.

The comfort level in the bathroom is set using the wall-mounted dial of the Caleffi 472 actuator assembly, which controls flow through the Caleffi 221 radiator valve. The capillary tube connecting the dial and actuator is routed through the wall cavity. A pair of Caleffi 338 angle valves make the transition between the 1/2" PEX tubing and the ports on the towel warmer radiator. These valves allow the radiator to be isolated from the circuit if ever necessary.

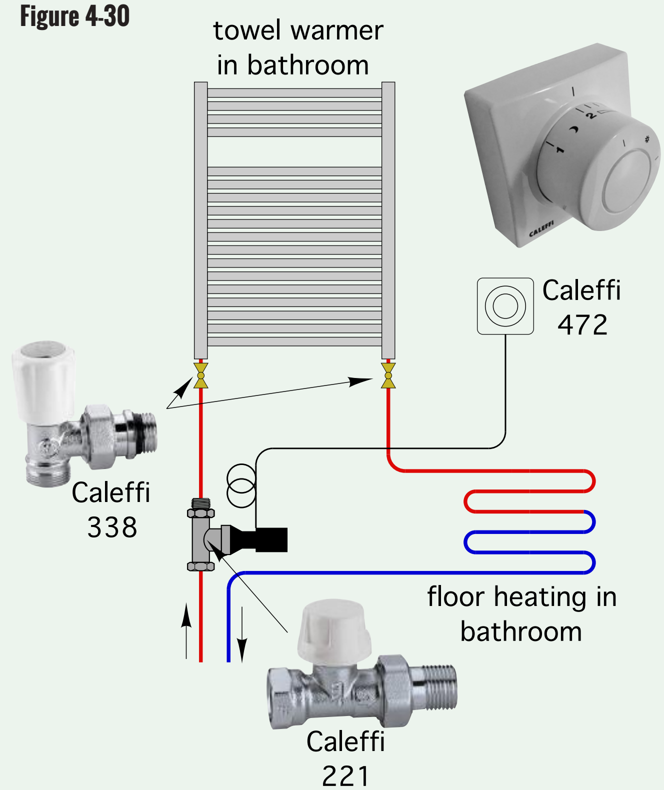
Two or more Caleffi 472 actuator assemblies could also be used for controlling flow in independent zone circuits. However, the capillary tube length is limited to 78 inches, which means that the valve bodies need to be relatively close to the location of the setting dial.

Another application for non-electric thermostatic control is a situation where flow rate needs to be controlled *based on the temperature of a pipe surface, or a sensor mounted in a sensor well.* This can be done using a Caleffi 203 actuator assembly combined with a Caleffi 220 or 221 radiator valve.

One example of such an application is maintaining a setpoint temperature to the radiant panel circuits using injection mixing, as shown in figure 4-31.

A portion of the cool water returning from the radiant panel circuits passes through the throttling valve and mixes with hotter water that has passed through the injection valve. The mix proportions determine the supply temperature to the manifold station. The amount of water passing through the injection valve depends on the setting of the

Figure 4-30



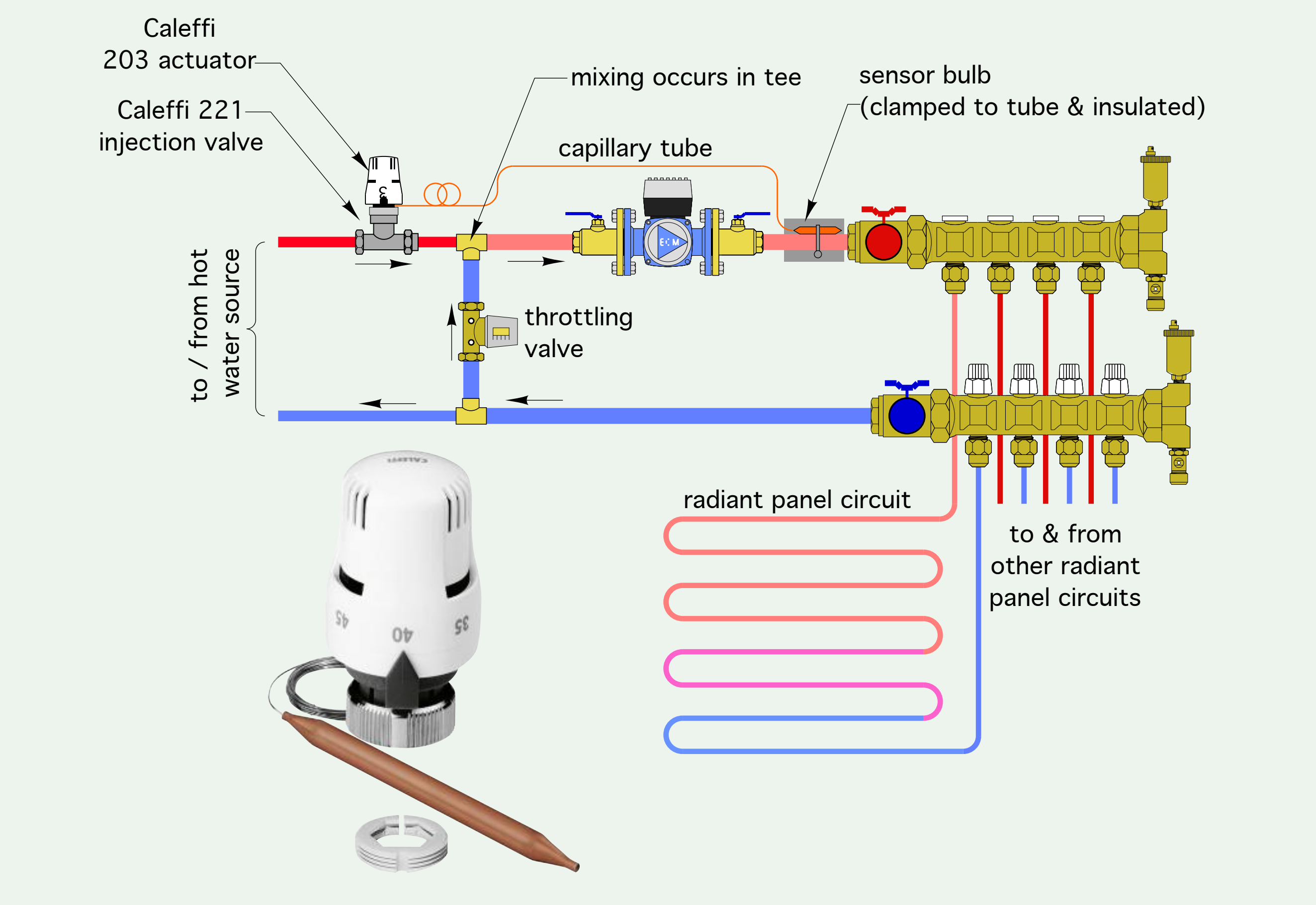
203 actuator and the temperature at the sensing bulb. If the sensed temperature is lower than the dial setting, the valve opens more, and vice versa. The numbers on the knob of the 203 actuator assembly are setpoint temperatures in ºC.

The knob for the 203 actuator assembly mounts to the injection valve. A capillary tube connects this assembly to a sensing bulb that's clamped to the pipe supplying the manifold station. The Caleffi 203 actuator assembly has a 78-inch-long capillary tube connecting the actuator with the sensing bulb. This capillary tube cannot be cut. Any access length of capillary tube should be neatly coiled near the valve.

The throttling valve in figure 4-30 creates the differential pressure necessary to drive hot water through the injection valve as it opens. As the pressure drop through the throttling valve increases, the induced hot water flow rate through the injection valve also increases.

The throttling valve should be adjusted when the injection valve is fully open. Start with the throttling valve fully open, thus creating its minimum pressure drop. Slowly close the throttling valve while measuring the mixed supply temperature. The goal is to create a mixed supply water temperature that allows the radiant panel circuits to meet design load output when the injection valve is fully open.

Figure 4-31



5. EXAMPLE SYSTEMS

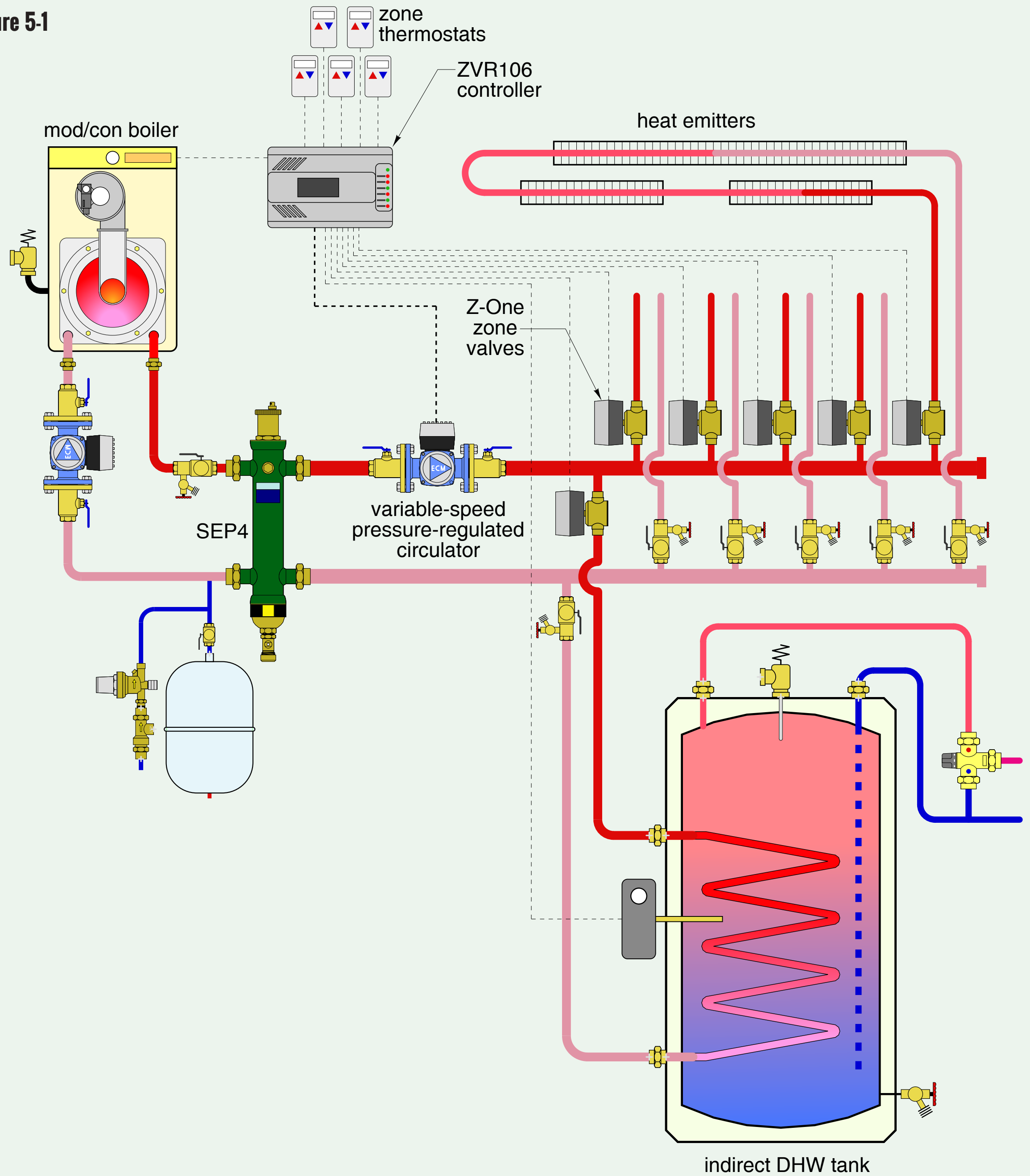
This section presents several examples of zoned hydronic systems. The hardware used in this system includes many of the devices described in previous sections. These systems show a variety of zoning techniques, sometimes within the same system. They also include provisions for hydraulic separation, air/dirt/magnetic particle separation, purging, pressure regulation, pressure relief and reduced heat migration. They all represent designs that can be constructed using currently available hardware, including many components available from Caleffi North America.

SYSTEM 1 – BOILER SUPPLIES ZONED SPACE HEATING & DOMESTIC HOT WATER

The system in figure 5-1 is a common application in which a single modulating/condensing boiler supplies zoned space heating and domestic hot water.

Domestic water heating is supplied as a priority load. When the aquastat on the indirect water heater calls for heat, the Caleffi ZVR106 controller supplies 24 VAC to the zone

Figure 5-1



valve for the water heater. It also turns on the variable-speed pressure-regulated circulator and signals the boiler to operate at an elevated supply water temperature. The five space heating zones are temporarily prevented from operating, allowing the full boiler heat output to go to the indirect water heater.

Space heating is supplied by five independent zones, each controlled by a thermostat. When any thermostat calls for heat, the ZVR106 controller opens the associated zone valve. It also turns on the variable-speed pressure-regulated circulator and signals the boiler to operate. The water temperature leaving the boiler is now controlled based on outdoor reset. This keeps the boiler operating at the lowest possible temperature and highest possible efficiency, while still maintaining comfort in the building.

The variable-speed pressure-regulated circulator automatically changes speed based on the number of active zone circuits.

A Caleffi SEP4 hydraulic separator ensures hydraulic separation between the boiler circulator and the distribution circulator. It also provides air, dirt and magnetic particle separation for the system.

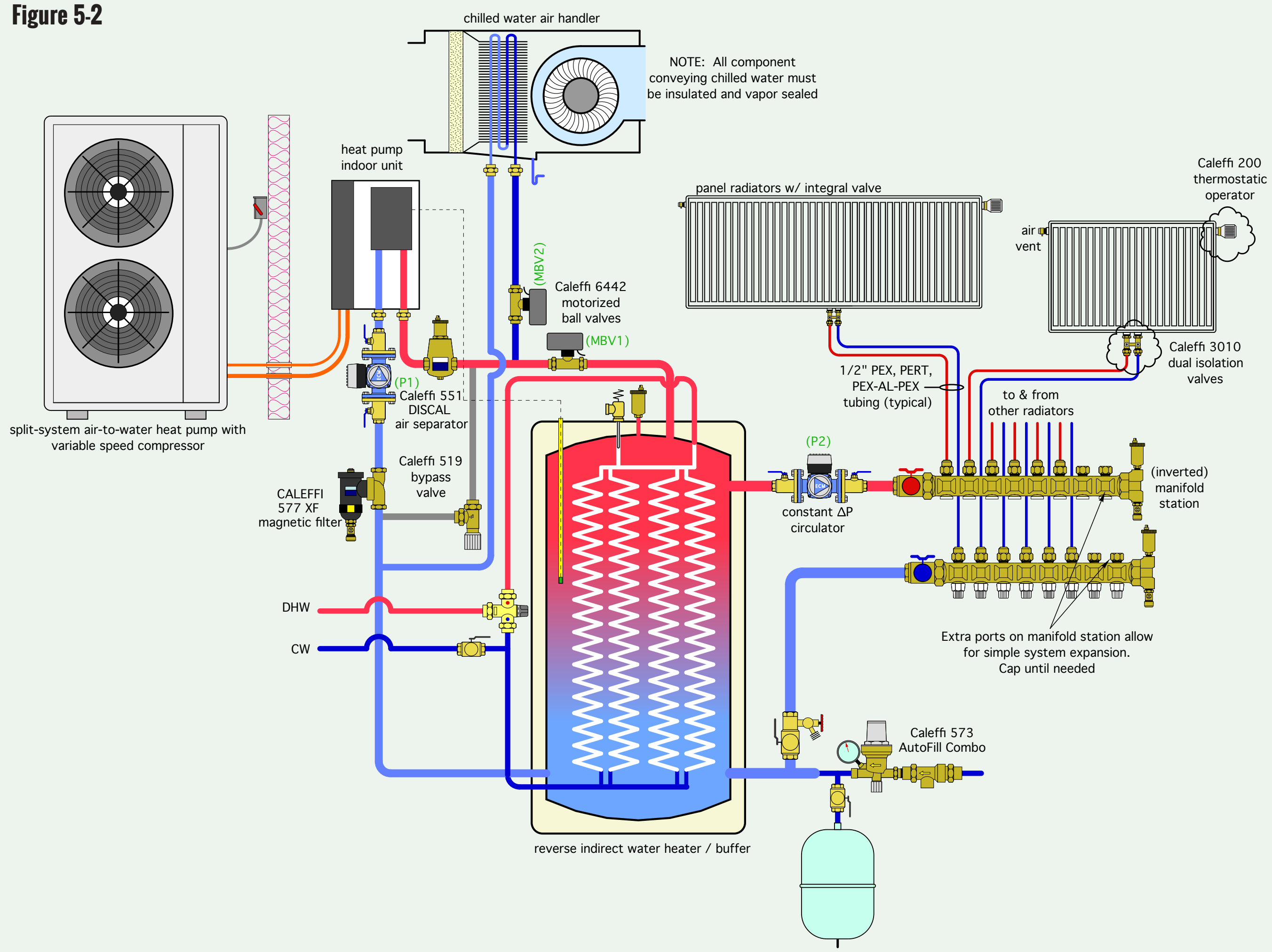
All zone circuits and the boiler circuit are equipped with combination isolation and purging valves.

The domestic hot water leaving the tank passes through an ASTM 1017 thermostatic mixing valve to ensure a maximum domestic hot water temperature of 120ºF to the plumbing distribution system.

SYSTEM 2: SPLIT SYSTEM AIR-TO-WATER HEAT PUMP SUPPLIES ZONED PANEL RADIATORS + COOLING + DHW

The system in figure 5-2 uses a split system air-to-water heat pump as the heat source for several panel radiators, each with their own thermostatic operator. It also includes a reverse indirect water heater that serves as a buffering mass for the highly zoned distribution system, as well as

Figure 5-2



the system's domestic water heater. A ducted air handler is used for cooling.

When the heat pump is called to operate, in either heating or cooling mode, its circulator runs for one to two minutes prior to the compressor starting. This is a common control function built into air-to-water heat pumps. It's intended to verify proper water flow through the heat pump prior to operating its refrigeration system. During this time, motorized ball valves (MBV1) and (MBV2) are both closed. All flow leaving from the heat pump's indoor unit passes through the differential pressure bypass valve, and then back into the indoor unit. This "holding pattern" prevents water that has not reached a suitable temperature from being injected into the reverse indirect water heater. It also prevents hot water from being temporarily routed to the cooling coil in the air handler as the system transitions from domestic water heating mode to cooling mode.

When the water leaving the heat pump's indoor unit has reached a suitable temperature for heating, motorized ball valve (MBV1) opens, allowing flow into the upper portion of the reverse indirect water heater. The bypass valve closes as soon as (MBV1) opens.

During heating mode, the heat pump monitors the temperature of the reverse indirect water heater, keeping it between 115 and 125ºF. This is typically high enough for adequate domestic water heating as cold water makes a single pass through the large internal heat exchanger coils. It's also hot enough to provide design load output through properly sized panel radiators.

During the heating season, the variable-speed pressure-regulated circulator (P2) operates 24/7 in constant differential mode. Its speed automatically adjusts as the thermostatic radiator valves on the panel radiators open, close or modulate flow.

Each panel radiator has an integral valve. Those valves are fitted with Caleffi 200 thermostatic operators, making each of the radiators an independently controlled zone. Each radiator is also equipped with a Caleffi 3010 dual isolation valve.

During cooling mode, the heat pump circulator (P1) starts and operates for up to two minutes before the refrigeration system begins cooling the water. During this time, motorized ball valves (MBV1) and (MBV2) remain closed. Flow passes through the differential pressure bypass valve and back to the heat pump. When the water leaving the heat pump has reached a suitable temperature for cooling, (typically 45 to 55ºF), motorized ball valve (MBV2) opens, allowing chilled water flow to the coil in the air handler. *All piping and components that convey chilled water are insulated and vapor sealed to prevent condensation.*

The controls for this system would prioritize domestic water heating over cooling if both modes became active at the same time. During warm weather, when cooling is often required, the heat pump can heat the tank from 115 to 125ºF in a few minutes and then allow the system to switch back to cooling.

This system is relatively simple. It only requires two circulators. Still, it provides multi-zone space heating, single zone cooling and domestic water heating.

SYSTEM 3 – BOILER SUPPLIES MULTI-ZONE/ MULTI-TEMPERATURE HEATING AND DHW

The system in figure 5-3 supplies multi-zone space heating and domestic water heating from a conventional boiler.

Two of the space heating zones serve higher-temperature heat emitters, such as fin-tube baseboard, convectors or fan-coils. The other two zones serve low-temperature radiant panel circuits.

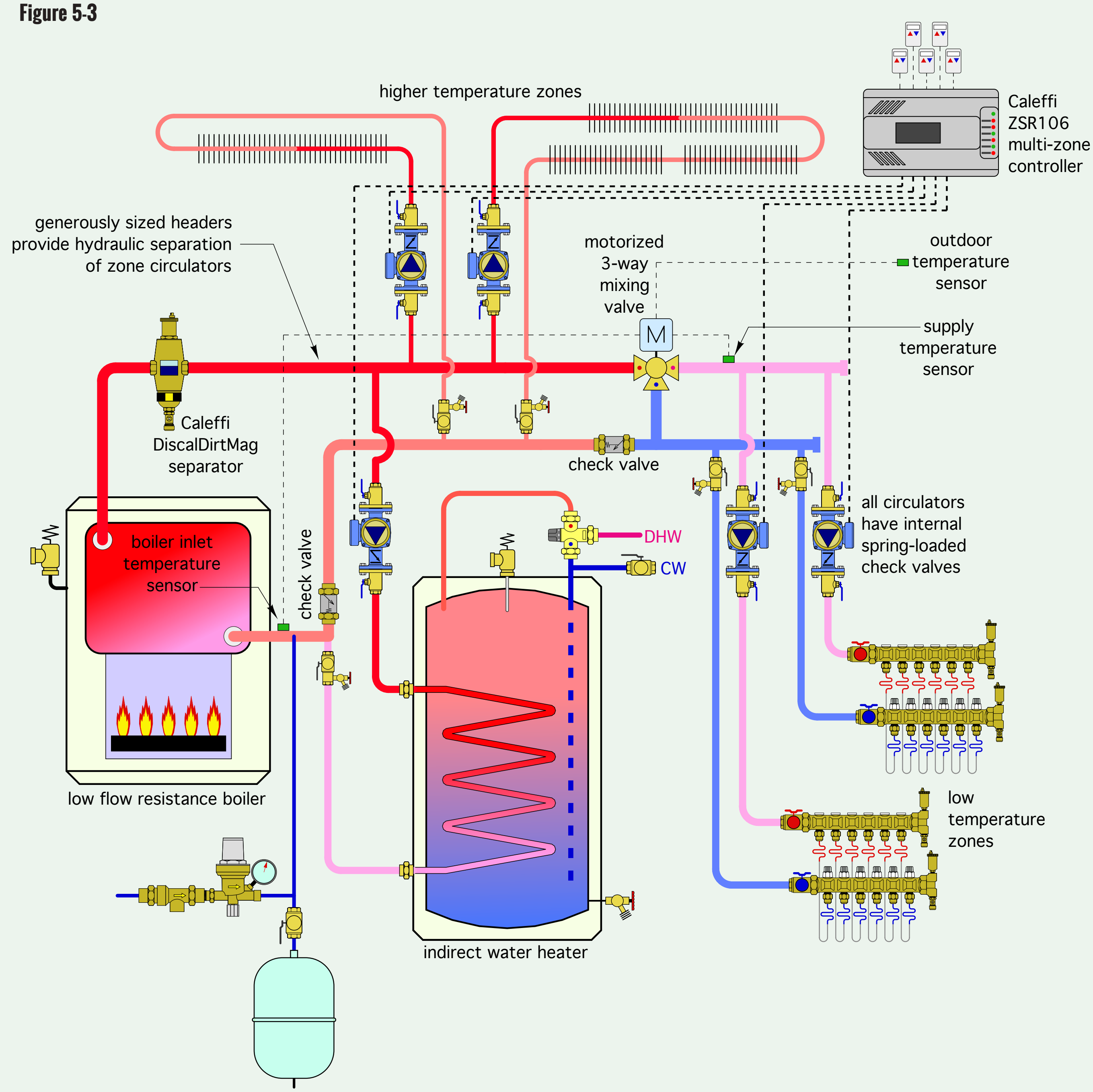
A 3-way motorized mixing valve is used to control the supply water temperature to the radiant panel circuits based on outdoor reset control. The controller operating this mixing valve also monitors the boiler's inlet temperature. When necessary, it reduces hot water flow into the mixing valve to maintain the boiler inlet temperature at or above 130ºF whenever possible. This protects the conventional boiler from sustained flue gas condensation.

Note that a check valve is required on the return side of the low-temperature piping to prevent the possibility of reverse flow through the mixing valve when either of the circulators for the higher-temperature zones are operating. Another check valve is used to minimize heat migration into the return header when the indirect water heater is operating. This is especially helpful in warm weather, when uncontrolled heat loss from piping adds to the building's cooling load.

Domestic hot water is provided by an indirect water heater, which is operated as a priority load. The piping serving the indirect water heater is kept close to the boiler to minimize piping heat loss.

The combination of the low-flow-resistance cast iron boiler and generously sized header piping provides adequate hydraulic separation between simultaneously operating circulators.

Figure 5-3



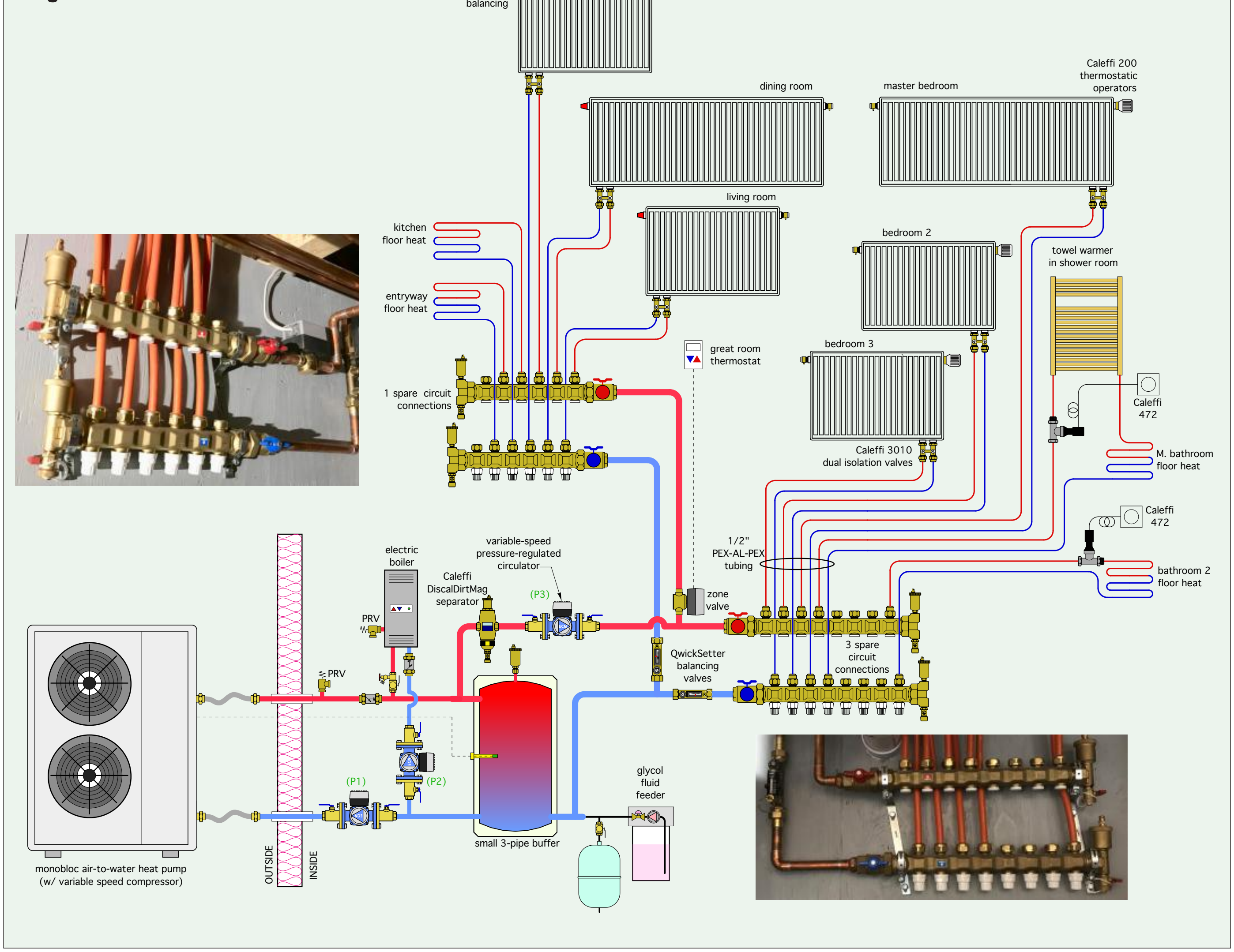
The Caleffi DISCALDIRTMAG™ separator handles all air, dirt and magnetic particle collection for the system.

Purging valves are provided on the return side of each zone circuit and the circuit supplying the indirect water heater.

SYSTEM 4 – MONOBLOC AIR-TO-WATER HEAT PUMP SUPPLIES MULTI-ZONE SYSTEM

The system shown in figure 5-4 is based on a real installation. It uses a monobloc air-to-water heat pump as its primary energy source. An electric boiler is included for supplemental and back up heat if needed. Two homerun distribution subsystems are used to meet specific project zoning requirements.

Figure 5-4



During the heating season, the heat pump continually monitors the temperature of a small buffer tank. The heat pump controls are set to maintain the tank temperature based on outdoor reset control, with an upper temperature limit of 120ºF at design load conditions.

When necessary, the heat pump signals the electric boiler and its associated circulator to operate for supplemental heat input to the buffer tank.

The home this system is installed in has a large open area that includes the kitchen, dining room and living room. This area is treated as a single zone. It's heated by three panel radiators and two floor heating circuits all supplied from a single manifold station, and thus, all operate at the same water temperature. Flow to this manifold station is controlled by a single zone valve operated by an electronic thermostat.

The three bedrooms and two bathrooms are each controlled as separate zones using two types of thermostatic valves. The three bedrooms each have a panel radiator equipped with integral valve regulated by a thermostatic operator. One bathroom has a single floor heating circuit. Flow through that circuit is controlled by a Caleffi 472 thermostatic valve with wall-mounted setting dial. The master bathroom has a towel warmer radiator in the shower area, as well as floor heating. The towel warmer and floor circuit are connected in series and are also controlled by a Caleffi 472 thermostatic operator with a wall-mounted setting dial. The 472 thermostatic operators are mounted to Caleffi 221 radiator valves that can be accessed from the basement.

Flow through the entire distribution system is provided by a single variable-speed pressure-regulated circulator that only requires 44 watts of electrical input when operating at full speed, and often at 20-25 watts under part-load conditions. This circulator operates 24/7 during the heating season.

The entire system operates with a 30% solution of propylene glycol antifreeze. An automatic fluid feeder is used to maintain system pressure.

This system demonstrates that several types of zoning hardware (thermostatic and motorized) can be combined to meet project requirements. It's also a system that could be expanded, initially or in the future, to include chilled water cooling through an air handler, as well as domestic water heating.

SYSTEM 5 – CONVENTIONAL BOILER SUPPLIES MULTI-ZONE SPACE HEATING AND DHW

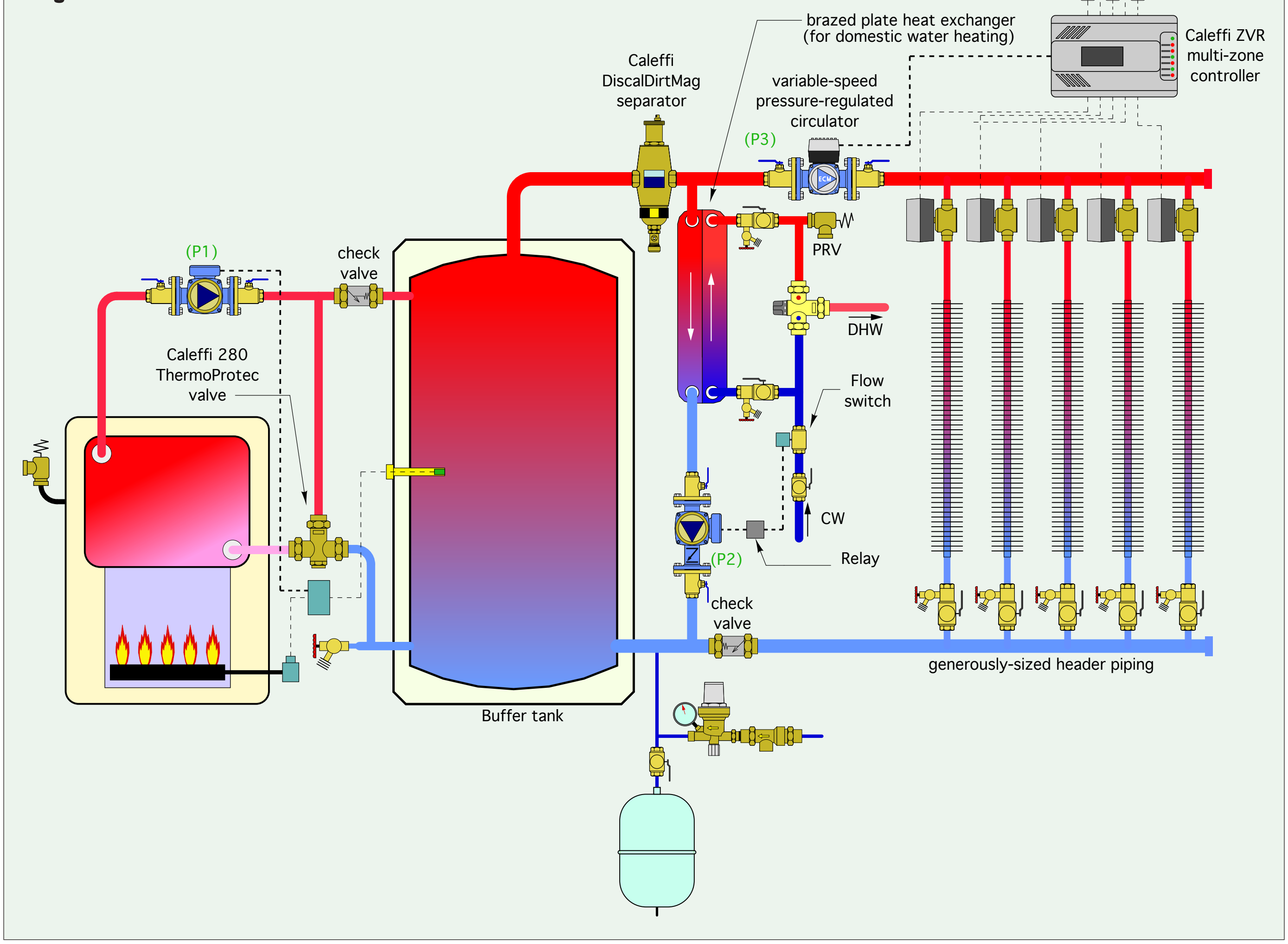
The system in figure 5-5 uses a conventional gas-fired cast iron boiler to supply five zones of high-output fin-tube baseboard. It also includes a brazed plate stainless steel heat exchanger that provides on-demand domestic hot water.

A setpoint temperature controller continually monitors the temperature of the buffer tank. It fires the boiler as necessary to maintain the tank temperature in the range of 120 to 160ºF.

The boiler is protected against sustained flue gas condensation by a Caleffi 280 ThermoProtec™ mixing valve, which keeps the boiler inlet temperature at or above 130ºF whenever possible.

When any of the five space-heating thermostats call for heat, the Caleffi ZVR106 Multi-Zone Valve Control operates the associated zone valve(s) and turns on the variable-speed pressure-regulated circulator. The circulator automatically adjusts its speed to maintain constant differential pressure as the zone valves open and close.

Figure 5-5



The heat emitters are high-output fin-tube baseboard sized to provide design heating load at a supply temperature of 140ºF.

Domestic water is heated “on demand” using heat stored in the thermal mass of the buffer tank. Whenever there’s a draw from a hot water fixture of 0.7 gallon per minute or more, the flow switch closes its contacts to power the coil of a relay, which turns on circulator (P2). Hot water from the upper portion of the buffer tank passes through the primary side of the brazed plate heat exchanger as domestic water passes — in counterflow — through the other side. The heat exchanger has been sized so that it can supply 115ºF domestic water when the input water from the tank is 120ºF. A Caleffi 521 MixCal valve limits domestic hot water delivery temperature to 120ºF.

The heat exchanger is equipped with two combination isolation/flushing valves. These allow the domestic water side of the heat exchanger to be isolated and periodically flushed with a mild acid solution to dissolve and remove possible scaling.

A spring-loaded check valve in the return header minimizes heat migration into space-heating piping during non-heating months when the tank is being heated solely to produce domestic hot water. Another check valve near the upper left piping connection of the buffer tank prevents reverse thermosiphon flow through the boiler when it is off.

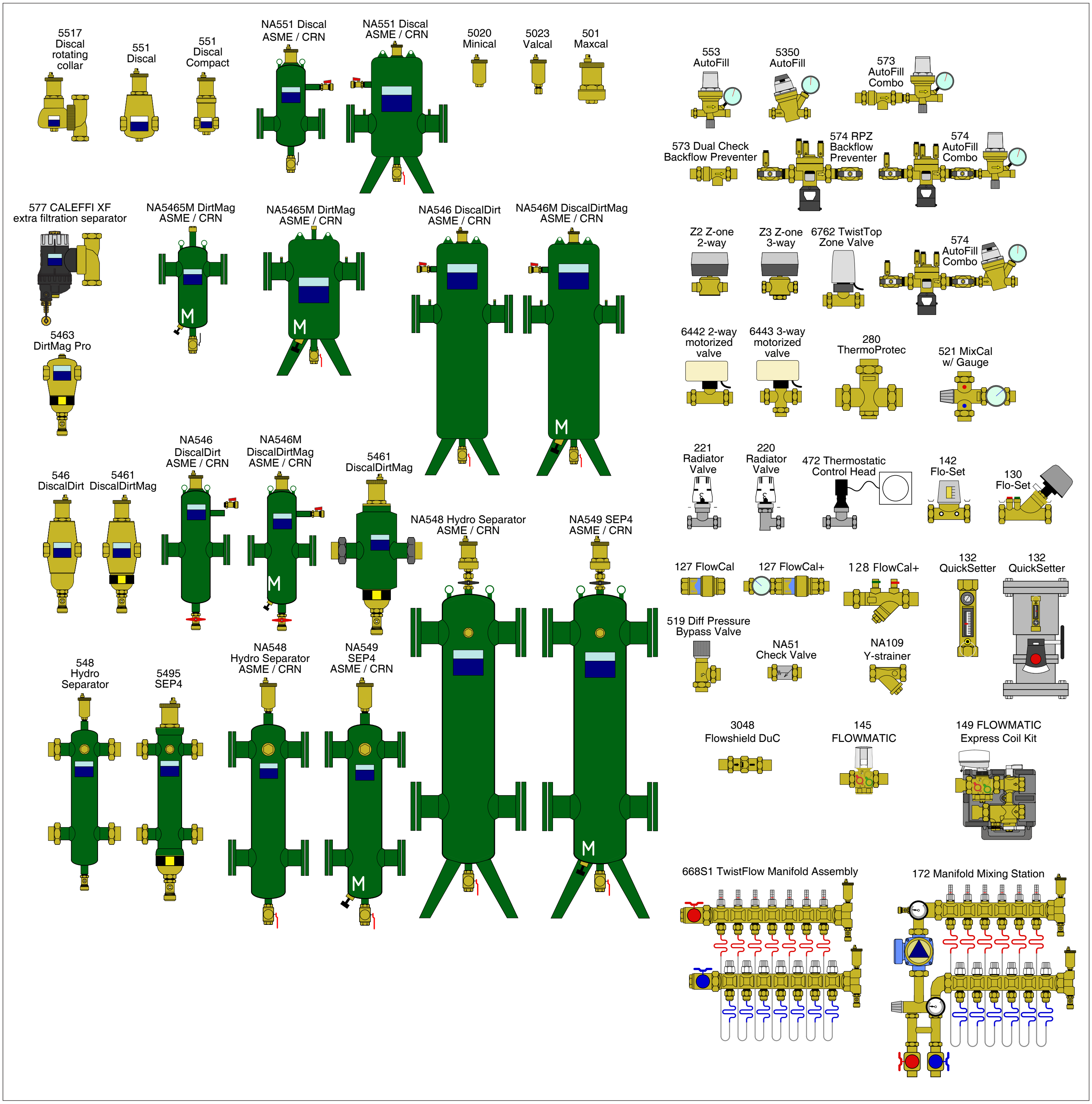
Other details include:

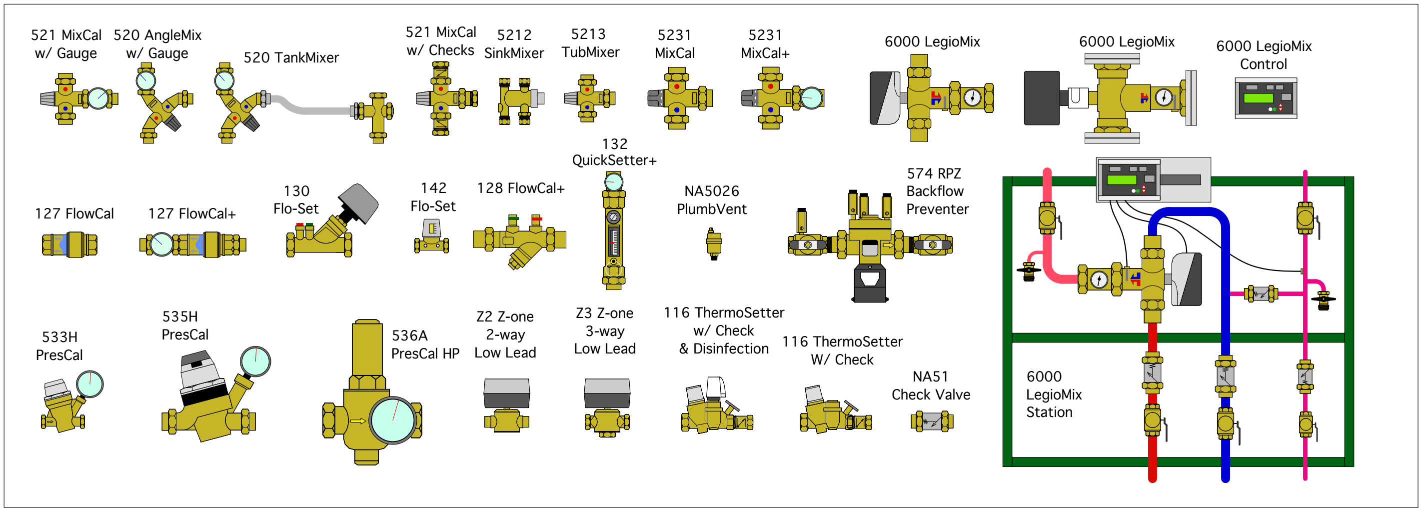
• A Caleffi DISCALDIRTMAG® separator to handle air, dirt and magnetic particle separation.
• Purging valves at the return side of each zone circuit.
• Automatic feed water assembly with pressure-reducing valve and backflow preventer.
• A pressure relief valve on the domestic water side of the heat exchanger.

SUMMARY

The ability to route heating or cooling exactly where it's needed and when it's needed is the "expected" capability for any heating or cooling system. Properly configured hydronic systems have a well-established record for delivering this expectation. The techniques and hardware currently available for hydronic zoning allow each system to be "tailored" to exact project requirements. This issue of *idronics* has shown many examples of these approaches and emphasized where each can be best applied. Hydronic system professionals who take the time to understand these techniques will be ready to apply them over many future projects.

APPENDIX A: CALEFFI HYDRONIC COMPONENTS





521 MixCal w/ Gauge
520 AngleMix w/ Gauge
520 TankMixer
521 MixCal w/ Checks
5212 SinkMixer
5213 TubMixer
5231 MixCal
5231 MixCal+
6000 LegioMix
6000 LegioMix
6000 LegioMix Control
127 FlowCal
127 FlowCal+
130 Flo-Set
142 Flo-Set
128 FlowCal+
132 QuickSetter+
NA5026 PlumbVent
574 RPZ Backflow Preventer
533H PresCal
535H PresCal
536A PresCal HP
Z2 Z-one 2-way Low Lead
Z3 Z-one 3-way Low Lead
116 ThermoSetter w/ Check & Disinfection
116 ThermoSetter W/ Check
NA51 Check Valve
6000 LegioMix Station