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CALEFFI Hydronic Solutions

32

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# Troubleshooting Hydronic Systems

# FROM THE GENERAL MANAGER & CEO

Dear Plumbing and Hydronic Professional,

My Dad loved to troubleshoot. Few things gave him more satisfaction than figuring out a fix to a problem.

A fond memory from a childhood camping trip is him sitting in the boat, chin in hand, staring for what seemed like forever at the cantankerous 20 hp outboard motor tilted up on the stern. The motor usually started with ease, but on this occasion refused to operate. You could sense him pondering “Why, why is this happening?”

He suddenly stood and announced “of course, the float”! Apparently there was a valve inside the gas tank’s float assembly that would stick and starve the engine of gas. He tested this theory by bypassing the float. The engine started up. Yeah! Time to fish!

In retrospect, my dad was not just sitting and staring at the engine. He was thinking about how all the parts of the motor had to work in harmony as a system.

Trouble shooting hydronic systems requires similar thinking. How do the interconnected components work together to produce the desired end result? How can seemingly small changes, such as moving the expansion tank connection from one side of a circulator to the other, immediately correct a longstanding issue with the system’s performance?

This issue of idronics helps guide technicians through the process of troubleshooting many generic performance issues using a systematic approach. It describes common symptoms associated with performance problems, the potential underlying causes of those symptoms, and suggested corrective actions.

We hope you enjoy this issue of *idronics* and encourage you to send us any feedback by e-mailing us at idronics@caleffi.com.

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# 1. INTRODUCTION

In North America, there's an ongoing need for technicians who can diagnose and correct issues with all types of HVAC systems. Labor projections consistently show that this demand will become even more pressing in the future.

Most manufacturers offering "packaged" heating and cooling systems provide product-specific training that covers installation and service issues for their equipment. This is also the case for manufacturers of hydronic heat sources, such as boilers and heat pumps.

However, hydronic heating and cooling *systems* contain hardware from many diverse and independent manufacturers. There are also many viable ways to assemble that hardware, depending on the specifics of the project, budget and capabilities of the devices used. These circumstances create potential performance issues that no manufacturer can necessarily anticipate nor cover in training.

Technicians who have worked with hydronic systems for several years typically gain the knowledge and experience needed to quickly diagnose problems and restore normal operation, but novice technicians lack broad troubleshooting skills, especially when dealing with highly customized systems.

Very few building owners have the background to correctly troubleshoot and maintain the hydronic systems in their buildings. Many are quick to "blame" the system's heat source whenever a comfort issue develops. For example, if the temperature in one area of a house drops below the thermostat setpoint on a cold winter night, a homeowner often assumes that the heat source (boiler, heat pump, etc.) is undersized. They are not necessarily thinking about the overall *system*.

**Figure 1-1**

Experience has shown that many performance issues with hydronic systems are *not* the "fault" of the heat source, but rather how the distribution system interfaces with the heat source, or a lack of proper detailing in parts of the system other than the heat source.

This issue of *idronics* addresses *generic* performance issues with hydronic heating and cooling systems. It does not cover the detailed operation of specific and often complex or proprietary devices, such as boilers, heat pumps or controllers. It does cover issues that commonly occur in a wide range of hydronic systems, and often regardless of the brand of heat source or controllers used. Examples of such issues include flue gas condensation, heat source short cycling, corrosion, insufficient flow, insufficient heat output and lack of hydraulic separation.

This issue begins with a discussion of the physical processes at work in all hydronic systems. These include thermal equilibrium, hydraulic equilibrium and transient versus steady state operation. These processes need to be understood and respected as "inescapable." No person, device or method can circumvent the principles of thermodynamics or fluid mechanics. Technicians who allow these principles to guide their troubleshooting often discover the underlying problems faster than

**Figure 1-2**

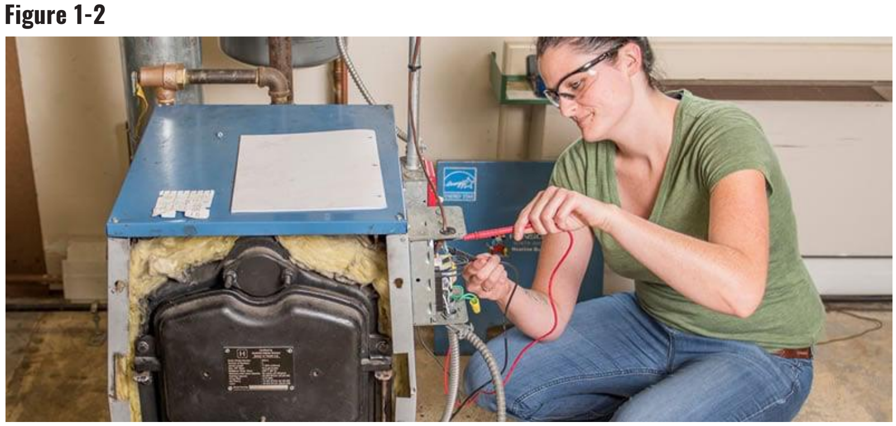
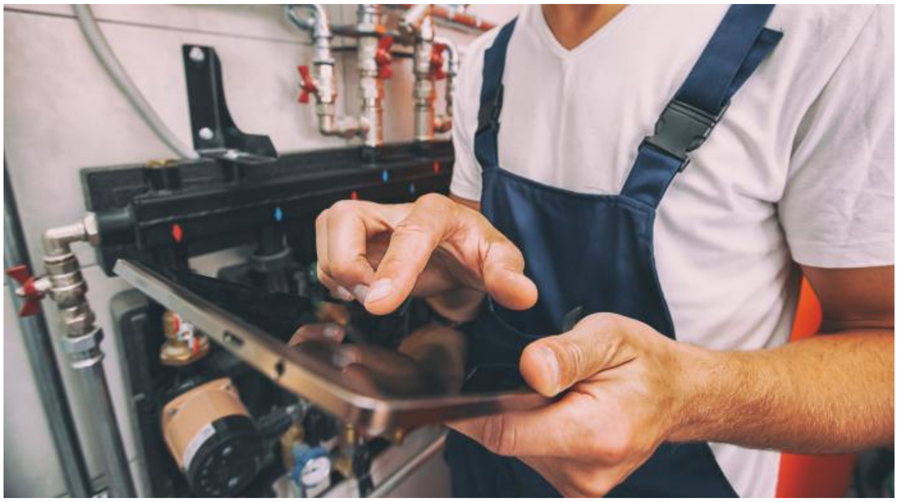


**Figure 1-3**



those who randomly guess about what's wrong with the system.

A sequential process for trouble-shooting residential and light commercial hydronic systems is then presented. That process consists of identifying symptoms, diagnosing one or more likely causes for those symptoms, and following suggested corrective actions to alleviate the problem.

In some cases, the underlying cause of a performance issue could present itself as multiple and wide-ranging symptoms. For example, air in the systems could be the root cause of noise, corrosion or inadequate heat delivery. Those possibilities will be addressed as areas the technician needs to be aware of, and to investigate in the process of solving the performance issue.

This issue concludes with several examples of systems that exhibit multiple performance issues, along with modifications that eliminate those issues.

Several common performance issues, as well as best practices to eliminate or correct those issues, have been covered in previous issues of *idronics*. This issue makes extensive cross reference to those previous issues where appropriate, as sources of more detailed information. PDF files for all previous issues are freely available under the "library" tab at idronics.caleffi.com. Digital access to this journal is also available at this link. The interactive content is fully searchable and is complemented with video and resource links. Readers are encouraged to access the broad base of information available at this website.

# 2. PHYSICAL CONCEPTS THAT AID TROUBLESHOOTING

All hydronic systems are governed by long-established and unchanging physical principles based on thermodynamics and fluid mechanics. Technicians who understand and apply these principles will often correctly identify underlying problems faster and more accurately than those who randomly guess about what's wrong with the system.

### THERMAL EQUILIBRIUM

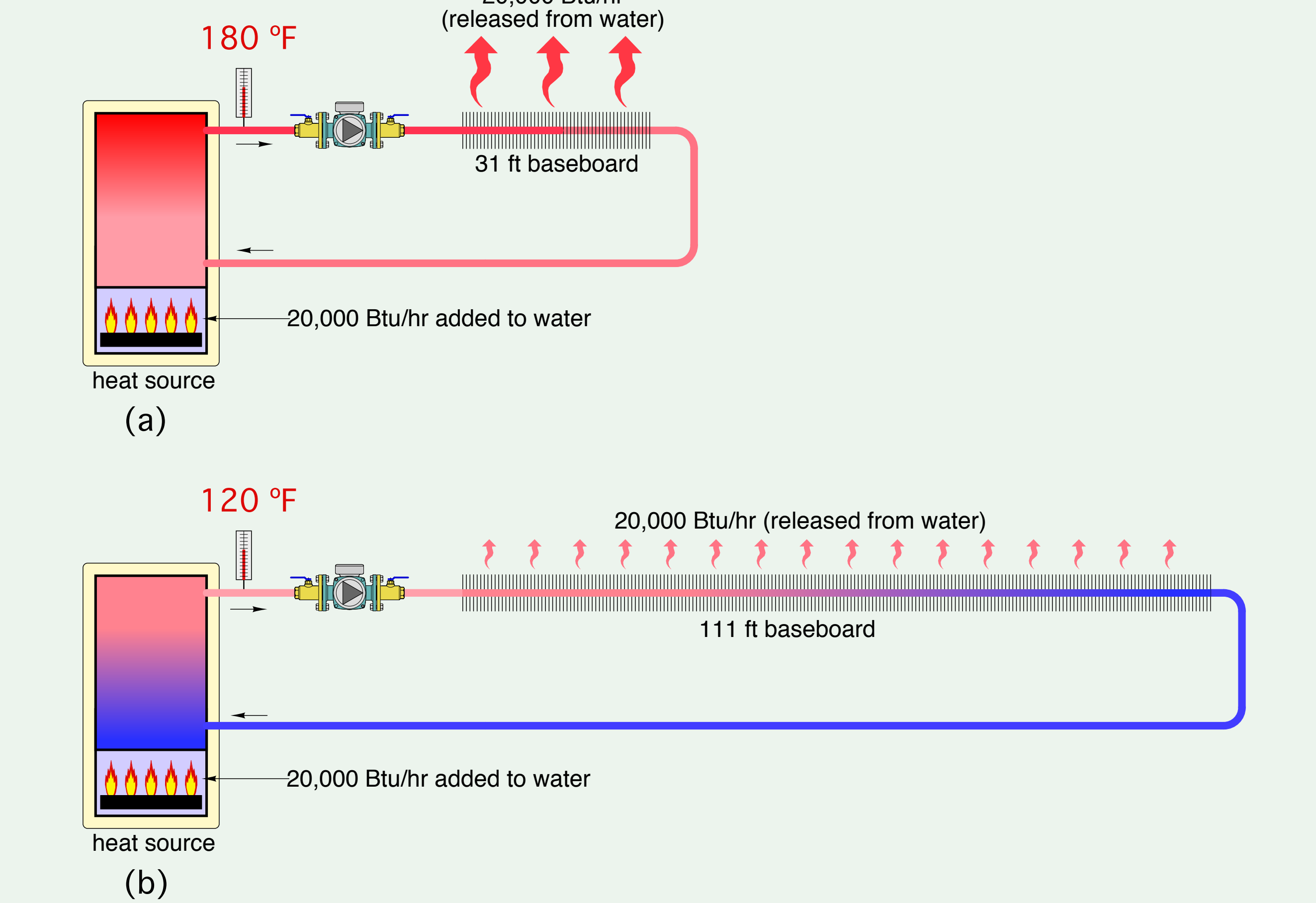
All hydronic heating systems, regardless of size, complexity, materials used, etc., *naturally seek to stabilize their operation at conditions where the rate of heat dissipation from the distribution system equals the rate of heat production at the heat source.* This "balance" between the rates of heat production and heat dissipation is called thermal equilibrium.

The "evidence" that thermal equilibrium exists is stable water temperatures in all parts of the system. For example, the water temperature leaving the boiler might remain stable at 160ºF, likewise, the water temperature entering the boiler may remain stable at 145ºF. The water temperatures in all other parts of the system, regardless of their numerical values, also remain stable. Such stability only occurs when energy input is balanced with energy dissipation.

If not for the intervention of controls within the system, every system would eventually settle to a state of thermal equilibrium. That condition may or may not deliver proper heating to the building. It may or may not produce safe operating conditions. It may or may not allow the heat source to operate at optimal efficiency. Those important considerations "don't matter" when a system is allowed to operate limited only by natural thermodynamic and fluid mechanics principles.

When asked about what controls the water temperature in a hydronic system, many people, including some heating professionals, respond that it's the temperature setting of the controls within the heat source. That answer, while partially true, is also incomplete. The water temperatures in all parts of a system, supplied by a specific heat source,

Figure 2-1



and operating under thermal equilibrium, also depends on the total surface area of all the active heat emitters in the system. This concept is illustrated in Figure 2-1.

Both of the simple hydronic heating systems shown in Figure 2-1 have the same heat source, which imparts heat to the circulating water at a rate of 20,000 Btu/hr. The system in Figure 2-1 (a) has 31 feet of residential fin-tube baseboard as a heat emitter. The system in Figure 2-1 (b) has 111 feet of the same baseboard.

Consider a situation where the heat source's temperature controller in both systems is set very high, perhaps 200ºF, and the circulator in each system is operating at some nominal but realistic flow rate. Also assume that heat loss from the piping connecting the baseboard to the heat source is negligible.

The system in Figure 2-1 (a) will reach thermal equilibrium when the water temperature leaving the heat source is 180ºF. At that condition, the 31 feet of baseboard is dissipating 20,000 Btu/hr. In simple terms, there is *no need* for the water temperature in the system to climb to any higher, and it won't - regardless of the 200ºF setting on the heat source's controller. The water temperature leaving the heat source will only increase to the value where thermal equilibrium is established. <u>Understanding this response is important when diagnosing a system where the water temperature is not reaching the setting of the heat source's temperature controller.</u>

When the heat emitters are changed from 31 to 111 feet of baseboard, the system reaches thermal equilibrium when the water temperature leaving the heat source is 120ºF. *The increased surface area of the heat emitters is solely responsible for this new operating condition.* The fact that the heat source's controller remains set at 200ºF is irrelevant. The water temperature in the system will not climb above 120ºF.

Most hydronic systems, especially older systems, or those with oversized heat sources, *will not reach thermal equilibrium.* After the heat source starts, the water temperature steadily climbs *toward* a thermal equilibrium condition, *but the high limit controller on the heat source typically turns off further heat input before thermal equilibrium is achieved.* This is especially true if the heat source's heating capacity is oversized for the amount of heat emitter present. Assuming that the circulator continues to operate, the water temperature in the system decreases as heat is dissipated from the heat emitters into the space to be heated. When the water temperature has dropped through the operating differential of the controller, the heat source restarts and a similar cycle is likely to occur. Multiple repetitions of this cycle are possible as long as the thermostat in the heated space continues to call for heat.

This cyclic operation of the heat source is very typical. In effect, it results in heat being added to the building in *pulses*, rather than as a continuous (e.g., steady) process. The rate of heat delivery is determined by the output rating of the heat source. The "on-time" of each heat delivery pulse is determined by the thermostat. The total heat added to the space during each pulse is approximately equal to the output rating of the heat source multiplied by the "on-time" of the heat source. The thermal mass of the system helps to "smooth out" this pulsed heat input effect, which often makes it less noticeable to occupants. Tens of thousands of North American hydronic heating systems operate this way, and in most cases, it is acceptable.

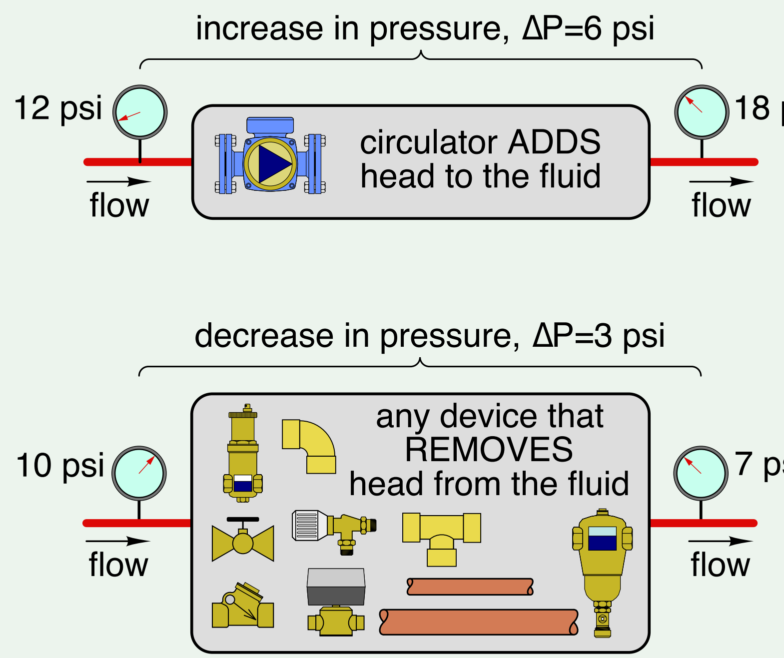
The fact that many systems don't reach thermal equilibrium is good in the sense that it doesn't allow the water in the system to climb to dangerously high temperatures. For example, if the heat source capacity in Figure 2-1 was doubled to 40,000 Btu/hr, and the same 31 feet of baseboard remained, the water temperature leaving the boiler would have to climb above 250ºF in order for the system to reach thermal equilibrium. While this condition is theoretically possible using a pressurized closed-loop system, it is risky from a safety standpoint. Water at that temperature will instantly flash to steam if the pressure is lost, and the result could be a devastating explosion. Although this modified system will consistently *attempt* to achieve thermal equilibrium, that attempt will be "cut short" by the system's temperature limiting controllers.

The concept of thermal equilibrium helps designers and technicians understand what the system "wants to do." It explains why some systems do not operate at the water temperature set on the heat source limit controller. It also implies what's possible if the temperature limiting controls on the heat source failed, and thus, the justification for a secondary controller, such as a manual reset high limit.

## HYDRAULIC EQUILIBRIUM

Just as all hydronic systems seek to operate with a balance between thermal energy input and thermal energy dissipation, they also seek to operate with a balance between *mechanical* energy input and dissipation. The mechanical energy input to the system's fluid is provided by one or more circulators. The mechanical energy dissipation is caused by friction between the moving fluid molecules, as well as between those molecules and the internal surfaces of components such as piping, valves and heat exchangers.

Figure 2-2




The mechanical energy imparted to the fluid in a hydronic system by a circulator is called "head." The units for head energy are (ft•lb/lb). The unit of ft•lb (pronounced "foot pound") is a unit of *energy*. As such, it can be converted to any other unit of energy, such as a Btu. Thus, head can be interpreted as the number of ft•lbs of mechanical energy imparted to each lb of fluid passing though the circulator. However, engineers long ago chose to cancel the units of pounds (lb) in the numerator and denominator of this ratio, and express head in the sole remaining unit of *feet*. To make a distinction between feet as a unit of distance and feet as a unit of fluid energy, the latter can be stated as *feet of head*.

When head energy is added to or removed from a liquid in a closed-loop piping system, there will always be an associated change in the pressure of that fluid. Just as a change in temperature is "evidence" of a gain or loss of thermal energy, a change in pressure is evidence of a gain or loss in head energy. When head is lost, pressure decreases. When head is added, pressure increases. This concept is illustrated in Figure 2-2.

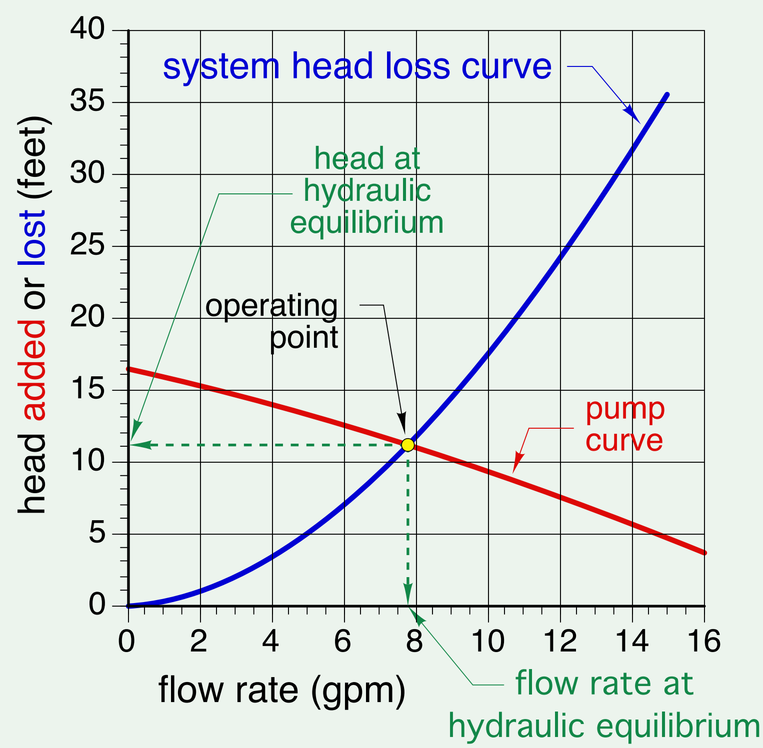
It's possible to predict the flow rate that will develop when in a specific circulator is installed in a specific hydronic circuit. *That flow rate will be such that the head energy added by the circulator is exactly the same as the head energy dissipated by the piping circuit.* This condition is called "hydraulic equilibrium."

The flow rate at hydraulic equilibrium is found by plotting the head loss curve of the hydronic circuit on the same graph as the pump curve for the circulator. An example of this is shown in Figure 2-3.

The point where the head loss curve of the hydronic circuit crosses the pump curve of the circulator is called the "operating point." This is where hydraulic equilibrium occurs.

The flow rate in the circuit at hydraulic

Figure 2-3



equilibrium is found by drawing a vertical line from the operating point down to the horizontal axis. The head input by the circulator (or head loss by the piping system) can be found by extending a horizontal line from the operating point to the vertical axis.

**For more detailed information on hydraulic equilibrium, as well as system head curves and pump curves, see idronics #16.**

*All hydronic systems reach hydraulic equilibrium within a few seconds of a circulator starting.* Flow rate increases during those initial seconds and stabilizes at a value that results in hydraulic equilibrium.

Once established, the system will remain at the flow rate corresponding to hydraulic equilibrium *unless* something occurs that affects either the head loss curve or the pump curve.

Examples of what could change the circuit head loss curve include:
- The type of fluid in the circuit changes.
- The temperature of the fluid changes.
- Changes are made to the pipe type, pipe size or to the components in the piping circuit.
- Valve settings are changed.

Examples of what could change the pump curve include:
- Change to a different circulator.
- Change the circulator to a different speed setting.
- Altering the circulator's impeller.

Technicians who are troubleshooting flow-related issues in a hydronic system need to understand (and appreciate) the concept of hydraulic equilibrium. For example, if the flow rate is below some anticipated value, the head energy imparted by the circulator may be too low, or the head loss created by the system's piping components may be too high, or both. Anything that decreases the head dissipation ability of the circuit, such as larger piping, short piping lengths, valves with higher Cv ratings, less fittings, etc., will typically shift hydraulic equilibrium to a higher flow rate, and vice versa.

## STEADY STATE VS. TRANSIENT OPERATION

When hydronic systems are planned, and components in those systems are selected, it's customary to assume a situation called "design conditions." The building being heated is assumed to be surrounded by air at or very close to the coldest expected winter temperature, and thus the building's heating load is at or very close to some maximum value, which is estimated based on heating load calculations.

The hydronic system in the building is assumed to be operating continuously (e.g., steady state) to deliver heat to all conditioned spaces so that they are maintained at some specified air temperature. That temperature is typically in the range of 68 to 72ºF for residential buildings or other buildings where humans are wearing "normal" winter clothing and participating in light activity, and 60-65ºF for industrial, shop or other types of buildings where occupants are more heavily clothed or working at higher activity levels.

The heat source, circulators, heat emitters, piping and all other components in the system are selected under the possible (but unlikely) scenario that design load conditions could persist for days on end, until the outdoor temperature eventually moderates. The underlying goal is to prevent uncomfortable conditions regardless of the duration of design load conditions.

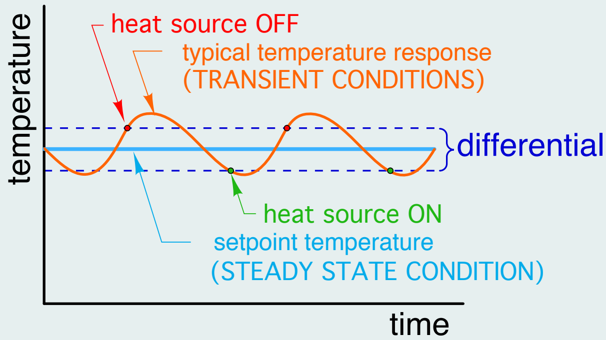
While this design approach is "conservative" in one sense, it's also unrealistic in terms of how a hydronic system operates during the majority of a typical heating season. Systems that have components sized and selected to handle design load conditions will not operate continuously over most of the heating system when heating loads are less (often far less) than design load values. Instead, most of the devices in the system will turn on and off several times every day, and sometimes several times every hour, to prevent overheating during partial load conditions. This behavior is called "transient" system operation.

Under common transient conditions, the water temperature leaving a heat source will change almost continuously, and flow rates in various portions of the system might also change as different zone circuits turn on and off, or valves modulate.

Figure 2-4 illustrates a typical transient boiler water temperature versus time graph, compared to a (theoretical) steady state temperature condition. The boiler fires when its leaving water temperature has dropped slightly below some setpoint temperature (represented by the green dots). The boiler turns off when its leaving water temperature is slightly above this setpoint (represented by the red dots).

In a theoretically "ideal" system, the water temperature leaving the boiler would remain perfectly stable at the setpoint value as time elapses. This would be a true steady state condition. In a "real" system, the boiler's leaving water temperature is usually increasing and decreasing

**Figure 2-4**




based on the differential setting of the boiler's temperature controller. Over several firing cycles, and assuming that heat dissipation by the load is stable, the *average* water temperature leaving the boiler should be close to the value represented by the steady state line.

If a technician happened to measure the water temperature at the instant the burner turned off, that temperature would only exist for a moment. A few seconds later, the temperature could be slightly higher due to control overshoot. A few more seconds later, the temperature would be less as heat is dissipated from the water.

The simple graph in Figure 2-4 doesn't show what are likely to be even more complex transient temperature variations caused by longer periods when the boiler is off, or sudden changes in boiler temperature when a cold zone circuit first activates.

A technician who is troubleshooting a system that is operating under transient conditions needs to realize that the temperatures, flow rates, electrical currents, etc., that they read from instruments at some moment in time are just a "snapshot" of overall system operation, and may or may not point to a problem. For example, if the high limit controller on a heat source is set for 180ºF, and the measured water temperature leaving the heat source at some moment is 140ºF, that difference doesn't necessarily mean that "something is wrong" with the heat source. Perhaps the heat source was just turned on from being off for several hours. Or maybe a zone circuit just turned on and a slug of cool water just entered the heat source.

Hydronic systems are typically "moving targets" in terms of acquiring performance data that's to be used to determine what changes or service procedures need to be made. Technicians need to be careful about drawing rapid conclusions based on observing a system operated for only one or two minutes. In some systems, several minutes of observation may be necessary to determine if all the intended coordination of devices is occurring.

# 3. TROUBLESHOOTING PROCESS

All modern hydronic heating systems provide three basic functions:

1. Converting the chemical energy in a fuel (or electrical energy) into heat and imparting that heat to water or to a water-based fluid. Boilers of many different configurations and sizes are the component where this conversion occurs.

2. Converting electric energy into mechanical energy called head and imparting that energy to the system's fluid. The circulators in a hydronic system enable this conversion process.

3. Transporting a fluid that now contains both thermal and mechanical energy to where that energy is needed to maintain comfort in a building.

Hydronic cooling systems have similar energy flows, only from the conditioned space back to the device providing the chilled water.

Fundamentally, troubleshooting a hydronic heating system is a matter of verifying that these processes are occurring, in a pre-established sequence, and in an expected manner, starting at the fuel supply and tracing the process all the way to the level of comfort present in the building. The root cause of a performance issue is often discovered when one of the steps in the planned flow of energy from source to end use is interrupted or impared. That interruption or impairment could be caused by a physical failure of some component, or by improper selection, installation, maintenance or adjustment of a component.

When the underlying cause of a problem is not "obvious," it's important to maintain a sequential approach to troubleshooting, rather than taking random guesses as to what might be causing the problem. For example, it makes no sense to remove and replace a circulator that's not working as expected, only to later find out that the thermostat controlling that circulator had dead batteries, or has been unintentionally turned off. There's little doubt that such random approaches to troubleshooting have occurred and continue to occur. Even if the underlying problem is eventually discovered and corrected, the time and expense associated with needless "tinkering" with the system frustrates all those involved.

In some cases, the cause of improper operation is immediately apparent. For example, if the technician walks into a mechanical room and water is spraying out of the side of a boiler or from some other component, it's obvious that at least that component is not in a normal state. Likewise, any trace of smoke or burning odor coming from an electrical component is not normal and implies service is necessary — perhaps immediately.

These abnormal situations are often the easiest to diagnose and correct. In some cases, they are caused by a failure of the component due to manufacturing defects. In other cases, the underlying cause of the failure is due to improper application, lack of maintenance, improper adjustment, uncontrollable external conditions such as electrical voltage spikes, brownouts, or even vermin chewing on piping, insulation or wiring.

Troubleshooting becomes more challenging in situations where the underlying problem is not obvious. Perhaps the owner states that the temperature in one bedroom seems to fluctuate but under no apparent recurring pattern. Another complaint might be that some "weird noise" occasionally seems to come from the mechanical room. Still another would be that the system's pressure relief valve drips water on every cold winter morning but is otherwise fine.

The steps that follow are meant to guide a reasonably competent technician who is trying to correct an issue with a typical zoned hydronic heating system with which they have no previous experience.

### <u>STEP 1</u>: Learn what the system is supposed to do and how it is operated by the occupants. Ask questions.

This initial step is important and often overlooked. It makes no sense to try to correct what someone might perceive as a problem, when the system is actually performing just as its designer intended.

For example, a complaint might be that some spaces in a building cool slightly below their set comfort level at some repeatable times in morning and early evening but are otherwise fine. The underlying cause could be an indirect water heater that has been configured as the "priority" load in the system. When a call for domestic water heating occurs, all space-heating zones are temporarily and automatically turned off, in some cases for up to 30 minutes, by the system's controller(s). The lack of heat input during that time might allow some spaces to cool slightly below normal. Be that as it may, the system is performing as intended, at least based on the settings made by the last person to configure the system's controls. If that performance is unacceptable to the owner, a simple setting change on a controller could correct the issue.

*<u>When first examining an unfamiliar system, technicians should also ask the building owner or maintenance personnel</u>*

*if there is documentation for the system.* Did the designer or installer create a piping and electrical schematic? Did the installer create a sequence of operation for the system? Are there installation and operation (I/O) manuals for the major components, perhaps organized into a binder in the mechanical room? This type of documentation can help quickly clarify the intended operation of the system.

**For more detailed information on documenting hydronic systems, see idronics #20.**

It's also important to ask the building occupants how they operate and maintain the system. Don't make assumptions.

**Figure 3-1**

Some possible inquiries include:

• Do they use thermostat setbacks at night or for other extended periods? What type of temperature/time programming do they use with their programable thermostats?

• Do they use large amounts of domestic hot water at certain times of the day that might coincide with a drop in space-heating comfort?

• Do they run ventilation fans or open windows for fresh air during winter?

• What type of routine maintenance do they perform (or have others perform) on the system? Are there records of that maintenance and who performed it?

• If a garage is occasionally heated by the system that also heats the house, how often is it heated, and to what temperature?

• Have any carbon monoxide or smoke detectors in the vicinity of the mechanical room ever sounded an alarm?

• Have there been any recent power outages, voltage spikes, brownouts, loss of building water pressure, seismic events or close thunderstorms prior to a problem developing with the system?

• Has anyone other than the owner or occupant had access to the mechanical room?

• Have there been any recent modifications to the system?

• Have any chemicals been added to the water in the system?

• Have there been any paints, pool chemicals, laundry detergents/bleaches or other chemicals stored in the mechanical room.

• Have they seen, heard or smelled anything unusual as the system operates, such as water on the floor, error codes on displays, abnormal sounds or odors associated with fuel, flue gases or electrical overloads?

Few building owners would intentionally avoid disclosing information that might lead to the underlying cause of problems with their system. However, many don't realize that something that they may have observed *could be* the underlying cause. The more information the technician can gather "up front," the faster they are likely to zero in on the cause of the problem.

## STEP 2: Write down or otherwise record all current controller settings.

In some situations, a performance issue can be partially or fully resolved by changing one or more settings on system controllers. However, making random adjustments to controller settings can quickly lead to problems, especially if the original settings need to be restored and the person making the adjustments doesn't remember what those settings were.

To avoid this problem technicians should take the time to write down or otherwise record all controller settings "as found." Furthermore, any changes to a controller setting should be documented with the "as found" setting, date the setting was changed, who changed the setting, and the revised setting.

Technicians should also record the "as found" pressures and temperatures for the system.

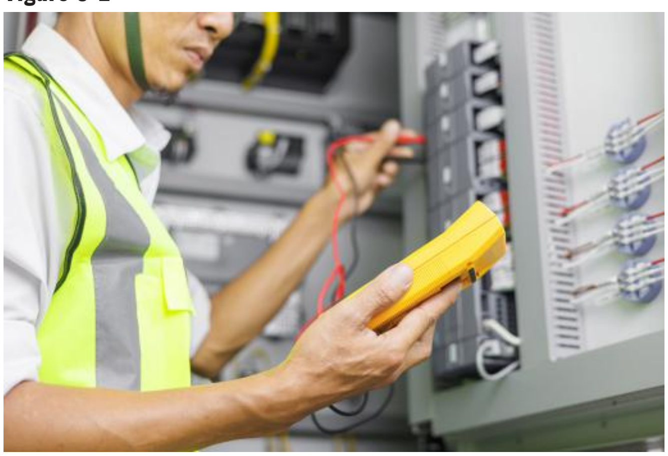
The troubleshooting steps that follow should also be considered before making adjustments to controller settings.

## STEP 3. Verify that electrical power and fuel are available to the system.

This step helps to eliminate the possibility that the problem is lack of available fuel or electricity to operate the system.

Verify that fuel oil, natural gas, propane, electricity or other fuel is available at the heat source. Is there fuel in any associated storage tank? Are all fuel shutoff valves open? Are all associated electrical circuit breakers or disconnects closed? Keep in mind that a closed circuit breaker or disconnect *is not a guarantee* that electrical power is available at the heat source. Use a multimeter to verify that line voltage is available at the power input terminals of the heat source. If it's not, work backward on the electrical supply circuit to find the issue.

**Figure 3-2**



## STEP 4. Verify that all thermostats are functioning properly.

Most heating and cooling thermostats operate on 24 VAC. They enable the heat source to operate. They also "call" for their associated zone to operate.

Verify that the thermostat being tested is set to heat mode. If the thermostat uses batteries, verify that the low battery indicator is not on. If the thermostat has multiple time/temperature settings, adjust it to temporarily override those settings. Adjust the temperature setting to a high "test temperature" of 80ºF or more to ensure that it should be calling for heating operation.

**Figure 3-3**

If the thermostat has an "R" and a "C" terminal, and electrical power to the system is on, there should be a nominal 24 VAC voltage between these terminals. If not, check the transformer that supplies power to the thermostat. Also check for any loose wires on the baseplate of the thermostat, and for any bent or broken pins that connect the front of the thermostat to the baseplate.

Most heating thermostats that are wired directly to a boiler enable boiler operation by closing an isolated electrical contact between the "R" and "W" terminals. in this case, a jumper wire temporarily installed between these terminals on the thermostat will simulate a call for heat, and thus, allow the system's response to a call for heat to be evaluated.

Thermostats used to directly enable heat pump operation (e.g., thermostat is wired directly to the heat pump) typically close an isolated electrical contact between the "R" or "RH" terminals and the "Y" terminal. *Always check the documentation for the thermostat to verify the terminal designations used to call for heating or cooling before using jumpers*.

## STEP 5. Verify that the heat source is *enabled* to operate whenever one or more zone thermostats are calling for heat.

Most hydronic heat sources are enabled to operate when electricity can pass through an external circuit connected to two terminals on the heat source. Some boilers label these terminals as "T" and "T". Some heat pumps label the two terminals as "R" and "Y." Although the labelling is typical, it is not universal. *Always verify which terminals a specific heat source uses to enable its operation.* Check the electrical section in the product's installation/operating manual.

Before attempting to enable heat source operation, verify that suitable voltage is available to the line voltage input terminals on the heat source. If no voltage is detected, work backward through all the safety devices present between the circuit breaker panel and the electrical input terminals of the heat source. This includes the circuit breaker, manual-reset high-limit controller (if present), low water cut-off device (if present), service switch or any other safety device.

Enabling of the heat source can typically be tested by installing a jumper wire across the two terminals mentioned previously. Assuming line voltage is available to the heat source, some action should occur as soon as the jumper is installed. It could be the click of a relay, an indicator light turning on, a motor starting or a change in status on the device's display, or combinations of these actions.

*The electrical enablement of the heat source is not a guarantee that the heat source immediately begins producing heat* (e.g., the burner ignites, or the compressor starts). For example, if the water temperature in a boiler is between the high limit temperature and the high limit temperature minus its controller's differential setting, the burner will not fire until the water cools through the differential. Likewise, a heat pump may not immediately start its compressor if the pressure in the refrigeration system is high, and a time delay is required to equalize refrigerant pressure. The latter process typically requires two to three minutes. Most heat pumps have internal time delay circuits to ensure that this process takes place before allowing the compressor to restart.

If the heat source operation has been enabled, and it fails to start after a reasonable time delay of several minutes, it should be tested according to its manufacturer's troubleshooting procedure. There could be several underlying causes for failure to start, including failure of some internal component, blown internal fuse, tripped internal circuit breaker, firmware settings, a faulty sensor or a sensor detecting some out-of-range temperature or pressure.

If the heat source is operating, and has been operating steadily for at least five minutes, (e.g., is at or near a steady state condition) measure the supply water temperature. Is that temperature reasonable in comparison to the settings of the controller(s) that turn the heat source on and off? Does the water temperature leaving the heat source continue to increase toward the high-temperature limit setting?

If outdoor reset control is being used to operate the boiler, the expected (e.g., "target") supply water temperature depends on the current outdoor temperature and the settings of the boiler reset controller. The target supply water temperature of the boiler reset control can be estimated using Formula 3-1.

**Formula 3-1**

$$T_{\text{target}} = T_{inside} + RR(T_{inside} - T_{outside})$$

Where:
$T_{\text{target}}$ = Target supply water temperature (ºF)
$T_{\text{inside}}$ = Desired inside air temperature (ºF)
RR = reset ration set on controller
$T_{\text{outside}}$ = outside air temperature (ºF)

For example: When the desired indoor air temperature set on the reset controller is
70ºF, and the reset ratio set on the controller is 0.4, and the outdoor air temperature is 10ºF, the target supply water temperature should be:

$$T_{\text{target}} = T_{inside} + RR(T_{inside} - T_{outside}) = 70 + 0.4(70-10) = 94^{\circ} F$$

If the water temperature leaving the boiler under these conditions was within +/-10ºF of the target temperature, the boiler is likely functioning correctly. Keep in mind that boilers with on/off burners must have a differential temperature between "burner on" and "burner off" conditions. If the boiler reset controller were set for a differential of 10ºF, and the target supply water temperature is calculated as 94ºF, the burner should turn on when the water temperature leaving the boiler is 94 – (10/2) = 89ºF, and the burner should shut off when the water temperature leaving the boiler is 94 + (10/2) = 99ºF.

Always check all settings on any controller(s) associated with operating the heat source and see if the burner or compressor is responding in accordance with those settings.

If the water temperature leaving a heat source *that is operating at or close to steady state conditions* is not within a reasonable deviation of the heat source's controller settings, there may be an internal issue with the heat source. Keep in mind that steady state operation is not as common as transient operation, where the heat source is warming from a cool start, or when a sudden influx of cool water from a recently activated zone circuit occurs. Technicians need to assess if any deviation from expected supply water temperature is the result of a transient condition, or the result of some other issue such as undersizing, faulty fuel supply, or a low refrigerant charge in heat pumps.

### STEP 6: Check that zone control devices are operating.

For zone valve systems, check that each zone valve opens when its associated thermostat is calling for heat. Keep in mind that some zone valves or manifold valve actuators that use *thermal motors* can require up to three minutes to fully open after receiving 24 VAC power through a thermostat. If power is available at the zone valve and manifold valve actuator, and the valve fails to open, the actuator is likely the source of the problem and will need to be replaced.

Many zone valves and manifold valve actuators contain isolated end switches that close when the zone valve or manifold valve actuator reaches its fully open state. The closed end switch is typically used to signal that the circulator should turn on and the heat source should be enabled to operate.

For systems using zone circulators, check that the circulator associated with the thermostat being tested turns on. If not, verify if line voltage is present at the circulator when it is being called to operate. Be sure that all wiring connections to the circulator are correct and tight. If line voltage is present, and the circulator is not operating, it has likely failed in some manner. If line voltage is not present when the zone circulator is called to operate, work backward through the wiring and devices that supply line voltage to the circulator until the lack of line voltage is found.

**For more detailed information on zoning and how zone valves or zone circulators are wired, see *idronics* #14.**

Possible causes for failure of zone valves or zone circulators include:

• Lack of line voltage to devices due to open or defective circuit breakers, fuses or a disconnect.
• Lack of 24 VAC output from the transformer supplying zone valves or manifold valve actuators.
• Loose or incorrect wiring connections.
• Failure of a relay that supplies line voltage to a zone circulator.
• A blown fuse in the zone control panel.
• An error code displayed on the thermostat.
• Shorted or broken wiring from the thermostat to the remainder of the system.

### STEP 7: Verify that there is not excessive air in the system.

All closed-loop hydronic systems are intended to operate with insignificant amounts of air mixed with water. When excessive air is present, the system's circulator(s) will not provide proper flow. There will likely be gurgling or swishing sounds in the piping, especially within the circulator, which is an immediate clue to the troubleshooter that an air issue is present. There might even be an "air binding" condition, where a large amount of air collects in higher portions of the system and completely blocks flow.

Modern methods for eliminating air from a system involve two concepts:
1. Forced water purging to eliminate bulk air.
2. Use of a microbubble air separator to capture and eject initially dissolved air.

Forced water purging relies on high-speed water flow through piping from some external pressure source (i.e., a hose connected to a pressurized water system, or a purging pump). The water is forced through the system to push bulk air ahead of it and eventually out the side port of a purging valve. This step is especially important when commissioning a new system, or when filling a system that has been substantially drained for service. Forced water purging eliminates the vast majority of the air from the system.

Microbubble air separation can be thought of as an *ongoing process* for capturing smaller residual amounts of air in the system, especially air that is present as dissolved gas molecules (e.g., oxygen, nitrogen, etc.). It's done using one of several high-efficiency air-separating devices, such as the Caleffi DISCAL or SEP4 separators. These devices are designed to encourage dissolved gas molecules to coalesce into tiny bubbles that can then be captured, routed to an automatic air vent at the top of the separator, and ejected from the system by internal water pressure.

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

Recurring air problems are often the result of improperly designed, installed or maintained systems. Causes of recurring air problems include:

- Improper placement of the expansion tank relative to the circulators.
- Insufficient static pressure in the system.
- Anything that causes a sub-atmospheric pressure at the location of a float-type air vent.
- Loose valve packings or circulator flange gaskets.
- Lack of backflow prevention, combined with a drop in plumbing system pressure.
- A clogged screen on a feed water valve, allowing system pressure to drop to a point where a slight vacuum develops at the high points of the piping.
- The feed water system is completely turned off, preventing any water from entering the system to make up for minor water losses.
- A waterlogged expansion tank that allows a negative pressure to occur in the system when the water cools.
- Unnecessary draining and refilling of the system. Adding "fresh" water to a closed-loop system on a periodic basis is not necessary or beneficial.
- Use of polymer tubing without an oxygen barrier.

The suggested procedure for correcting air problems in existing system is as follows:

1. For hydronic systems connected to cold water plumbing, verify that the screen in the feed water valve is not clogged and that any valves needed for makeup water to enter the system are on.

2. Ensure that the water pressure in a system serving a low-rise building (three stories or less) is at least 12 psi in the mechanical room. If it's not, boost the pressure in the system.

3. Look for any signs of leakage or weepage, such as water stains on the floor or piping components, or buckets placed under the discharge piping from a pressure relief valve. Correct any such leaks, snug valve packings or circulator flanges that show evidence of weepage.

4. Check the location of the system's expansion tank relative to its circulator(s). The expansion tank should connect near the circulator inlet. This allows the differential pressure developed by the circulator to add to system pressure.

**See idronics issues #12 and #16 for more information on proper placement of expansion tanks.**

If the expansion tank is located near the outlet of the circulator(s), it should be relocated because it can be the underlying cause of the recurring air problem.

5. Check to see if the system's air separator is working. Old-style "air scoop" separators provide marginal performance. Modern microbubble air separators, such as the Caleffi DISCAL, provide high-efficiency air separation. On systems with recurring air issues, consider replacement of air scoop separators with microbubble separators.

6. If the system exhibits signs of significant internal air, use forced water purging to eliminate as much of the bulk air as possible.

**See idronics #15 for more detailed information on forced water purging.**

## STEP 8: Attempt to determine the flow rate in each active zone circuit.

If each circuit is equipped with a device such as a Caleffi Quicksetter valve (seen in Figure 3-4), a flowmeter or a circulator with a digital display, the flow rate can be read directly. If balancing valves with pressure tappings are present, and a compatible manometer is available, the

**Figure 3-4**

flow rate can be estimated based on the pressure drop across the balancing valve.

There is no specific flow rate that a hydronic circuit *must* operate at for correct heat transport. Flow rates of approximately one gallon per minute per 10,000 Btu/hr of expected heat transport rate are typical. That flow rate will produce a temperature drop of about 20ºF between the supply and return side of the circuit *when the supply water temperature is at or close to its design load value.* Slightly higher flow rates are fine, provided they do not create flow noise or pipe erosion. For copper tubing, the suggested maximum flow rate for piping routed through occupied spaces is four feet per second. To avoid erosion in copper tubing, the flow velocity should not exceed six feet per second.

Keep in mind that even though the system may operate at a temperature drop of approximately 20ºF under design load conditions (e.g., when supplied with water at the design load temperature), it will operate at lower temperature drops when the water temperature supplied to the heat emitters is lower than the design load value, such as when the supply water temperature is regulated by outdoor reset control.

One sign of an insufficient flow rate is a high temperature drop between the supply and return side of a circuit. When the supply water temperature is near design conditions, a temperature drop over 25ºF is generally an indicator of insufficient flow rate.

Insufficient flow could be caused by several things, including:
• The circulator is too small, or the circulator speed setting is too low.
• A zone valve has failed to open.
• A mixing valve with a low Cv is present in the flow path.
• One or more valves in the circuit are partially shut.
• A filter, strainer or other component in the circuit is clogged with debris.
• The circuit was not installed as designed, and now contains significantly more fittings or other devices — especially when all such fittings and devices are piped in series.
• In extreme cold conditions, it's possible that water in some portion of the circuit is frozen, creating a flow blockage.

## <u>STEP 9</u>: Check the condition of the system fluid.

Properly installed closed-loop hydronic systems that are constructed mostly of metal piping components can contain the same water for many years without experiencing corrosion issues. This is possible because the dissolved oxygen molecules in the initial fill water quickly react with ferrous metal in the system (e.g., cast iron or steel) to form thin and essentially harmless oxide films. At that point, the further oxidation potential of the water is minimal.

However, no hydronic system is sealed to the point where no oxygen can enter the system through circulator flange gaskets, valve packings or non-barrier polymer tubing. Systems that experience significant water loss, and corresponding entry of fresh makeup water due to various abnormalities, allow oxygen to be replenished inside the system. This can lead to formation of sludges, such as magnetite or other types of oxygen-fueled corrosion.

During servicing, technicians should draw a small sample of system fluid (approximately 1 pint) and examine it for color, smell, consistency and the presence of particles. Water that is slightly gray in color, and has a slight metallic odor, is generally fine. However, water or mixtures of water and antifreeze that are dark brown or black in color, or have a pungent odor, typically indicate oxidation within the system. Fluid that is highly viscous in nature and with a dark color often indicates a chemical breakdown of rubber or other non-metals in the system. It could also indicate oxidation of ferrous metal. The presence of fine, dark- colored "grit" (e.g., magnetite) in the fluid is also an indicator of corrosion due to oxidation of ferrous metals.

Technicians should use test strips or test meters, such as shown in Figure 3- 5, to evaluate the pH of the system fluid.

pH values of 7.0 to 8.0 are generally fine. However, low pH values (under

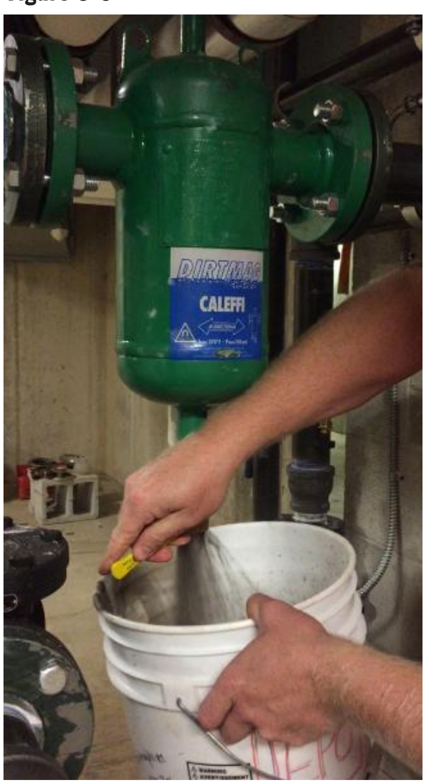
**Figure 3-5**

7.0) indicate acidity. This condition is more prevalent in systems using glycol-based antifreeze and operating at high temperatures. The antifreeze eventually breaks down into an acid. Left unchecked, this condition can cause widespread corrosion in the system. Corrective actions include draining the fluid, internally cleaning the system with a hydronic detergent to remove residue, and refilling with either demineralized water or a mixture of demineralized water and inhibited glycol-based antifreeze. Stabilizer chemicals can also be added to preserve the pH of the fluid.

**See *idronics* #18 for detailed information on water quality in hydronic systems.**

Systems that exhibit dark and gritty fluid should also be fitted with a magnetic dirt separator, such as the Caleffi DIRTMAG or SEP4 separator. These devices contain strong magnets that can capture iron oxide particles and allow them to be periodically flushed from the system, as shown in Figure 3-6.

**Figure 3-6**




## STEP 10: Check the condition of the heat emitters.

The heat emitters in a hydronic system are usually *not* the underlying cause of "insufficient heating" complaints. However, there are some circumstances where, with all other portions of the system operating normally, the heat emitters could be the source of insufficient heating.

**Check for the following on fin-tube baseboard systems:**

- Are all dampers on the baseboard housing fully open?
- Is the fin-tube element reasonably clean (not heavily coated with dust or other debris)?
- Have the fins on the element been extensively deformed or damaged?
- Is there air in the baseboard? Listen for "gurgling" or "trickling" sounds, indicating the presence of air.
- Are upholstered furniture, boxes, drapes, shelves or other objects blocking inlet and outlet airflow through the baseboard?
- Are there isolation or zone valves housed inside the baseboard enclosure that may be blocking flow?

**Check for the following on panel radiator systems:**

- Are the isolation valves at the inlet and outlet of the radiator fully open?
- Is the thermostatic operator on a radiator valve (if present) fully open?
- Does the spring-loaded stem on the radiator valve fully extend when the thermostatic operator is removed?
- Are the convective fins inside the radiator reasonably clean?
- Is there anything blocking convective airflow upward through the radiator fins?

**Figure 3-7**

- Is there air in the radiator? Listen for "gurgling" or "trickling" sounds, indicating the presence of air.
- Are upholstered furniture, boxes, drapes, quilts, shelves or other objects blocking inlet and outlet airflow through the radiator (see Figure 3-7)?

**Check the following on systems using air handlers or fan-coils:**

- Are there any isolation valves at the inlet and outlet of the air handler's coil that could be blocking or restricting flow?
- Is there air in the air handler's coil? Listen for "gurgling" or "trickling" sounds, indicating the presence of air.
- Is there electrical power at the power input terminals of the air handler?
- Are any internal controls within the air handler configured properly?
- Does the blower operate normally?
- Is the air inlet filter reasonably clean?
- Are there any signs of electrical overload on circuit boards or other electrical components? Are there any fuses that might be blown, or internal circuit breakers that might be tripped?
- With the filter removed, are the surfaces of the air handler's coil reasonably clean?

• Check that the condensate trap (if present) is not clogged.
• Are all air dampers in the ducting system at least partially open?

**Check the following on systems using radiant panels:**

• Are all manifold valves at least partially open?
• Is there evidence of air in the manifold station? Listen for "gurgling" or "trickling" sounds, indicating the presence of air.
• On manifolds with flow meters, verify the flow rate in each active circuit when the associated circulators are running.
• On floor-heating systems, check that the floor has not been covered with objects such as boxes, furniture, rugs, carpet padding or other objects that could significantly restrict upward heat flow.
• Verify the presence of adequate underfloor insulation. Suggested values for the underside insulation R-value are at least 10x the total R-value of any materials covering the radiant floor panel.
• If the system uses aluminum heat transfer plates installed under a subfloor, be sure that the plates make tight contact with the tubing and tight contact with the underside of the subfloor. Poorly formed or bent plates that create gaps between the tubing and plate surfaces, or between the plate and subfloor, can substantially reduce heat transfer (see Figure 3-8).

**Figure 3-8**

## FURTHER CONSIDERATIONS

At this point in the troubleshooting procedure, the following functions are assumed to have been checked and verified as operating properly:

• Electrical power (line voltage and 24 VAC) is available to all portions of the system that require these voltages.
• Fuel is available to the heat source at the required pressure.
• All thermostats have been checked and are functioning properly.
• The system is not "air bound."
• Zone valves or zone circulators are operating normally.
• The heat source operates when any zone thermostat calls for heat.
• The heat source is producing heated water.
• Flow in all active zone circuits is within an acceptable range.
• The heat emitters are reasonably clean and have flow passing through them when the system's circulator(s) are on.
• There are no valves with broken stems present in the circuit(s).

Assuming that all of the above functions are normal, some heated fluid will be moving through the distribution system and heat emitters. However, the *rate* of heat transfer, and the locations to which that heat is being delivered, may still not produce acceptable comfort in all areas of the building. This could be the result of inadequate sizing of the heat source, piping, circulators or the heat emitters. It could also be the result of inaccurate load estimating.

## WHEN IT'S THE BUILDING, NOT THE HEATING SYSTEM

It's also possible that the underlying cause of inadequate heating *is one or more issues with the building, rather than the heating system*. Issues may be from failed or missing weatherstripping on doors, windows or attic hatches; new penetrations through the building's thermal envelope for wiring or plumbing; or deteriorated insulation in exterior surfaces due to water leaks. Natural convective air currents through inactive air-conditioning ducting located in unconditioned attics can also create a persistent cooling effect in winter, as illustrated in Figure 3-9.

When a problem with the building envelope is suspected as the cause of inadequate comfort, a weatherization specialist may be helpful in identifying the issue(s) using tools such as thermographic imaging (see Figure 3-10), blower doors (see Figure 3-11) and smoke canisters (see Figure 3-12), which can detect very minor air leaks.

**Figure 3-9**

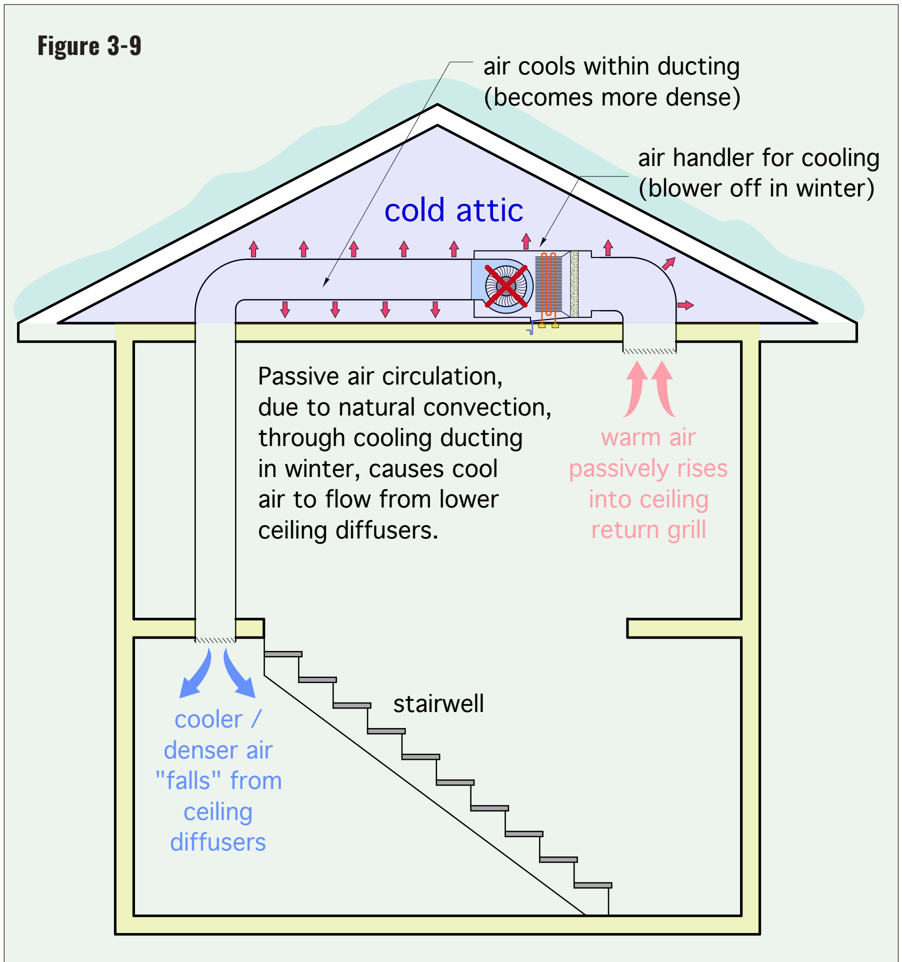



**Figure 3-10**

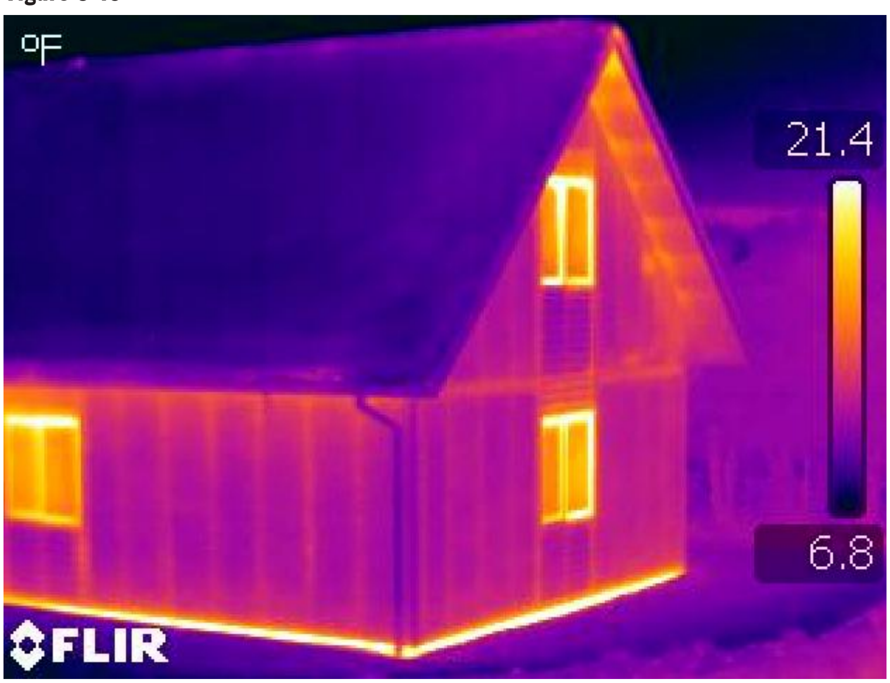



**Figure 3-11**

Courtesy of John P. Gordon

**Figure 3-12**

Source: cleverlysolved.com

In many cases, the source of excessive heat loss (and associated discomfort) can be identified and partially or fully corrected through weatherization processes, such air sealing, new weatherstripping or added insulation. These building envelope improvements often have very good returns on investment and can recoup their costs many times over during the life of the building.

# 4. "CLASSIC" CAUSES OF COMPROMISED PERFORMANCE

Just as physicians can quickly "zero in" on the likely cause of a health issue by observing "classic" symptoms, technicians can quickly identify what's causing a problem in a hydronic system that exhibits "classic" symptoms.

This section presents many of these commonly encountered symptoms, provides one or more possible causes, suggests things to check and lists potential corrective actions.

Technicians need to remember that a given symptom could have multiple underlying causes. For example, a noisy zone valve could be caused by the use of a "high head" fixed-speed circulator, improperly set differential pressure bypass valve or by debris jammed inside the valve.

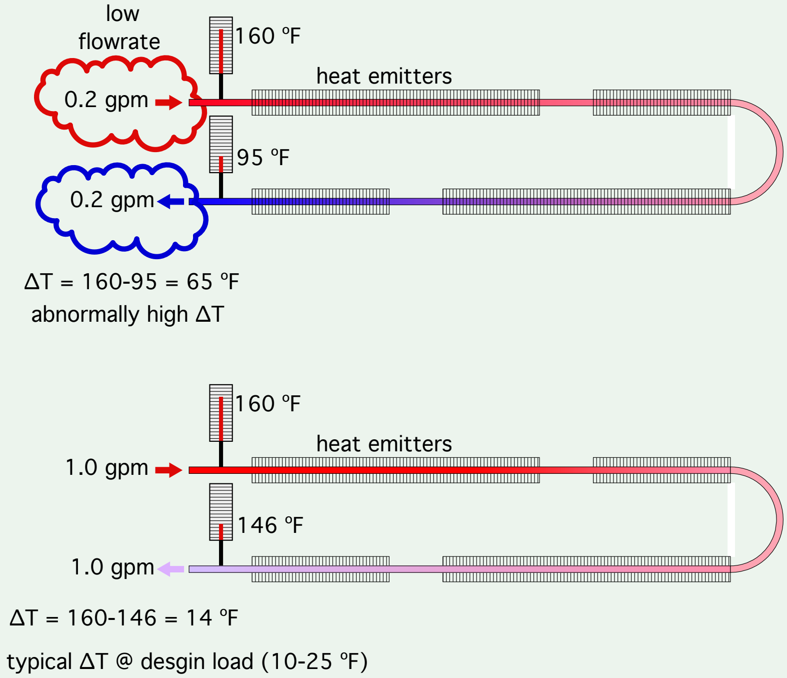
Likewise, an underlying problem could manifest itself through several different symptoms. For example, air in a system could present as noise in the piping, insufficient flow rate, insufficient heat output at a heat emitter or corrosion.

Thus, the information presented in this section should be considered as "starting points" when investigating a problem. Troubleshooting experience, gained over time and multiple systems, will expedite the process of identifying underlying causes for abnormal performance, and will help in selecting the best course of action for correcting the problem(s).

## 1. SYMPTOM: Large temperature drop between the supply and return sides of a hydronic heating circuit.

**Possible cause(s):** Most hydronic heating circuits that operate with a temperature drop of more than 25ºF when the heat source is delivering water at design load temperature are suffering from *low flow rate*.

**Figure 4-1**

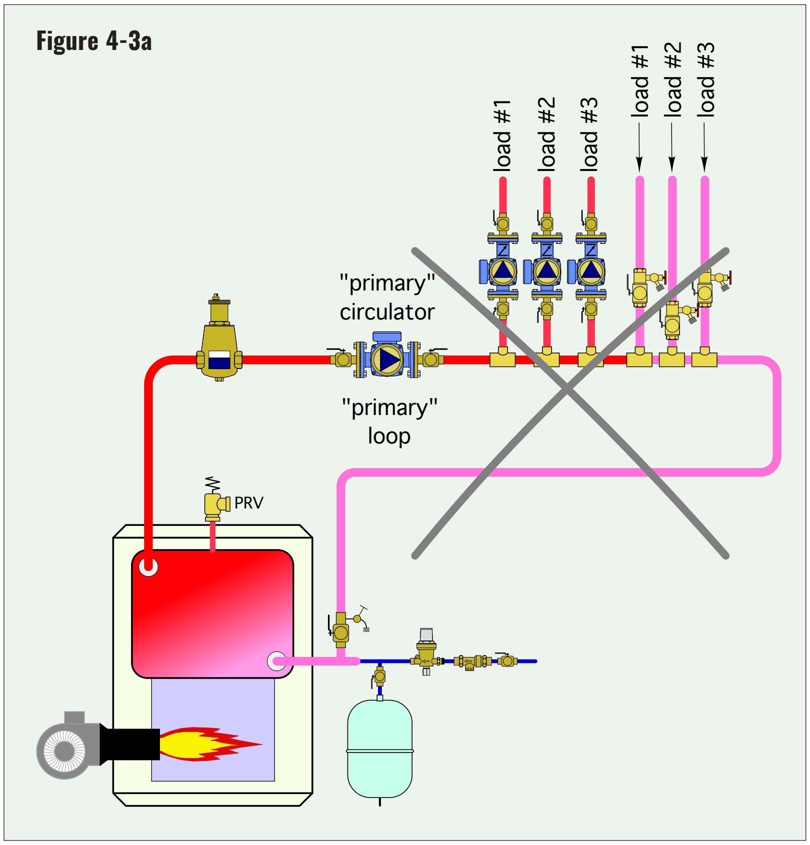


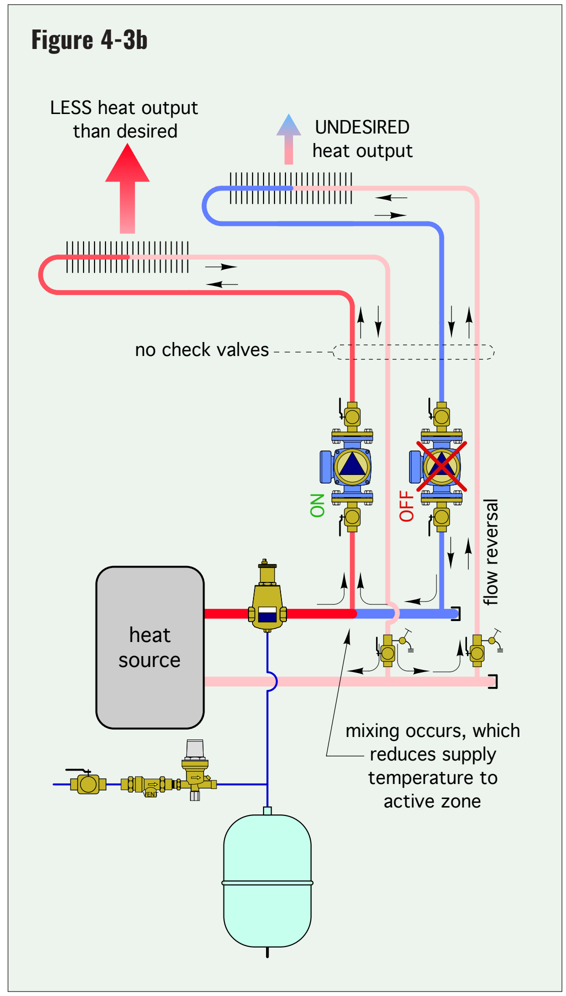

The possible exception being panel radiators or heating coils in air handlers that are sometimes intended to operate at design load temperature drops of 25 to 30ºF. Figure 4-1 illustrates the concept of insufficient flow rate causing a high temperature drop.

**Things to check:**

• Does the circulator have a pump curve sufficient for the intended flow rate in the circuit?
• Is the speed setting of the circulator too low?
• Does the temperature drop across the circuit change when the speed setting of the circulator is changed?
• Is the circulator wired for the correct voltage (120 or 240 VAC)?
• Is there evidence of air in the fluid (gurgling or swishing sounds)?
• Is there evidence of vapor cavitation (crackling sounds coming from the circulator)?
• Does the piping circuit have significantly more components or fittings than necessary or originally planned, causing higher head loss?

**Figure 4-2**




• Are there any partially closed or improperly selected valves that are restricting flow in the circuit?
• Are there any y-strainers, check valves, filters or other devices in the circuit that could be clogged?
• Is the pipe size too small for the intended flow rate?
• Was the circuit designed assuming water as the fluid, but is now operating with a higher percentage of glycol-based antifreeze?
• Are there any abnormal sounds coming from the circulator that could indicate debris stuck in the volute or impeller?
• Are there any large dents or deformations in any tubing within the circuit?
• Was the original cast iron boiler replaced with a high-flow resistance mod/con boiler without some type of hydraulic separation between the new boiler and remainder of system?
• Is there a thermostatic mixing valve with a low Cv in the circuit that has been selected based on pipe size? If so, it could create a significant flow bottleneck, especially problematic when installed near the circulator inlet. (See Figure 4-2).

**Potential corrective action(s):**
Because there are many possible causes for this condition, the corrective action is to verify proper functioning or sizing for each of the "things to check." Some calculations may be necessary to determine if a larger circulator is needed.

**See *idronics* #16 for detailed information on sizing piping and circulators.**

## 2. SYMPTOM: Flow is present in portions of system that are supposed to be off.

**Possible cause(s):**
• An undefined piping layout that "morphs" the concept of a primary loop with the concept of supply and return headers. Figure 4-3a shows one example.
• Lack of a check valve in each circuit that has a zone circulator (see Figure 4-3b).
• Stuck check valve or older-style "flo-control" valve in circuits exhibiting flow when the circulator is off. Figure 4-3c shows an example of an older-style "flo-control" valve.
• The plug in an older-style "flo-control" valve has been left in the manually open position.
• Using a swing-check in an attempt to prevent forward thermosiphon flow.
• A zone valve that fails to close when the zone thermostat is satisfied.

**Figure 4-3c**


Courtesy of Bell & Gossett division of Xylem.

**Potential corrective Action(s):**

- Modify any undefined piping system into a proven piping configuration (see *idronics* #19).
- Verify that all zone circuits using zone circulators have a spring-loaded check valve, or a flo-control valve, and that those valves are not jammed, clogged, left in a manually open state or otherwise compromised.
- Never use swing-check valves in an attempt to stop forward thermosiphoning. They do not have sufficient forward opening resistance.
- Verify that the actuator on the zone valve in the problem circuit fully closes when the thermostat is not calling for heat. If the actuator moves through its full range of travel and the problem persists, there may be debris stuck in the valve, preventing it from closing. Depending on the valve, it may be possible to flush the debris using pressurized water, or isolate and remove the valve body to check its internal operation.

**See *idronics* #19 for proven hydronic distribution systems.**

## 3. SYMPTOM: Inadequate flow in some branches of a distribution system.

**Possible cause(s):**

The flow rate in any branch of a multi-branch system depends on the flow resistance of that branch relative to that of the other branches. The higher the flow resistance of a given branch, the lower its flow rate relative to branches with less flow resistance.

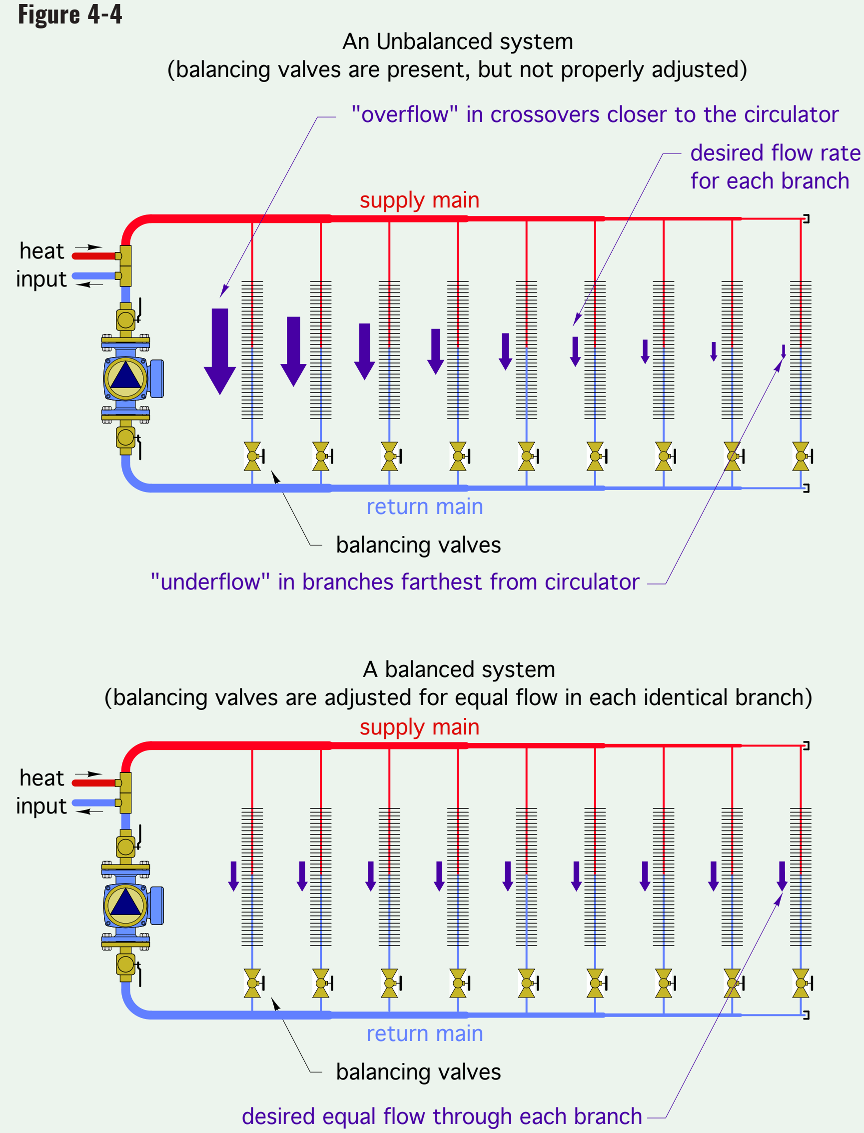
Figure 4-4 compares an unbalanced system with a balanced system. The assumption for the balanced system is that the same flow rate is desired through each branch.

Adjusting the system to achieve the desired flow rate in each branch is called balancing, and it requires a properly adjusted balancing valve in each branch. The lack of balancing valves, or the improper setting of balancing valves (if present), is often the cause of inadequate flow in some branches.

**Things to check:**

- Are balancing valves present in each parallel branch?

**Figure 4-4**



• If balance valves are present, have they been adjusted to achieve the desired flow rate in each branch?
• Aside from the balancing valves, are there any devices in the branch experiencing inadequate flow that could be causing high flow resistance (plugged Y-strainers, other valves, high fittings count, high flow resistance heat emitters, etc.)?

**Potential corrective action(s):**
After ruling out devices that could cause high flow resistance in the problem branch, and assuming balancing valves are present, follow a standard balancing procedure to set the balancing valves. If adequate flow in all branches cannot be achieved, it's likely that a larger circulator is needed.

**See *idronics #8* for a detailed discussion on hydronic system balancing.**

## 4. SYMPTOM: Dark-colored water/fluid in the system.

**Possible cause(s):**
Water in a closed-loop hydronic system typically takes on a light gray hue and a slight metallic odor during the first few weeks of operation. This is generally normal. Dark-colored water (or a mixture of water and antifreeze) usually indicates that oxygen is entering the system and has reacted with ferrous metals to form oxides. It can also indicate thermal degradation of the antifreeze, especially in systems that have operated at elevated temperatures.

**Things to check:**
• If the system contains antifreeze, obtain test strips from the antifreeze manufacturer, or a test meter, as shown in Figure 3-5, and test the pH of the fluid. A normal pH should be between 7.0 or 8.0. If the pH is lower than 7.0, the antifreeze may have become acidic and should be replaced. Check with the boiler manufacturer for the acceptable range of pH required on their equipment.
• Does the system experience frequent infusions of fresh water due to a relief valve that cycles open repeatedly?
• Does the system contain non-barrier polymer or rubber tubing?
• Has anyone been intentionally draining and refilling the system?

**Potential corrective action(s):**
• Antifreeze that has become acidic should be disposed of properly. The system piping should be flushed and internally cleaned with a hydronic system detergent. *If the system is to be refilled with antifreeze, the water used to make the antifreeze solution should be demineralized.*

• If the system contains non-barrier tubing, and there is no practical way to replace that tubing with barrier-type tubing, the discolored fluid should be drained, the system internally cleaned with a hydronic detergent, and refilled with demineralized water. A chemical treatment manufacturer should be consulted to determine an oxygen-scavenging chemical that can be periodically added to the system. Makeup water should be minimized, and the system should be operated at the lowest water temperature that can deliver adequate heating. Adding a Caleffi DIRTMAG PRO separator to the system will also help collect magnetite at a location where it can be periodically flushed from the system.

**Figure 4-5a**

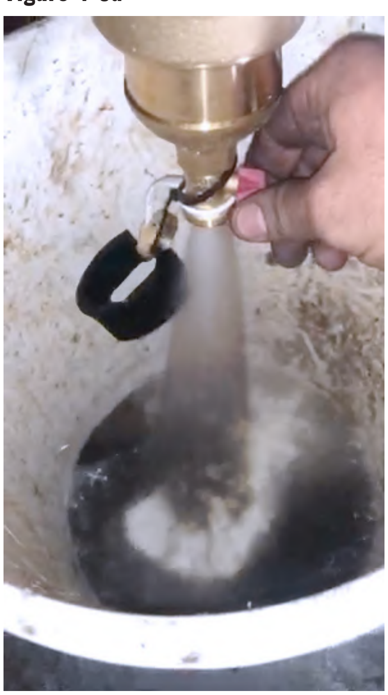


**Figure 4-5b**

**See *idronics #18* for more details on maintaining water quality in hydronic systems.**

## 5. SYMPTOM: Air noise inside the system.

**Possible cause(s):**
• Lack of forced-water purging during system commissioning or refilling following service.

Figure 4-6a

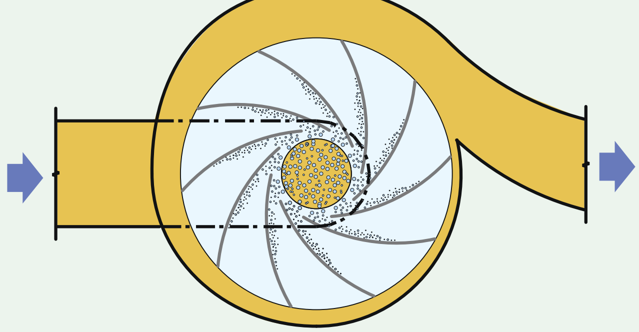
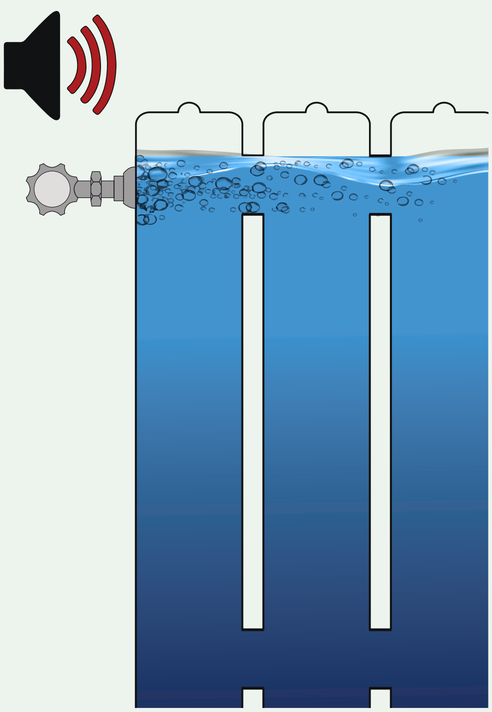


Figure 4-6b



• Gaseous cavitation within the circulator (see Figure 4-6a).
• Lack of a central microbubble air separator.
• An expansion tank improperly located relative to the circulator.
• Air trapped at one or more high points in the piping circuit (see Figure 4-6b).
• A drop in system pressure leading to sub-atmospheric pressure at the location of the air vents.
• Water draining from the piping located higher than a non-pressurized heat source when the circulator is off, and refilling piping when the circulator turns on.

**Things to check:**
• Has the system been purged using a forced-water stream since it was installed or last drained?
• Are there any manually operated air vents at high points in the circuit that can be opened to release trapped air?
• What is the static pressure in the system? A minimum pressure of 12 psi in the basement is suggested for closed-loop hydronic systems in low-rise (three-story or less) buildings.
• Is there a cap on the top of the central air separator vent that is screwed down tight?
• Are there any air vents, valves or other devices that could allow air into the system when the pressure inside the piping is sub-atmospheric? This is most common when non-pressurized heat sources, such as outdoor wood furnaces, supply piping that is routed several feet above the water level in the heat source?
• Is the makeup water assembly turned off, which could allow the system pressure to drop over time?

**Potential corrective action(s):**
• Set up and perform a forced-water purging of the system. Purge each branch or zone of the system separately. Be sure there are no air bubbles in the purging stream exiting the system.
• Consider adding purging valves in portions of the system that have chronic air problems.
• If the system doesn't have one, install a microbubble air eliminator, such as a Caleffi DISCAL. Be sure the cap on the vent of the air separator is not screwed down tight.
• Verify that static pressure in a closed-loop system installed in a low-rise building is at least 12 psi.
• Relocate the expansion tank connection near the inlet of the circulator.

See idronics #16 for information on the proper placement of expansion tanks.

See idronics #18 for information on purging procedures.

## 6. SYMPTOM: Frequent opening of the system's pressure relief valve.

**Possible cause(s):**
• A defective pressure-relief valve.
• A ruptured diaphragm in the expansion tank, causing it to fill with water (see Figure 4-7a).
• An undersized expansion tank.
• A water-logged standard (non-diaphragm) compression tank.

Figure 4-7a

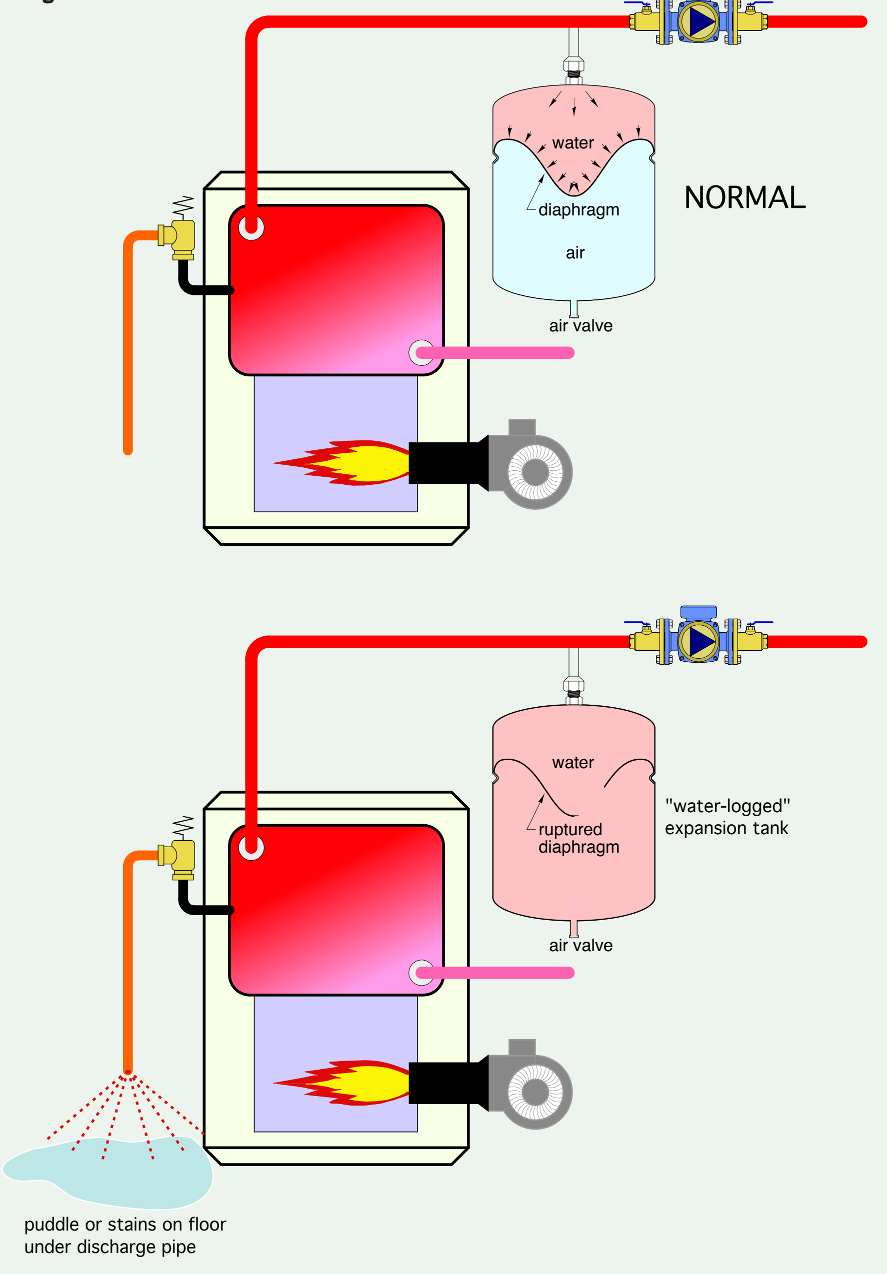



Figure 4-7b

Courtesy of Bell & Gossett division of Xylem.

• A failed or missing air level control device, typically required when a standard (non-diaphragm) type expansion tank is used. An example of such a device is shown in Figure 4-7b.
• Debris in the pressure-reducing valve supplying makeup water to the system.
• Unnecessarily high static pressure in the system.
• High system static pressure combined with a high head circulator.
• Leakage from a relief valve due to debris on the valve seat.

**Things to check:**
• Is the size of the expansion tank correctly matched to the system volume and temperature range?
• Is there a bucket placed under the discharge pipe from the pressure-relief valve that either contains water or shows signs that it did contain water (see Figure 4-7c)? This is an indication of leakage or discharge from the valve.
• Is there any evidence of water (such as a mineral trail) on the floor under the relief valve discharge pipe?
• Is the air pressure in the diaphragm-type expansion tank, as measured with an accurately calibrated gauge, properly adjusted to match the cold-water static pressure in the system?
• Is there water coming out of the Schrader valve on a diaphragm-type expansion tank when the stem of the valve is pressed in? If so, the diaphragm in the tank has failed and the tank needs to be replaced.
• What is the water level in the sight glass on a standard (non-diaphragm) expansion tank?
• Is an air level control device missing at the bottom of a standard (non-diaphragm) type expansion tank?
• What is the static pressure in the system?

**Potential corrective action(s):**
• Replace any diaphragm-type expansion tank if the diaphragm has failed.

**Figure 4-7c**

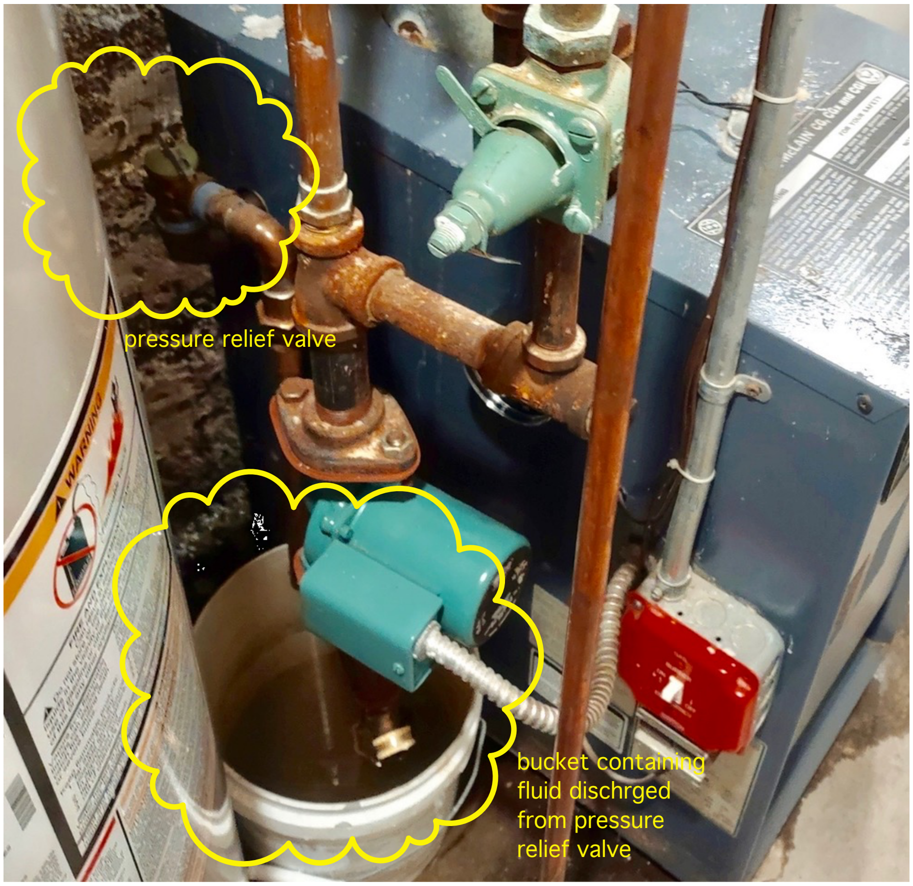
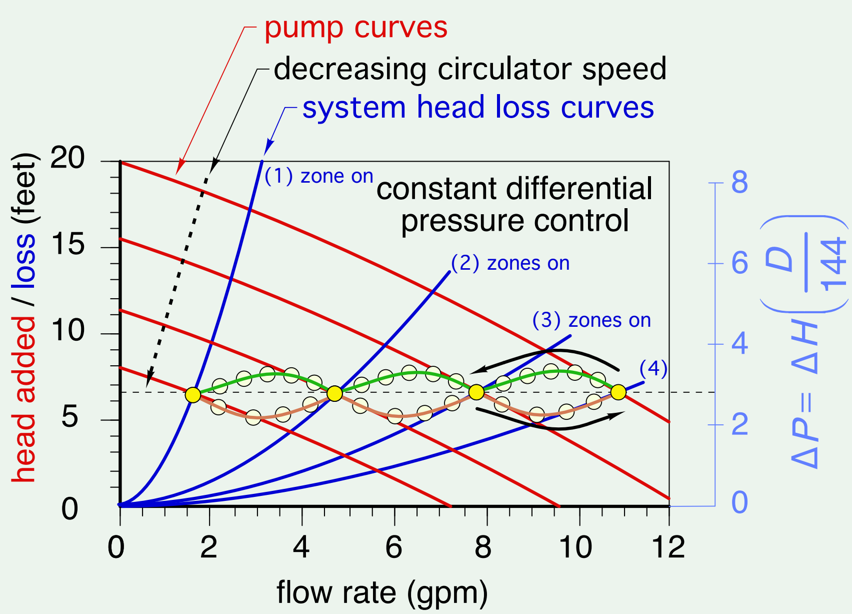



**Figure 4-8a**




• Verify that the expansion tank is properly sized and pressurized for the system.
• Allow the makeup water system to refill a standard expansion tank and verify the proper water level in the tank.
• Reduce the pressure setting of the pressure-reducing valve.
• Isolate and disassemble the pressure-reducing valve supplying water to the system, clean the screen and valve seat, and reassemble.
• Install or replace the air level control device on systems with standard expansion tanks.

**See idronics #12 for information on sizing and pressurizing diaphragm-type expansion tanks.**

## 7. SYMPTOM: Noise coming from the zone valves.

**Possible cause(s):**

• The flow rate through the valve is excessive due to high differential pressure across the valve.
• There is no means of differential pressure control in the system.
• A circulator with a “steep” pump curve is creating flow through the zone valves.
• Cavitation is occurring within the zone valve.
• Debris is lodged within the zone valve.
• The paddle or disc in the valve only opens through a portion of its normal range.
• Incorrect flow direction though the valve.

**Things to check:**

• What (if any) method of differential pressure control is used in the system?
• If a differential pressure bypass valve is present, what ΔP is it set for?
• If a variable-speed circulator is used, what operating mode is it set for?

• Is a “high head” fixed-speed circulator being used to create flow through the zone valves?
• Is the combination of high water temperature and low static pressure in the system sufficient to cause cavitation (vapor flashing) within the zone valve?
• Is flow passing through the valve in the correct direction?

**Potential corrective action(s):**
• Add some means of differential pressure control to the system. This could be a properly set differential pressure bypass valve, or a variable-speed circulator operating in constant ΔP or proportional ΔP mode, and with a setting reasonably matched to the differential pressure requirements of the system at design load conditions.

Figure 4-8a shows an example of constant differential pressure control for a system with four zone valves.

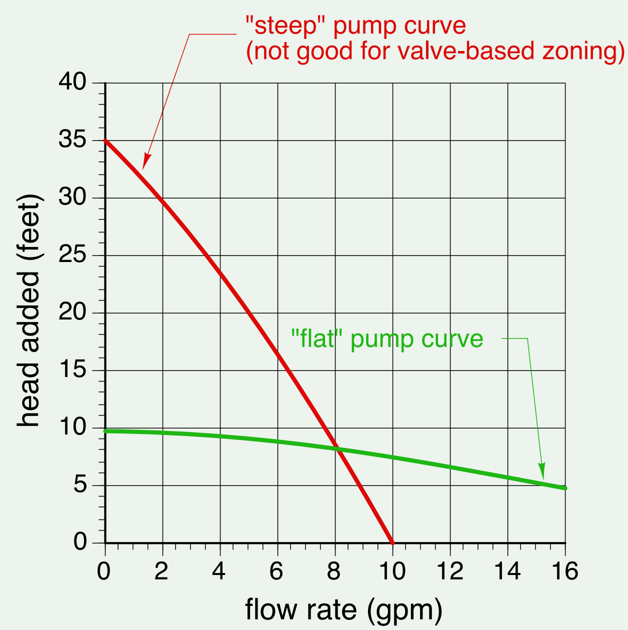
Each blue system head loss curve represents the head loss of the piping circuit as a function of flow rate. The curve gets progressively steeper as the number of active zone valves decreases. The variable-speed circulator, operating in constant differential pressure control mode, automatically adjusts its motor speed so that its pump curve intersects the system head loss curve at the differential pressure to which the circulator has been set. This is an ideal way to control differential pressure in any hydronic system using valve-based zoning.

**See idronics #7 for more detailed information on zoning hydronic systems.**

• If a fixed-speed circulator is used to create flow through the system’s zone valves, it should have a relatively “flat” pump curve. If a high head circulator with a “steep” pump curve is present, it should be replaced. Figure 4-8b shows a comparison between flat versus steep pump curves.

• If flow rate is too high for the current valve, consider a valve with a higher Cv rating.
• If cavitation is occurring within the valve, consider reducing water temperature and increasing system static pressure to prevent the water passing through the valve from reaching its vapor pressure.
• If none of the above actions correct the problem, disassemble the valve to check for debris, broken internal components or anything that limits the travel range of the paddle or disc in the valve. If damage is found, replace the valve body.

**Figure 4-8b**




## 8. SYMPTOM: “Ticking” sounds from the piping.

**Possible cause(s):**
• Pipes rubbing against wood or metal framing as they expand and contract (see Figure 4-9a).
• Pipes moving through improperly secured pipe supports.
• PEX tubing expanding or contracting within aluminum heat transfer plates.

**Things to check:**
• Are the holes through the framing for the piping misaligned, causing the pipes to rub against the framing in some locations (see Figure 4-9a)?
• Do locations where the piping passes through the framing or subfloor allow space between the outer surface of pipe and the holes through the framing (see Figure 4-9b)?
• Are some pipes rigidly clamped to wooden surfaces?
• Are there long lengths of straight pipe without expansion/contraction detailing?
• Does the system frequently undergo rapid changes in water temperature in the piping?
• Keep in mind that a given length of PEX tubing expands or contracts approximately 10 times more than the same length of copper tubing, when undergoing the same temperature change, as illustrated in Figure 4-9c.

**Potential corrective action(s):**
• Install plastic “hole liners” between the pipe and the holes through the framing.

Figure 4-9a

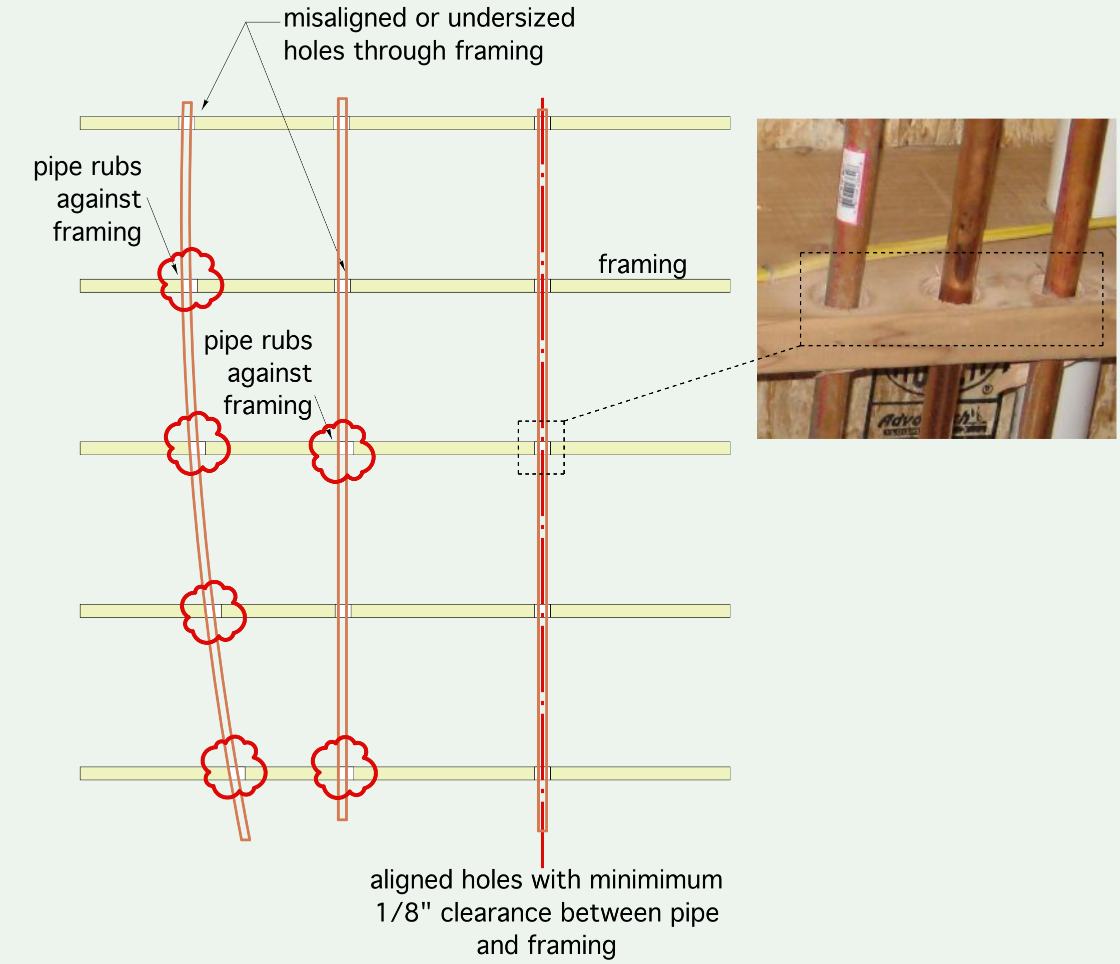
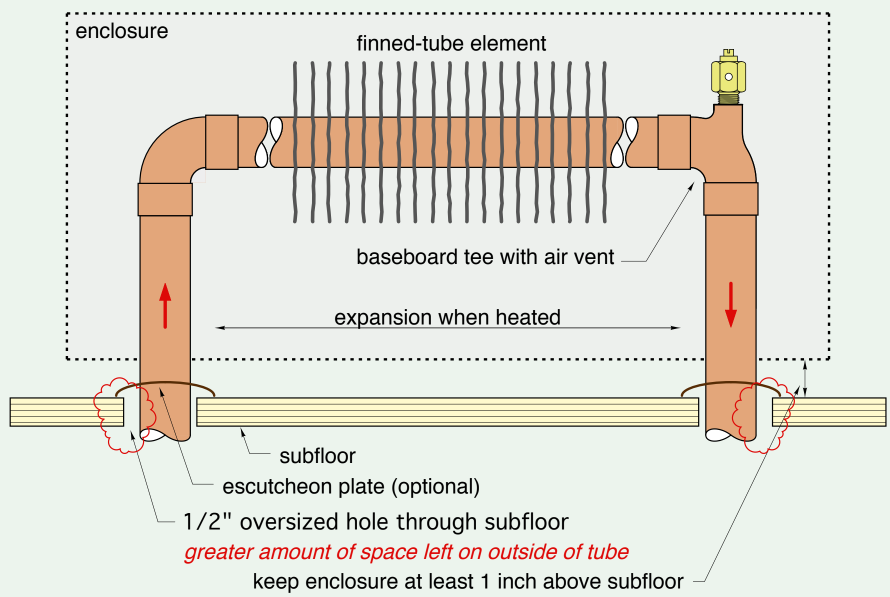
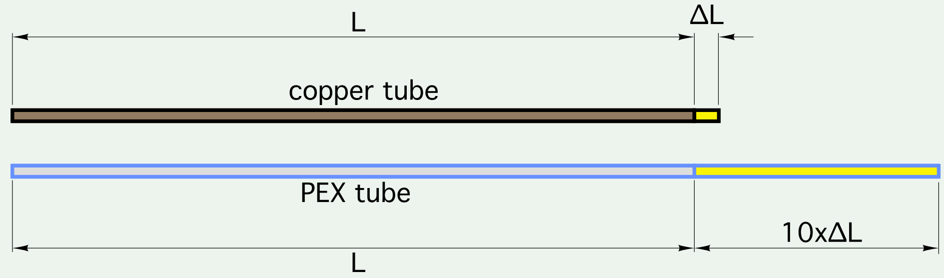



Figure 4-9b






• Always align the holes through the framing and size the holes to allow a minimum 1/8” space around the outside of the pipe.
• Use PEX-AL-PEX tubing in combination with aluminum heat transfer plates (lower coefficient of expansion).
• Use an outdoor reset control to make gradual changes in the water temperature.
• Use “cushioned” support clamps on the metal piping.
• Use expansion compensators on long straight runs of metal piping.

## 9. SYMPTOM: Noise coming from the circulators.

**Possible cause(s):**
• Air in the system is causing gaseous cavitation.
• Low system pressure and high water temperature are causing vaporous cavitation.
• High pressure drop upstream of the circulator (see Figure 4-10a).
• Debris inside the circulator volute or impeller.
• A closed or partially open isolation valve.
• A failed bushing in the wet rotor circulator.
• The wet rotor circulator is mounted with the motor shaft in a vertical orientation (see Figure 4-10b).
• Air is trapped in the circulator volute and held there by a closed spring check above the circulator volute (see Figure 4-10c).
• A thermostatic mixing valve with a low Cv value is located just upstream of the circulator (see Figure 4-10d).

**Things to check:**
• Has the system been properly purged?
• What is the water temperature and pressure at the inlet of the circulator?
• Are there any components upstream of circulator that can cause significant turbulence or pressure drop?
• Is there dirt or other debris lodged inside the circulator?
• • Is the circulator mounted in vertical pipe with upward flow (see Figure 4-10c)?
• Is the circulator mounted with its motor shaft in a vertical position?

**Potential corrective action(s):**
• Forced-water purging of the system.
• Increase system pressure to suppress vaporous cavitation.
• Decrease system water temperature to suppress vaporous cavitation.

Figure 4-10a

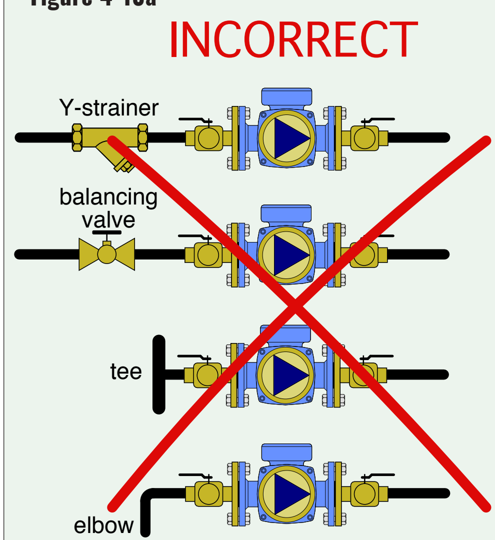
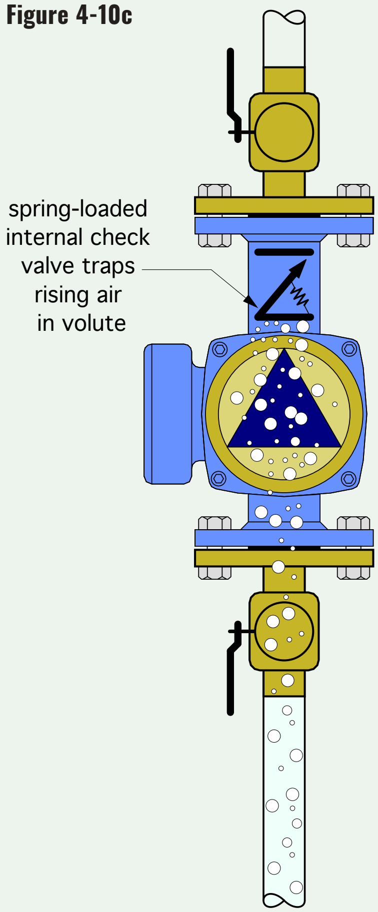



Figure 4-10b

Figure 4-10c

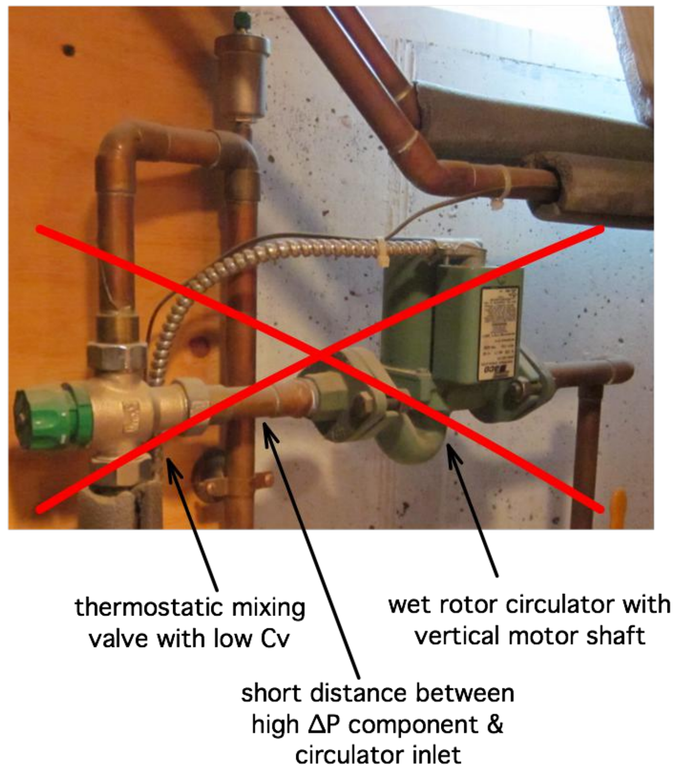



• Provide a minimum of 10 diameters of straight pipe upstream of all circulator inlets.
• Isolate and remove the circulator, disassemble it and check for any debris.
• Change the circulator rotor orientation from vertical to horizontal.
• Use an external spring-loaded check valve installed at least 10 pipe diameters above the circulator outlet, rather than the internal spring-check cartridge, if the circulator is in a vertical pipe pumping upward.

See idronics #15 for more information on air and dirt separation.

See idronics #16 for more information on sizing and locating circulators.

Figure 4-10d




## 10. SYMPTOM: Significant flow variations depending on which circulators in a multi-circulator system are operating.

### Possible cause(s):

• Lack of hydraulic separation between circulators.
• Several zone circulators drawing flow through a high-flow resistance heat source (see Figure 4-11a).
• Using long and small diameter headers to supply multiple zone circulators (see Figure 4-11b).
• Replacement of a low-flow resistance heat source, such as a cast iron sectional boiler, with a high-flow resistance heat source, such as a mod/con boiler with a compact heat exchanger, but without some detail for hydraulic separation.
• An undefined piping configuration created in an attempt to use principals of primary/secondary piping, but without closely spaced pairs of tees for each secondary load.
• Lack of check valves for each circulator when multiple circulators are connected to a common set of headers.

### Things to check:

• Does the diameter of the headers limit flow velocities to 2 ft/sec when all circulators served by those headers are operating?
• Is a high-flow resistance heat source piped directly to the headers serving multiple zone circulators?
• Are there circulators supplied from a common set of headers, but without internal check valves or external check valves downstream of each circulator?
• Is the piping a standard configuration or some variant that attempts to morph primary/secondary piping with headers?

Figure 4-11a

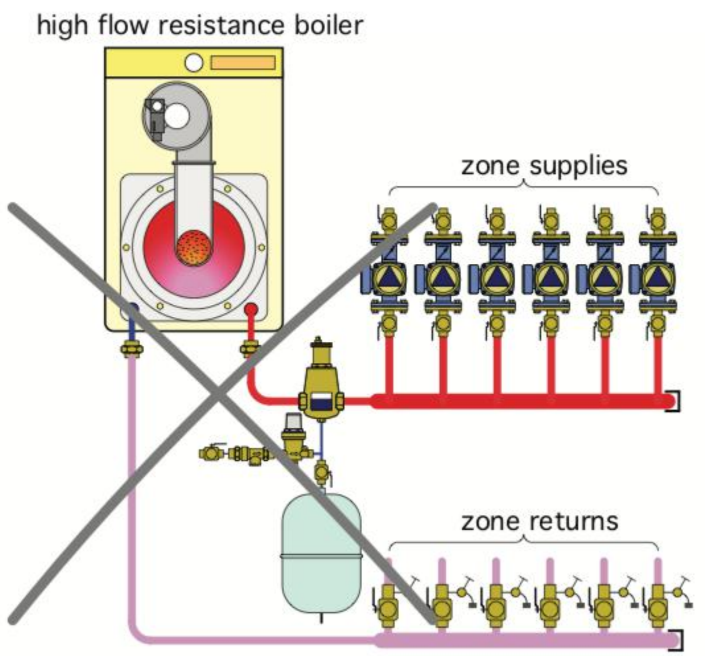
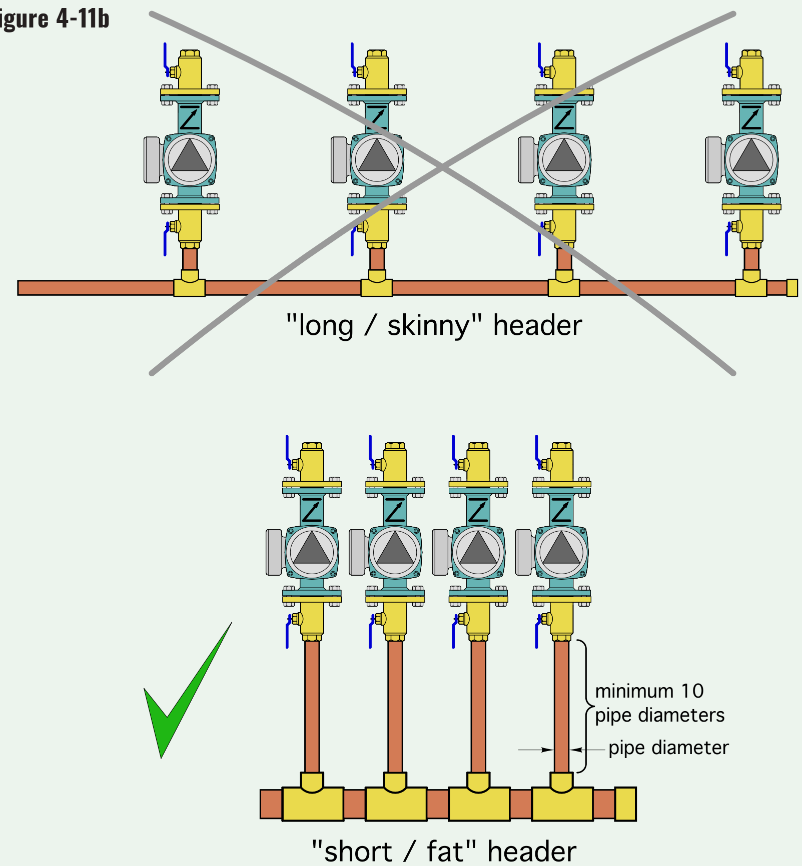



Figure 4-11b




• Was an older cast iron sectional boiler replaced with a mod/con boiler having high flow resistance, but without proper hydraulic separation detailing?

**Potential corrective action(s):**

• Use one of several methods to provide hydraulic separation between all circulators.

a. Use closely spaced tees to create a primary/secondary system.

b. Use a buffer tank with generously sized headers.

c. Use a hydro separator or SEP4 separator with generously sized headers.

• When replacing a low-flow resistance boiler, such as a cast iron sectional boiler, with a high-flow resistance heat source, use a separate circulator for the new heat source and separate the new heat source and its circulator from the remainder of the system using one of the above methods of hydraulic separation.

• Keep headers as short as possible and size them for a maximum flow velocity of 2 ft/sec.

• Install check valves in each circuit having its own circulator and supplied from the same set of headers.

idronics

See idronics #15 for detailed information on hydraulic separation.

## 11. SYMPTOM: Condensation on piping or piping components.

**Possible cause(s):**

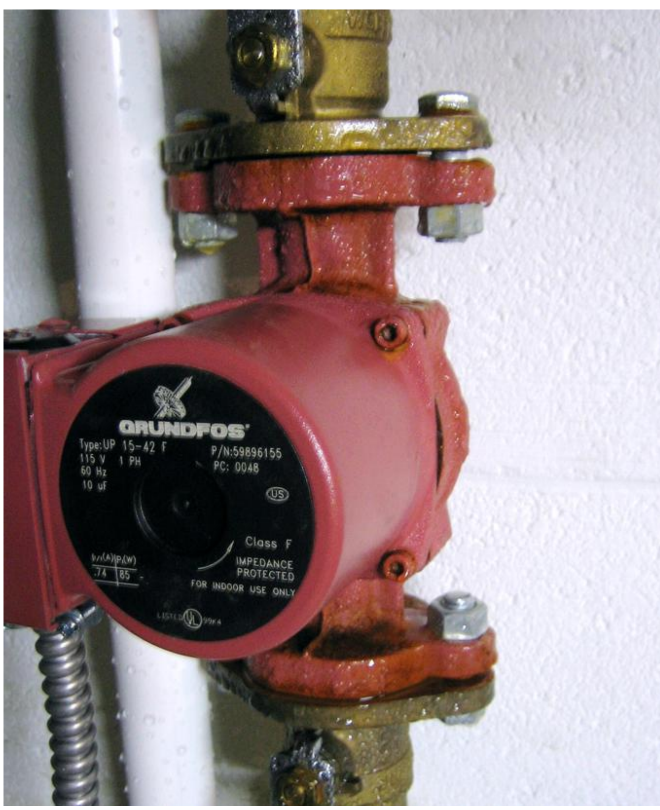
• Piping is carrying fluid below the dewpoint temperature of the surrounding air.

• A lack of insulation on chilled water piping (see Figure 4-12a).

• A lack of insulation on components carrying chilled water (see Figure 4-12b).

Figure 4-12a

Figure 4-12b




• Open seams or joints in the insulation allowing surrounding air to contact pipe or other components.
• Cold antifreeze solution is temporarily passing through piping but will eventually warm above the dewpoint of the surrounding air, eliminating the condensation.

**Things to check:**
• Are there ANY piping or piping components carrying chilled water or chilled antifreeze solution in the system that are not properly insulated and vapor sealed?
• Did a load circuit or zone circuit containing cold antifreeze (i.e., a snowmelting circuit or intermittent garage heating circuit) just turn on?
• Is the water seen on the piping or the floor below the piping potentially coming from a leak?

**Potential corrective action(s):**
• All piping and piping components that transport chilled fluid MUST be properly insulated and vapor sealed to prevent condensation.

**See idronics #13 for pipe insulation requirements and installation details for piping in chilled-water cooling systems.**

## 12. SYMPTOM: Corrosion or sludge accumulation inside the system.

**Possible cause(s):**
• Cast iron or steel piping components are being (incorrectly) used in an "open-loop" system.
• The system contains non-barrier tubing, such as domestic water PEX, polybutylene or early generation rubber tubing.
• The system is experiencing rapid "turnover" of water due to frequent cycling of a pressure-relief valve combined with automatic makeup water.
• The system is experiencing rapid "turnover" of water due to an undetected leak.
• The system has been intentionally drained and refilled several times based on the belief that doing so is beneficial.
• The system contains degraded glycol-based antifreeze.
• The system has been inadvertently filled with water having a pH less than 7.0.
• Impurities in the water allowed pitting corrosion to develop over time.
• Excessive flow velocities have allowed erosion corrosion to develop over time.
• The system was commissioned while containing large amounts of residual solder flux.
• Use of (unlined) steel expansion tank or panel radiators in an open-loop system.

Figure 4-13

• Air entering the system through float-type air vents due to improper pressurization.

**Things to check:**
• If the system is designed as "open-loop," all components should be copper, brass, bronze, stainless steel or engineered polymer. No cast iron or steel components should be used.
• Has the expansion tank failed due to internal corrosion?
• Does a water sample appear to have a dark or orange color?
• Is there any non-barrier tubing being used in a system that contains cast iron or steel components?
• If antifreeze is used, what is its appearance, smell and measured pH?
• Does the system hold pressure when the automatic makeup water assembly is turned off? If not, a leak is likely somewhere in the system.
• Is there evidence of frequent opening of the pressure-relief valve?
• Does a tested sample of the system fluid indicate acidity (e.g., pH < 7.0)?
• Do any float vents or screens in the flow path show evidence of a greasy residue (e.g., solder flux)?

**Potential corrective action(s):**
• Replace any cast iron of steel components in open-loop systems with stainless steel, brass, bronze or engineered polymer equivalents.
• Drain and flush the system with a hydronic detergent. Refill with demineralized water.
• Find and correct any leaks.
• If the system uses antifreeze, test the fluid annually for pH and reserve alkalinity.
• If extensive areas of non-barrier tubing are present, and in reasonable condition, isolate those portions of the system using a stainless steel heat exchanger.
• Verify that the system's expansion tank is functioning properly and is not "water-logged."

See idronics #18 for detailed information on water quality in hydronic systems.

## 13. SYMPTOM: Corrosion on the exterior of the piping components.

**Possible cause(s):**
• Solder flux left on piping and fittings creating a blue/green patina (see Figure 4-14a).
• Weepage from loose valve packings or a circulator flange gasket.
• Steel or iron piping or components joined directly to copper (causes oxidation of the iron or steel).
• Oxidation of cast iron or steel surfaces due to

Figure 4-14a

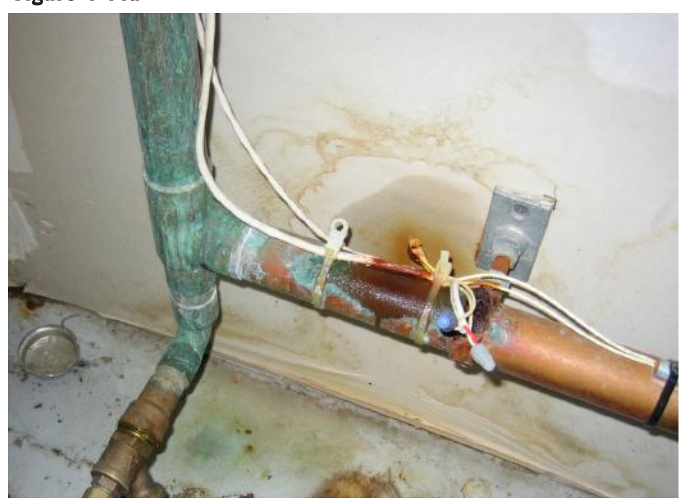


Figure 4-14b

Figure 4-14c

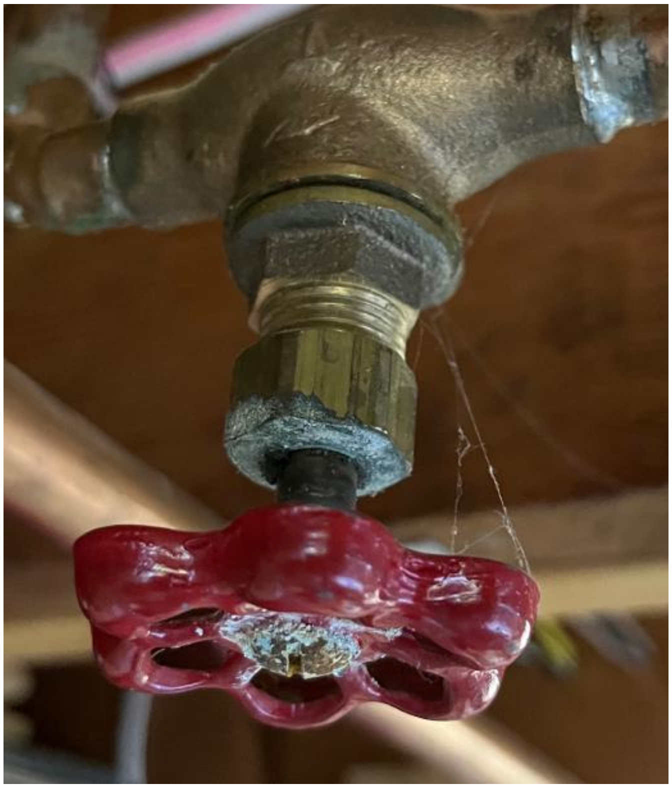


Figure 4-14d

condensation in chilled-water or geothermal-loop systems (see Figure 4-14b).

**Things to check:**

• Are there any greasy, sticky pipe or fitting surfaces near soldered joints?
• Is there a bluish/green patina surface oxidation on copper pipes or fittings?
• Are there white crusty deposits on valve stems or bodies (see Figure 4-14c)?
• Is there evidence of leakage from float-type air vents (see Figure 4-14d)?
• Are there any connections where steel or cast iron components are threaded directly to copper components?
• Are there any uninsulated steel or cast iron components in a chilled-water system?

**Potential corrective action(s):**

• Use detergent and water to remove all greasy solder flux from exterior surfaces of piping and components. Wipe the pipe surface clean.
• Clean any patina scaling from copper surfaces with a wire brush.
• Gently snug the bonnet nut on any valves showing signs of weepage.
• Use a brass union or other brass component to transition between copper and cast iron or steel.
• Replace or repair float-type air vents that show signs of leakage.
• Carefully fit elastomeric insulation to any components carrying chilled water or other fluids at temperatures lower than the dewpoint of the surrounding air. Ensure that all seams or joints in the insulation are sealed.

## 14. SYMPTOM: Corrosion of the venting system.

**Possible cause(s):**

• Return water temperature to the boiler is below the dewpoint of the flue gases causing them to condense in the venting and the chimney.
• Leakage at joints in the vent piping.
• Proximity to cleaning chemicals, pool disinfectant or anything containing chlorine.
• High sulfur content in the fuel oil.
• Higher than necessary excess air in the combustion process.
• Precipitation leaking down the chimney.

**Things to check:**

• Measure inlet water temperature to the boiler when it is operating at or close to steady state conditions. Inlet water temperature below approximately 130ºF can cause flue gases to condense.

Figure 4-15a

Figure 4-15b

• Inspect all galvanized vent connector piping between the boiler and the chimney. Are there any signs of corrosion (see Figure 4-15a)?
• Is there a "male" crimp joint facing upward in the galvanized steel venting? If so, condensation formed in the vent piping above the joint can leak onto the exterior surface of the vent piping below the joint (see Figure 4-15b).
• If the fuel oil is 500 ppm sulfur, switch to a low-sulfur fuel oil at 15 ppm max.
• Are there any pool chemicals, bleaches or other materials containing chlorine located near the boiler? If so their vapors can cause acids to form in the combustion chamber.
• Are there any signs of deterioration of the masonry chimneys?

**Potential corrective action(s):**
• Install an "anti-condensation" mixing valve such as a Caleffi ThermoProtec on any conventional boiler exhibiting sustained flue gas condensation.
• Seal all joints in the vent piping with a suitable high-temperature sealant.
• Replace leaking gaskets in the positive pressure venting pipe.
• Remove any materials containing chlorine from the proximity of the boiler.
• Provide outside air for combustion directly to the boiler.
• Replace any galvanized steel vent connector piping that shows signs of corrosion.
• Verify the correct air/fuel ratio of the combustion system to reduce the cooling of flue gases within the venting or the chimney.

**See idronics #7 and #10 for more information on protecting boilers from sustained flue gas condensation.**

## 15. SYMPTOM: Slow or inaccurate system response to changing temperatures.

**Possible cause(s):**
• A temperature sensor that's incorrectly *mounted* (see Figures 4-16a,b,c).
• A surface-mounted sensor mounted with the "saddle" groove not on the pipe surface. (See Figure 4-16b).
• A temperature sensor that's incorrectly *located* (see Figures 4-16d).
• A poor electrical connection between the sensor leads and the cable leading to the controller.
• Electrical interference affecting the sensor circuit.
• Out-of-range sensor resistance versus temperature.

Figure 4-16a

Figure 4-16b

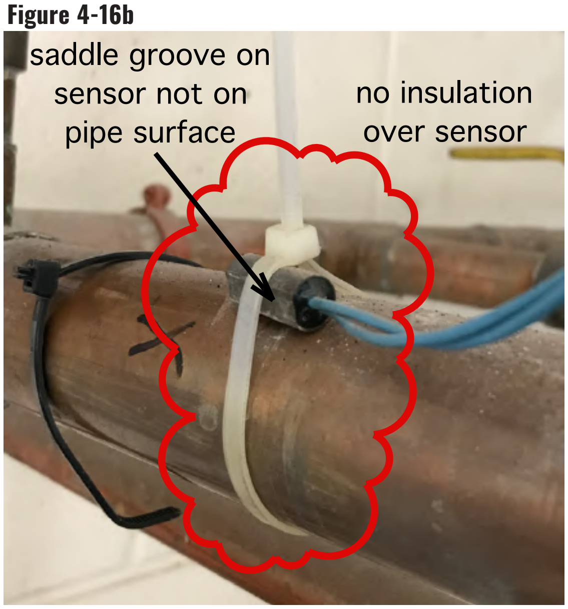
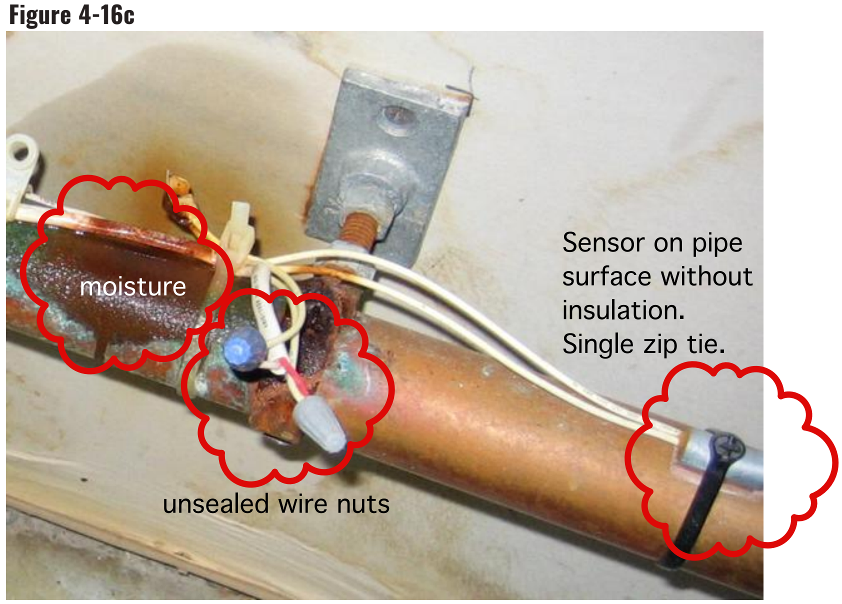



Figure 4-16c

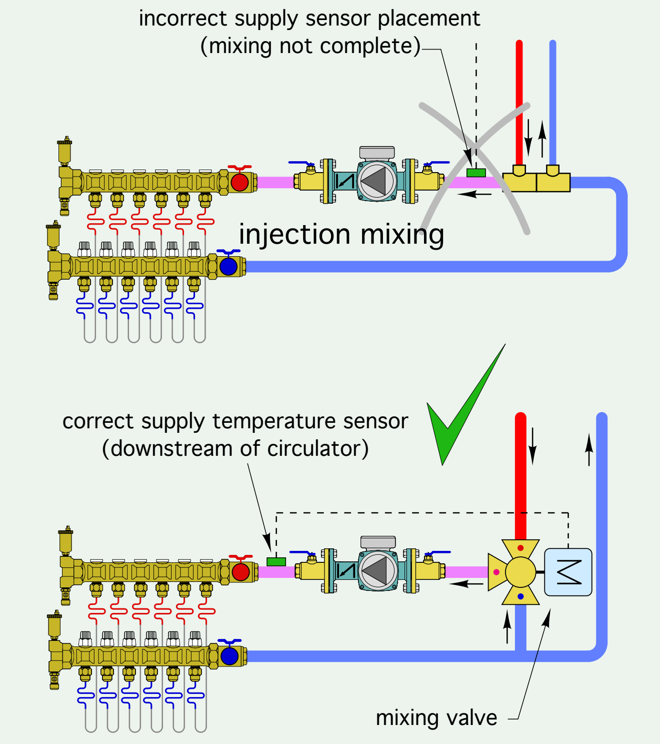



- Surface-mounted sensors that are not covered with insulation.
- High resistance caused by small diameter and excessively long sensor cables.
- A loose connection of the sensor cables to the controller terminals.
- Shorted or open sensor circuits.
- Controller settings.

**Things to check:**

- Verify that all surface-mounted sensors are in tight contact with the pipe surface and covered by insulation that extends at least 2 inches on either side of the sensor (see Figure 4-16e).
- Are the zip ties holding the sensor to the pipe intact and are they rated for the highest temperature that the pipe might reach?
- Are there any sensors that fit loosely into the sensor wells?
- Is there any sign of corrosion or loose connections where the sensor leads join the cables?
- Are there any sensor leads or cables running parallel and close to the AC wiring or near motors or transformers?
- Are there any sensors that are immersed in condensate within a well (typically on chilled-water applications)?
- Measure the resistance of suspect sensors when their temperature is stable and compare to the manufacturer's resistance vs. temperature chart.
- Verify that all sensor cables are of suitable diameter

Figure 4-16d




(gauge number), and that they are not longer than allowed by the manufacturer.

**Potential corrective action(s):**

• Be sure that the sensor mounting location is correct relative to the mixing points, circulators, heat sources, etc. When mixing is involved, mount the sensor in a location several inches downstream of the mixing point to ensure flow is fully mixed before passing by the sensor (see Figures 4-16d and 4-17)).

• Use *two* temperature-rated zip ties to secure a temperature sensor to the pipe surface.

• Cover strapped-on sensors with a minimum 3/8" thick elastomeric foam insulation sleeve that extends at least 2" on either end of the sensor housing, and seal the ends of the sleeve to the pipe to prevent air entry (see Figure 4-16e).

• Use thermal paste to bridge any small air gap between the sensor housing and the inside of the sensor well.

• Replace the sensor if its measured resistance is more than 2% in error of the manufacturer's resistance versus temperature curve.

• Use gel-filled compression connectors to bond the sensor leads to the cable.

• If the sensor cable must run parallel to and within a few inches of the AC wiring, use a twisted pair cable or shielded cable rather than a thermostat cable. Ground the shield layer on one end of the cable.

• When the sensor is mounted in a well on a chilled-water application, be sure the end of the well is sealed against water or water vapor entry.

• Check controller settings for potential adjustments to speed up or slow down controller response.

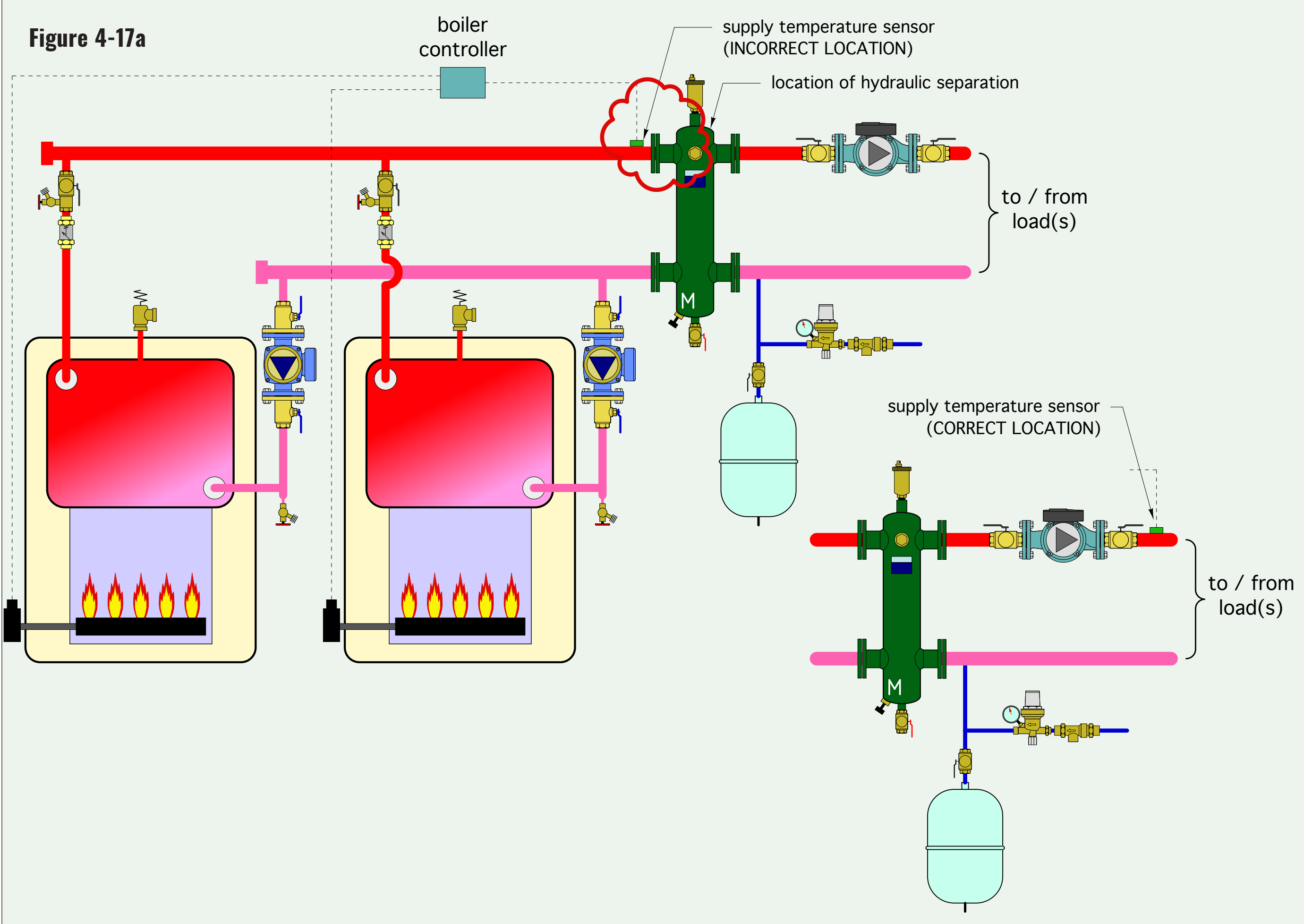
## 16. SYMPTOM: The heat source is short cycling.

**Possible cause(s):**

• The heat source is excessively oversized relative to the load.
• Insufficient flow through the heat source to carry away heat production ("flow bottleneck").
• Inability of the distribution system to dissipate the rate of heat production ("thermal bottleneck").
• Differential of the controller operating boiler is set too low.
• Lack of thermal mass in the distribution system.
• An undersized or fouled heat exchanger between the heat source and the load.

Figure 4-16e

**Figure 4-17a**




**Things to check:**

• What is the DOE heating capacity rating of the boiler, or nominal heating capacity of the heat pump, relative to a properly done design heating load estimate for the building?

• What is the temperature rise across the heat source when it is operating at or near steady state conditions?

• What is the total heat dissipation ability of the distribution system when supplied at the outlet water temperature of the heat source?

• What is the difference between the “on” temperature and “off” temperature of the heat source when it is enabled to operate (e.g., the operating differential of the controller managing the heat source)?

• If the system has a buffer tank, is it functioning properly? Is it piped correctly?

• Is there a heat exchanger between the heat source and the load? If so, is it sized properly and are its internal surfaces clean?

• Are there any Y-strainers in the flow path between the heat source and the load? If so, are the internal screens in the Y-strainers clean?

• Is the temperature sensor for the boiler controller in a system with hydraulic separation mounted downstream of the point of hydraulic separation (see Figure 4-17a)?

**Potential corrective action(s):**

• Single hydronic heat sources should not be sized greater than 10% above a properly estimated design heating load.

• Consider a staged heating plant with multiple heat sources if a wide range of heating capacity is needed.

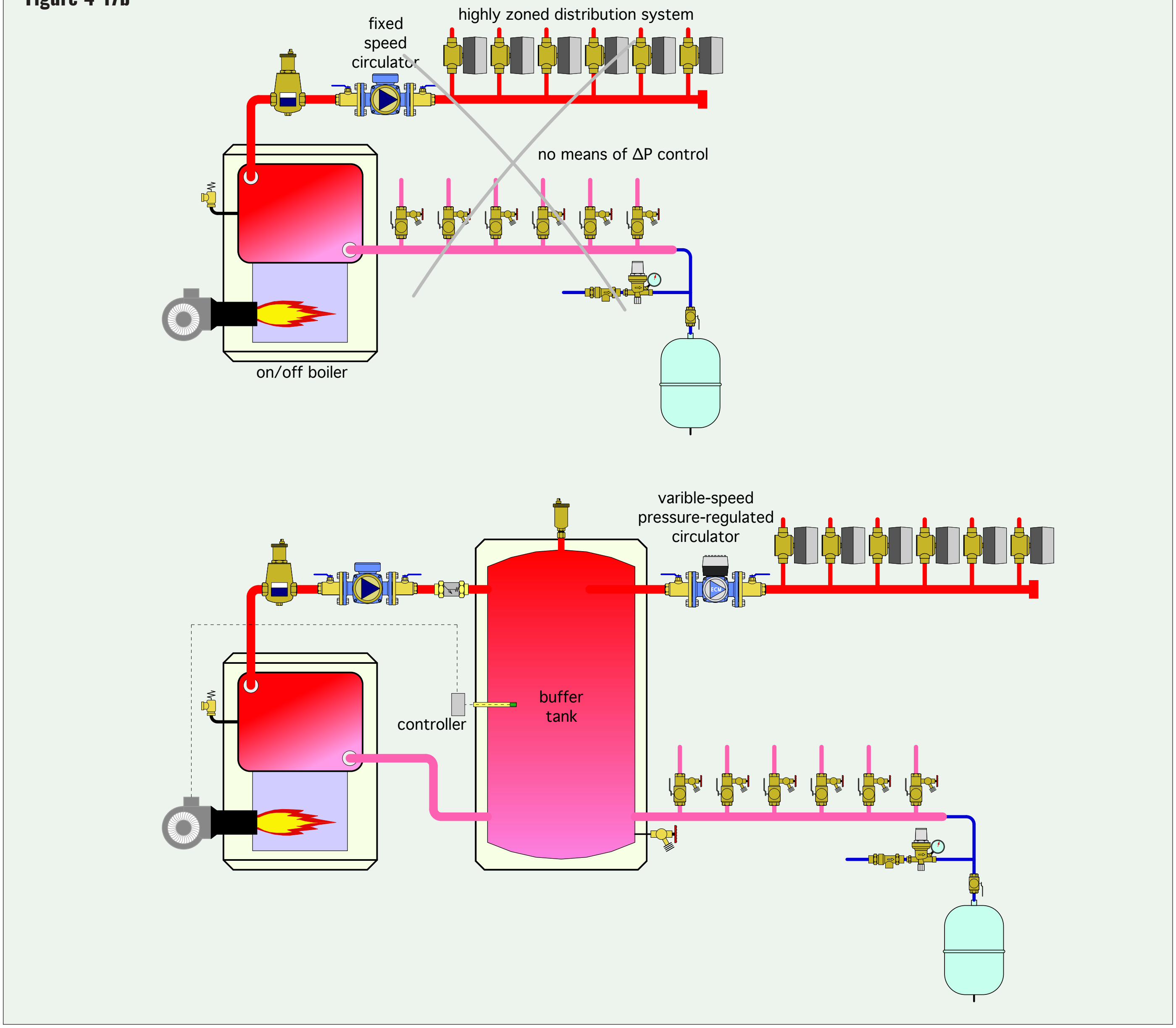
• Consider a modulating heat source (mod/con boiler or heat pump with a variable-speed compressor) if a wide range of heating capacity is needed.

• Consider adjusting the modulation rate of the heat source if possible.

• Verify that the flow rate across a boiler is not less than 1 gpm per 10,000 Btu/hr of heating output (which would yield a nominal 20ºF temperature rise). For heat pumps, the suggested flow rate is 2–3 gpm per ton (1 ton = 12,000 Btu/hr) of heat production.

• Check for anything that could limit flow rate through the heat source (such as several independently operated zone

**Figure 4-17b**




valves piped to a header directly connected to the heat source).

• Consider controls that coordinate the operation of multiple thermostats to help level the load.

• Add thermal mass between the heat source and load in the form of a buffer tank (see Figure 4-17b).

• Use a boiler reset controller with an “auto differential” function to control on/off heat sources. Auto differential widens the on/off differential of the heat source as the load decreases under warmer outdoor temperatures.

• Increase the on/off differential of the controller operating an on/off heat source.

• Consider options to partially reduce the firing rate of a boiler (i.e., reduce nozzle size on the oil burner, orifice change on gas-fired boilers, etc.). Verify what’s possible with the boiler manufacturer.

• Install controls that manage multiple load schedules to help level the load.

**See idronics #17 for information on thermal mass and buffer tanks in hydronic systems.**

## 17. SYMPTOM: Insufficient heat output from the heated wood-framed floor.

**Possible cause(s):**

• Lack of aluminum heat transfer plates (e.g., "plateless stapleup", see Figure 4-18a).
• Poorly fitted or installed heat transfer plates (see Figure 4-18b).
• High thermal resistance above the plates (subfloor and underlayment layers, padding, carpet, etc.).
• Lack of sufficient underside insulation below the tubing and plates.
• Sole reliance on bubble foil insulation below the tubing and plates (insufficient R-value).
• The supply water temperature setting is too low.
• The tube spacing is too wide for the required rate of upward heat transfer.
• Low flow rate in the tubing circuit.
• Leakage of outside air into the joist cavities where the tubing is located.
• Air temperature below the underside insulation is too low.
• Flow blockage due to kinked tubing.
• Lack of supplemental heat if load requires an average floor surface temperature above 85ºF.

**Figure 4-18a**

**Figure 4-18b**

**Things to check:**

• Are there properly installed aluminum heat transfer plates?
• What are the material layers (and total R-value of those layers) located between the bottom of the subfloor and the top of the finish floor?
• What is the R-value of the insulation under the tubing?
• What is the temperature of the space located under the underside insulation?
• What is the flow rate through the tubing circuit?
• What is the supply water temperature to the tubing circuit?
• What is the tube spacing (12" is generally considered maximum, with 8" spacing preferred for this type of installation)?
• Is there outside air leaking into the joist cavities?
• Does the space under the heated floor overheat at the same time that there is inadequate heat output to the space above the floor? This is indicative of insufficient underside insulation.
• Is there a thermostatic mixing valve with a low Cv rating used to supply reduced temperature water to the radiant floor circuits?

**Potential corrective action(s):**

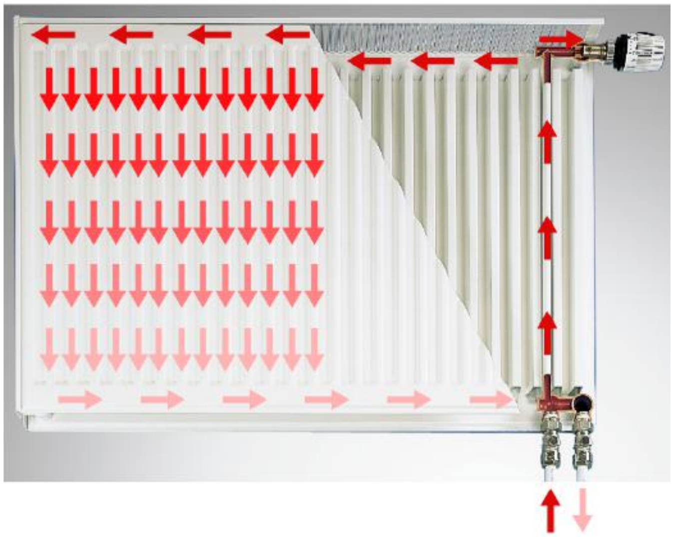
• Install aluminum heat transfer plates to the as-found "plateless" installation.
• Increase the underside insulation R-value to a minimum of 10 times the total R-value of materials above the plates.
• Verify adequate flow rate in the circuit and suggest a maximum circuit temperature drop of 20ºF under steady state design load conditions.
• Consider increasing the supply water temperature after verifying that the heat source and remainder of the installation can operate at a higher temperature.
• Be sure that no outside air can infiltrate into the heated joist cavities at the rim joist and sill locations.
• If a thermostatic valve with a low Cv rating is creating a high pressure drop, replace it with a valve having a Cv rating approximately equal to the desired flow rate through the valve to the radiant circuits.

## 18. SYMPTOM: A "banging" noise coming from a panel radiator equipped with a thermostatic valve.

**Possible cause(s):**

• Flow direction through the radiator valve is backwards, causing unstable movement of the valve disc over the valve seat, especially at low flow rates.
• Use of a fixed-speed circulator without a means of differential pressure control.
• Use of a "high head" circulator.
• Higher than necessary setting of the differential pressure bypass valve.

Figure 4-19a



• Higher than necessary ΔP setting of a pressure-regulated circulator.

**Things to check:**

• Is the flow passing through a radiator with an integral valve in the correct direction (so that flow "pushes" against the disc of the radiator valve? (Most radiators with closely spaced bottom supply and return connections, and integral valves, have their inlet connection on the left, as shown in Figure 4-19a).

• If an external radiator valve is present, does the flow arrow on the valve body correspond to the flow direction through the valve (see Figure 4-19b)?

• What is the required ΔP across the circulator when all radiator valves served by that circulator are fully open (requires some calculations)?

• If a differential pressure bypass valve is present in the system, what is its ΔP setting?

• If a pressure-regulated circulator is used, what is its ΔP setting?

• If a "high head" circulator is used, why was it selected?

**Potential corrective action(s):**

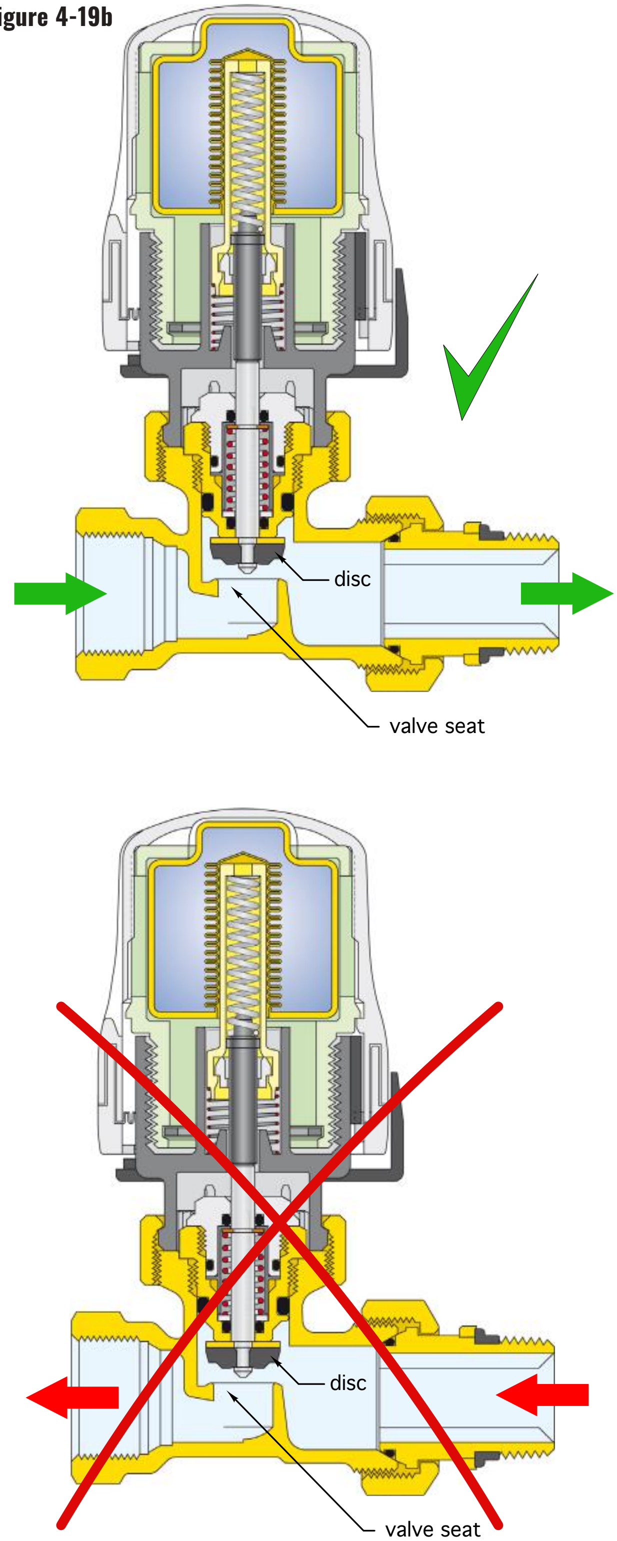
• Change piping connections to ensure flow through the radiator valve is in the correct direction.

• Reduce the ΔP setting of the differential pressure bypass valve.

• Reduce the ΔP setting of the pressure-regulated ΔP circulator.

• Change the fixed-speed circulator from a "high head" model to a circulator with a "flat" pump curve.

Figure 4-19b



# 5. RIGHTING SOME WRONGS

Figure 5-1a

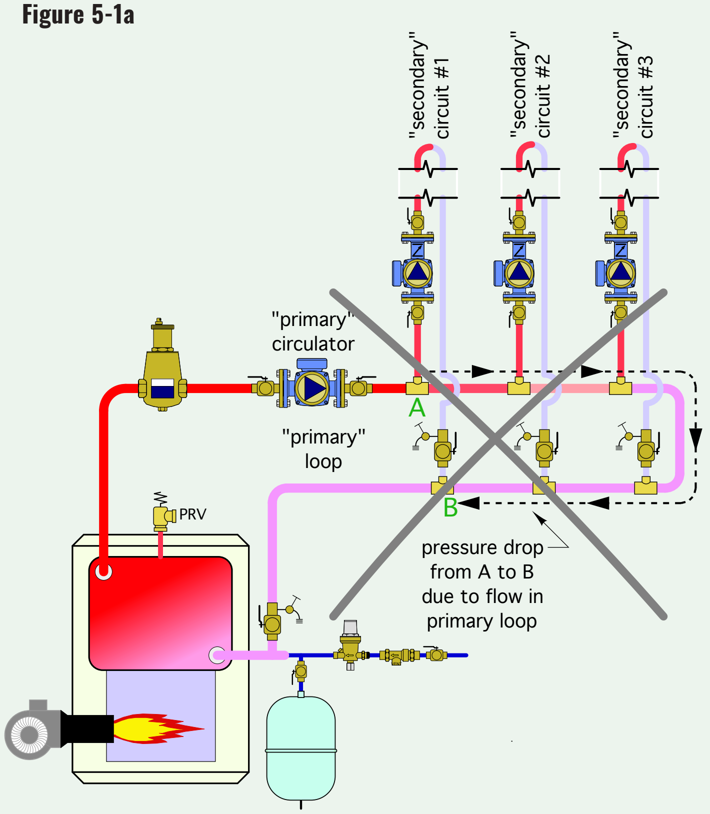
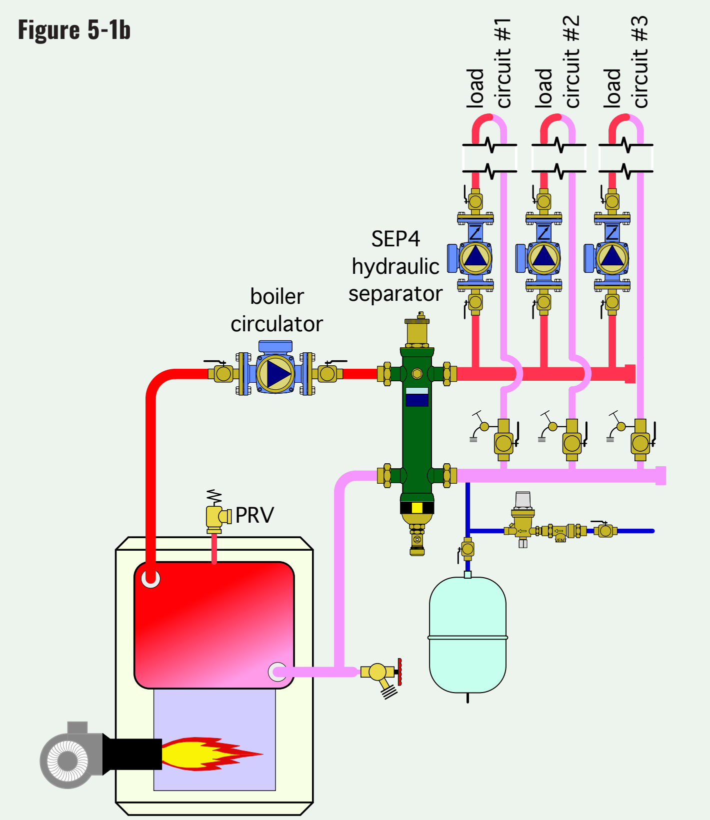



Figure 5-1b




Previous sections have described commonly encountered design or installation errors that compromise the performance of hydronic systems. This section presents examples of systems that embody several of those errors, and it shows at least one modified design that eliminates them. *Many of the errors shown have been found, often repeatedly, in real installations.*

## 1. WHAT'S WRONG: Incorrect attempts at creating primary/secondary piping.

The system shown in Figure 5-1a is an undefined piping layout. It attempts to combine the concept of a primary loop with the concept of supply and return headers.

The designer's objective was to provide the same supply water temperature to each of the three load circuits. Thus, the tees that supply each load circuit are located upstream of the tees that route water returning from the load circuits back to into the "primary loop."

This piping arrangement is the likely result of someone beginning to design a system around a primary loop, but in the process, reverting to the concept of "headers" when connecting the load circuits to that primary loop. The result is neither a primary/secondary system, nor any other acceptable piping topology.

The problem with this piping arrangement is the pressure differential created by head loss along the "primary loop." This pressure differential can induce flow through one or more of the load circuits when those circuits are *not* supposed to be delivering heat.

For example: Consider the pressure drop from point A to point B along the "primary loop" shown in Figure 5-1a. This pressure drop is due to head loss created by flow moving along the "primary loop." Once this pressure drop exceeds the forward opening threshold of the spring-loaded check valves in a given circulator, flow will be pushed through that circulator and its associated circuit. This will deliver heat to the space served by that circuit when there is no call for such heat.

**One solution:** The system shown in Figure 5-1b solves the problems described previously, while providing equal supply water temperature to each load circuit.

This system uses a Caleffi SEP4 hydraulic separator to decouple the pressure dynamics of the boiler circulator from that of the load circulators. The SEP4

Figure 5-2a

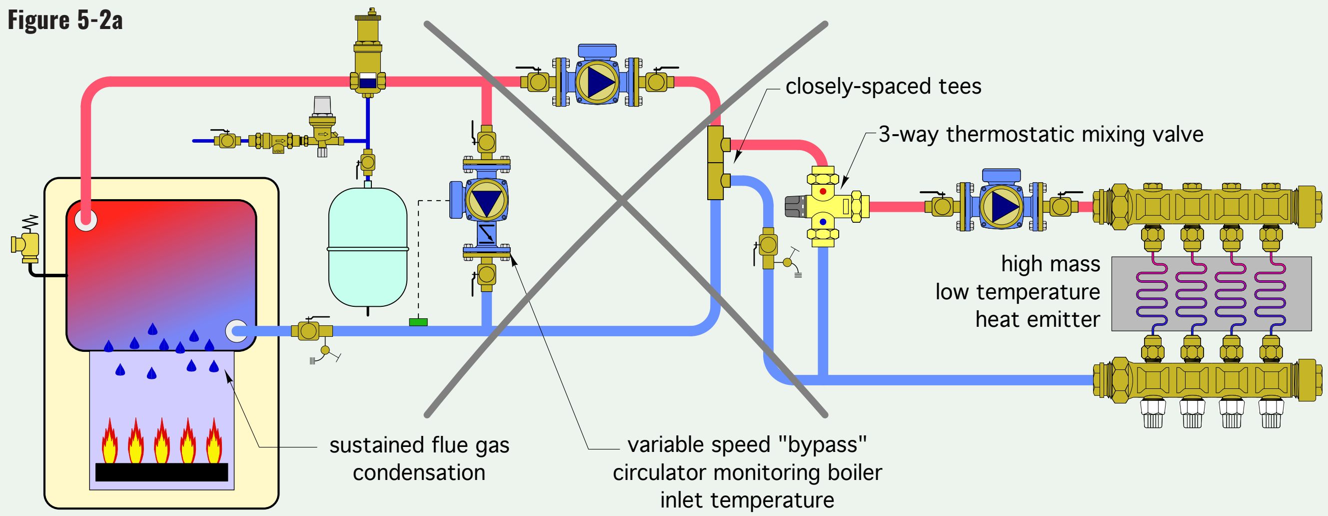
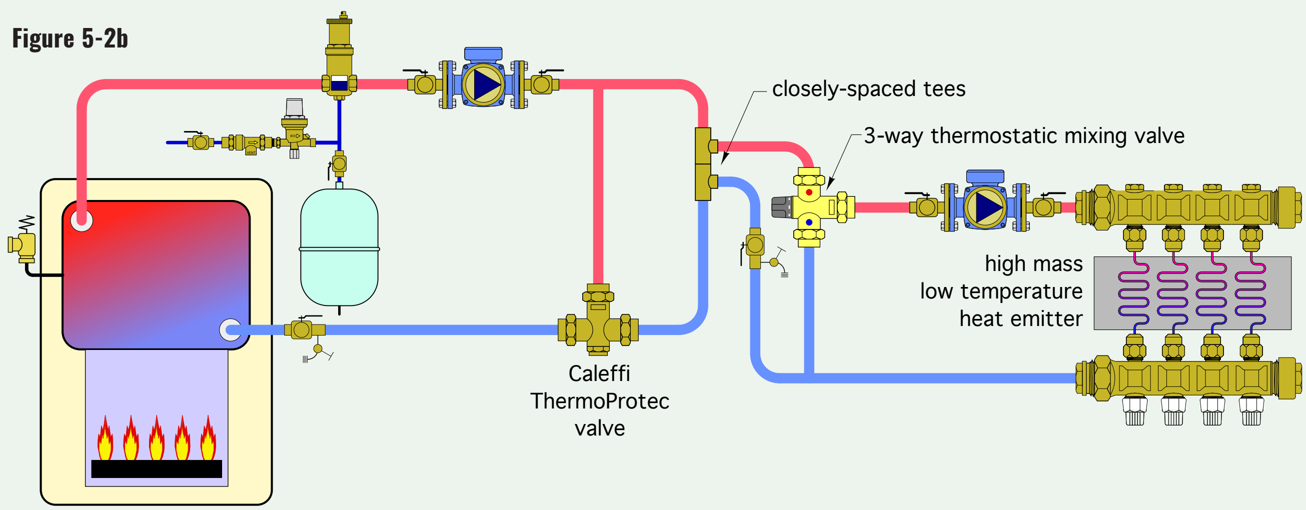



Figure 5-2b




also provides air, dirt and magnetic particle separation for the system. The short and generously sized headers in combination with the SEP4 also decouple the pressure dynamics of the load circulators from each other. Each load circuit receives water at the same supply temperature.

## 2. WHAT'S WRONG: A temperature-responsive boiler bypass circulator is installed with the intent of preventing sustained flue gas condensation, but condensation still occurs.

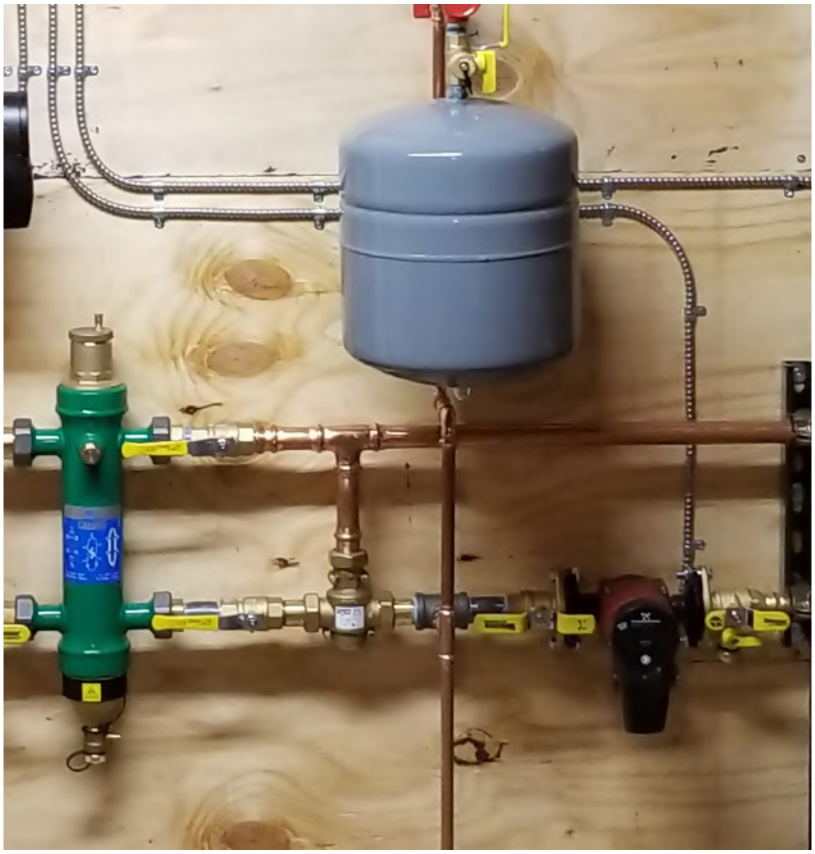
The system shown in Figure 5-2a uses a temperature-responsive "bypass" circulator that is supposed to boost boiler inlet temperature to a level where sustained flue gas condensation will not occur. A 3-way thermostatic mixing valve is used to control supply water temperature to the low-temperature/high-thermal mass load.

The original concept for this design is that the bypass circulator would increase speed when it detects that the boiler inlet temperature is below its setpoint (e.g., low enough to allow sustained flue gas condensation).

However, regardless of the flow rate created by the bypass circulator, this arrangement cannot increase the rate of heat generation by the boiler to match that *temporarily* created by the high thermal mass distribution system. *To ensure anti-condensation protection, the mixing system must have the ability, when necessary, to completely uncouple the heat production of the boiler from the heat dissipation of the load.*

One modification that solves the sustained flue gas condensation issue is to install a Caleffi ThermoProtec valve, as shown in Figure 5-2b.

Figure 5-2c



The ThermoProtec valve contains a thermostatic element to sense the boiler inlet temperature whenever the boiler circulator is operating, and when necessary, restrict the amount of cool fluid returning from the load so that the boiler inlet temperature remains above 130ºF.

Figure 5-2c shows an installation where a ThermoProtec valve is used to prevent sustained flue gas condensation in a cast iron boiler supplying a low-temperature distribution system.

Another viable option is to use a motorized 3-way mixing valve operated by a controller that senses boiler inlet water temperature as well as the supply water temperature to the load, as shown in Figure 5-2d.

This design eliminates the need to use two mixing valves, one for supply temperature control and the other for boiler protection. It replaces the central air separator and closely spaced tees with a SEP4 hydraulic separator to provide hydraulic separation between the boiler circulator and load circulator. The SEP4 also provides air, dirt and magnetic particle separation.

Figure 5-2d

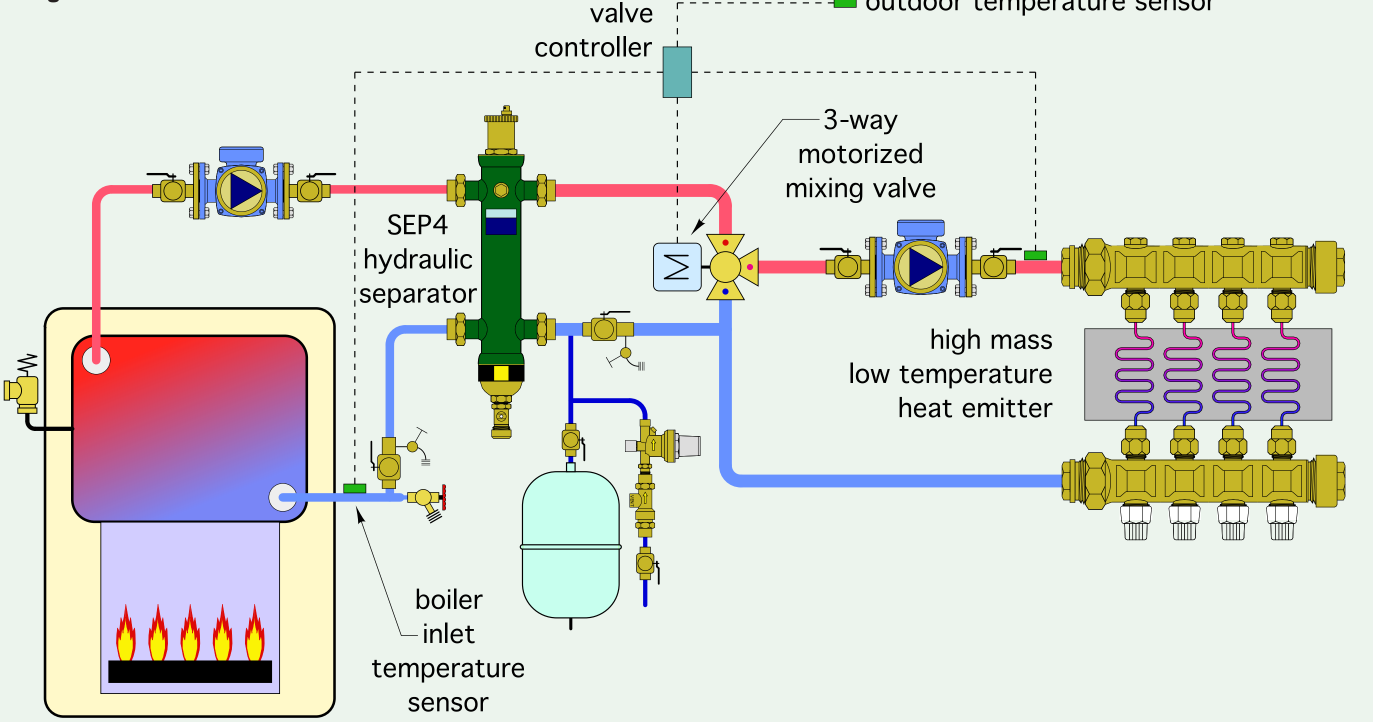
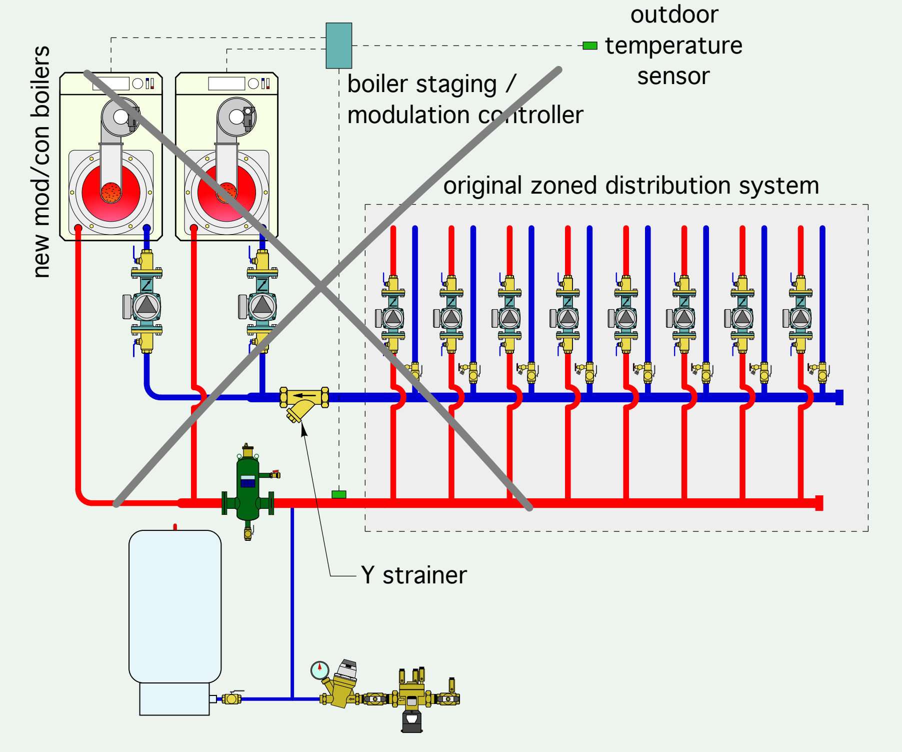


Figure 5-3a




flo-control valves, which is typically about 0.5 psi).

Other deficiencies include lack of isolation valves to service the Y-strainer, or to isolate either boiler if necessary.

Figure 5-3b shows a revised design that provides hydraulic separation between the boiler circulators and the load circulators. The Caleffi SEP4 provides hydraulic separation as well as high-efficiency air, dirt *and magnetic particle* separation. The latter function is especially important in older systems that often contain more ferrous metal and older seals, and thus, have a higher likelihood of containing iron oxides. The Y-strainer and central air separator are no longer necessary.

If this system were being designed without the need to include the existing zone circulators, a single

## 3. WHAT'S WRONG: Lack of hydraulic separation, heat migration into inactive zones and high electrical energy use.

An installer is asked to retrofit two high-efficiency mod/con boilers to an existing multi-zone distribution system. Each of the new boilers was shipped with a dedicated circulator. The installer included a Y-strainer to capture possible dirt in the existing portion of the system before it could enter the boilers. Figure 5-3a shows the resulting piping.

The main problem with this layout is that the boiler circulators are in series with the load circulators. Either boiler circulator, when operating, sets up a pressure differential between the supply and return headers, which will likely cause some flow in all the zone circuits that are supposed to be off (assuming that the pressure differential exceeds the forward opening resistance of the

Figure 5-3b

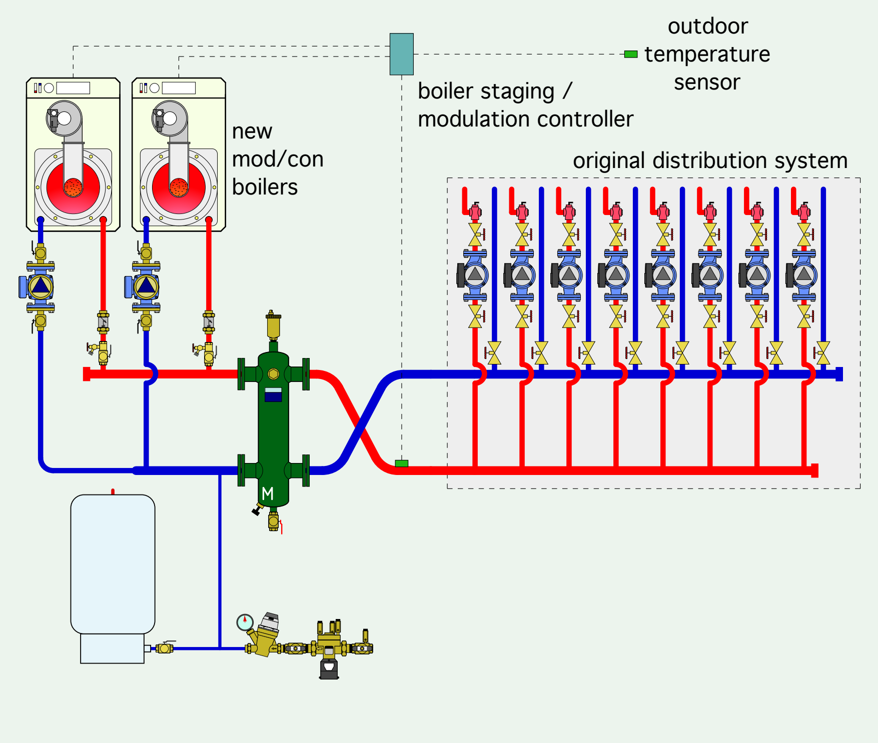
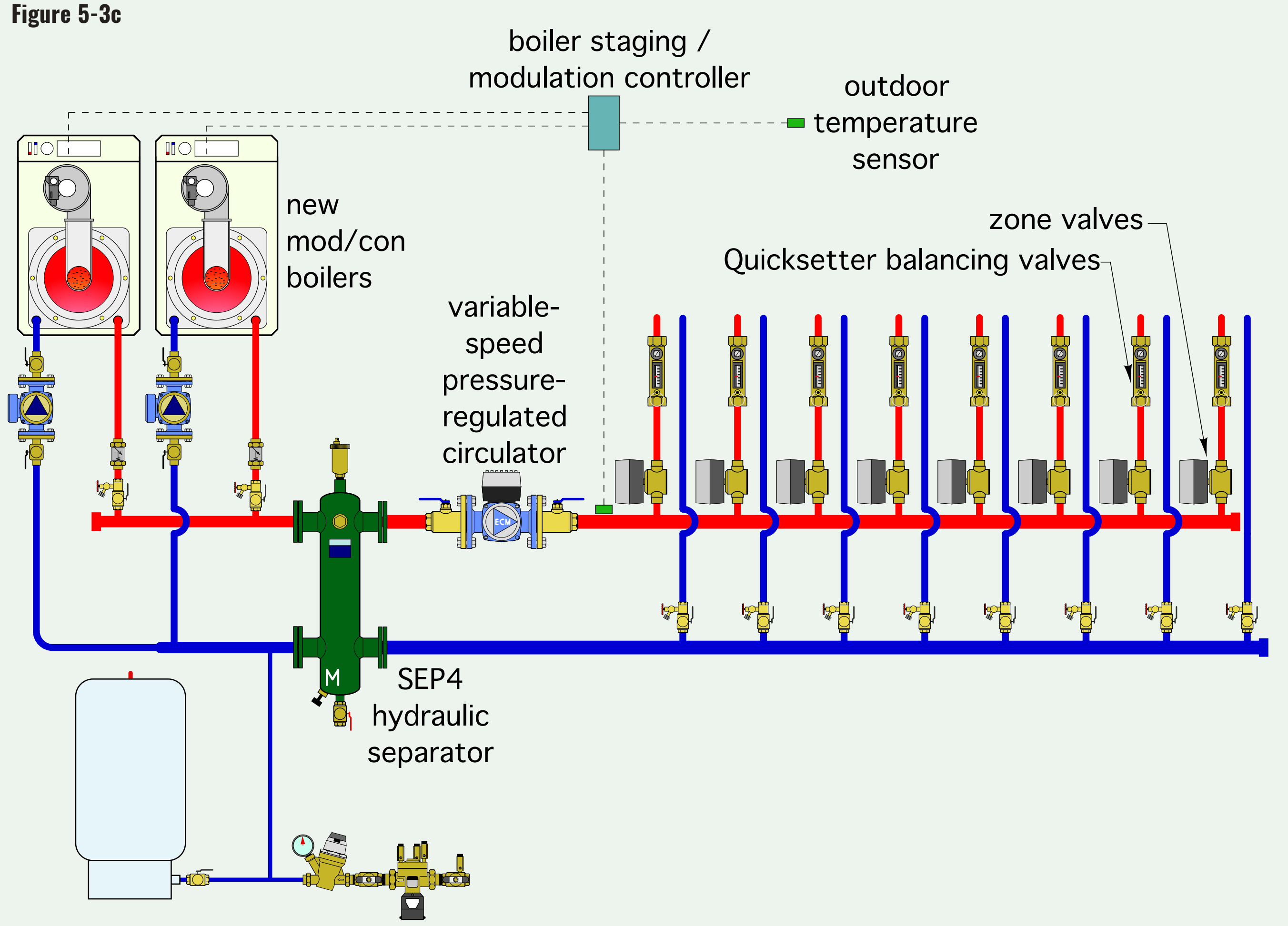


**Figure 5-3c**




variable-speed pressure-regulated circulator could be used in combination with a zone valve on each load circuit. This configuration would use significantly less electrical energy, while still providing stable and independent control of each load circuit. Figure 5-3c shows this configuration, which might also be justified as a retrofit strategy based on electrical cost savings.

## 4. WHAT'S WRONG: Short cycling of heat sources resulting in wasted energy.

Figure 5-4a shows one attempt at combining a monobloc air-to-water heat pump with an auxiliary mod/con boiler. The load is a highly zoned radiant panel heating system.

The thought behind this design was to let the heat pump supply warm fluid to the zone loads whenever possible, but also to use a temperature sensor input on the boiler to monitor the supply water temperature to the manifold station, and fire the boiler when necessary to boost that supply temperature. If the outdoor temperature was too cold for the heat pump to operate, the boiler would become the sole heat source.

Problems with this design include the need to keep the heat pump circulator (P1) operating whenever there is a call for heat from any zone. This would be true even if the heat pump was down for service. This configuration could potentially dissipate large amounts of heat outside the building during times when the boiler is the sole heat source. If the heat pump had to be removed for repair, temporary piping to complete the piping loop would be necessary.

There is also going to be short cycling of both heat sources since neither can modulate their heat output low enough to match the demand of a single operating load circuit.

Figure 5-4b shows a modified design that avoids these issues.

Figure 5-4a

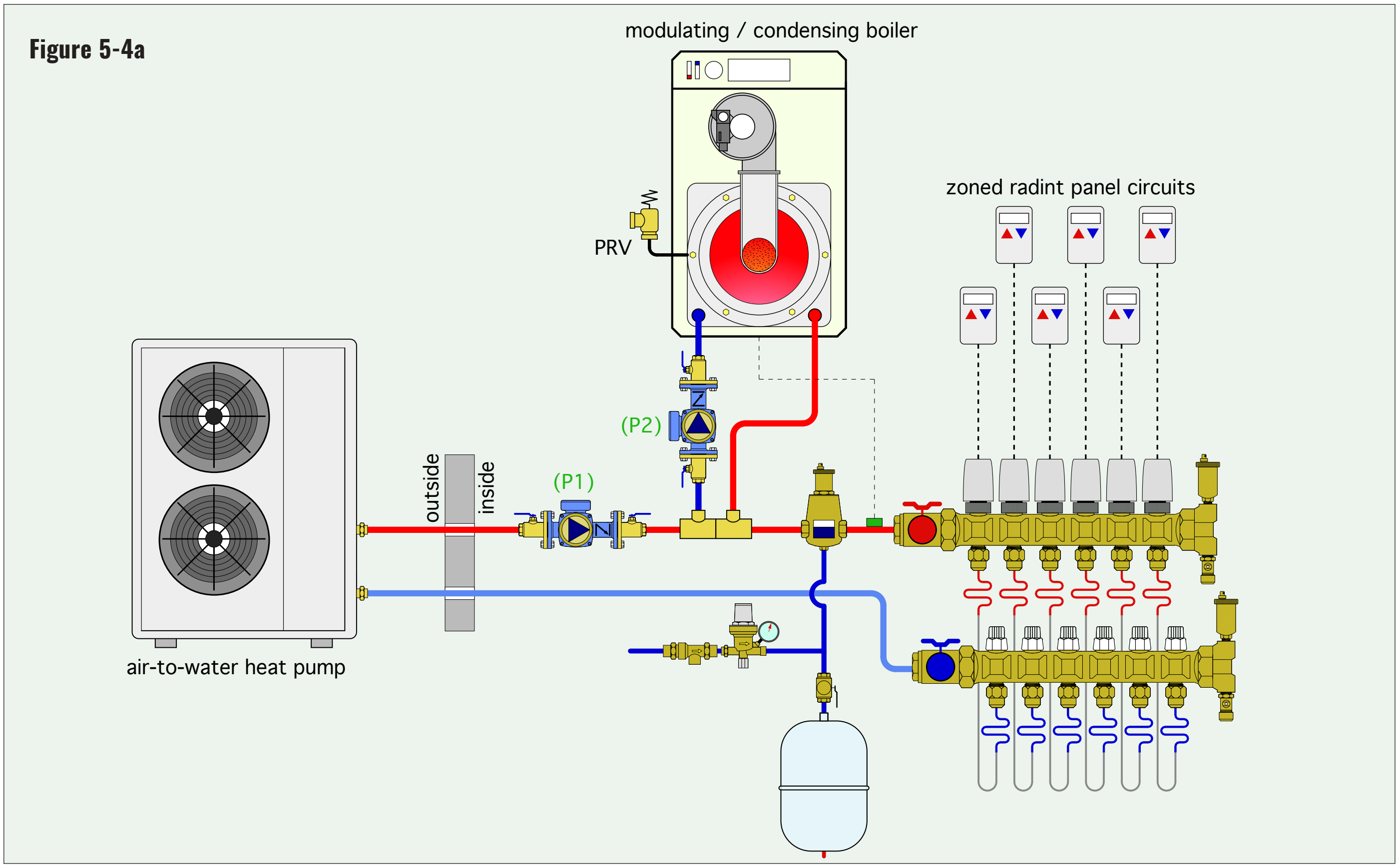
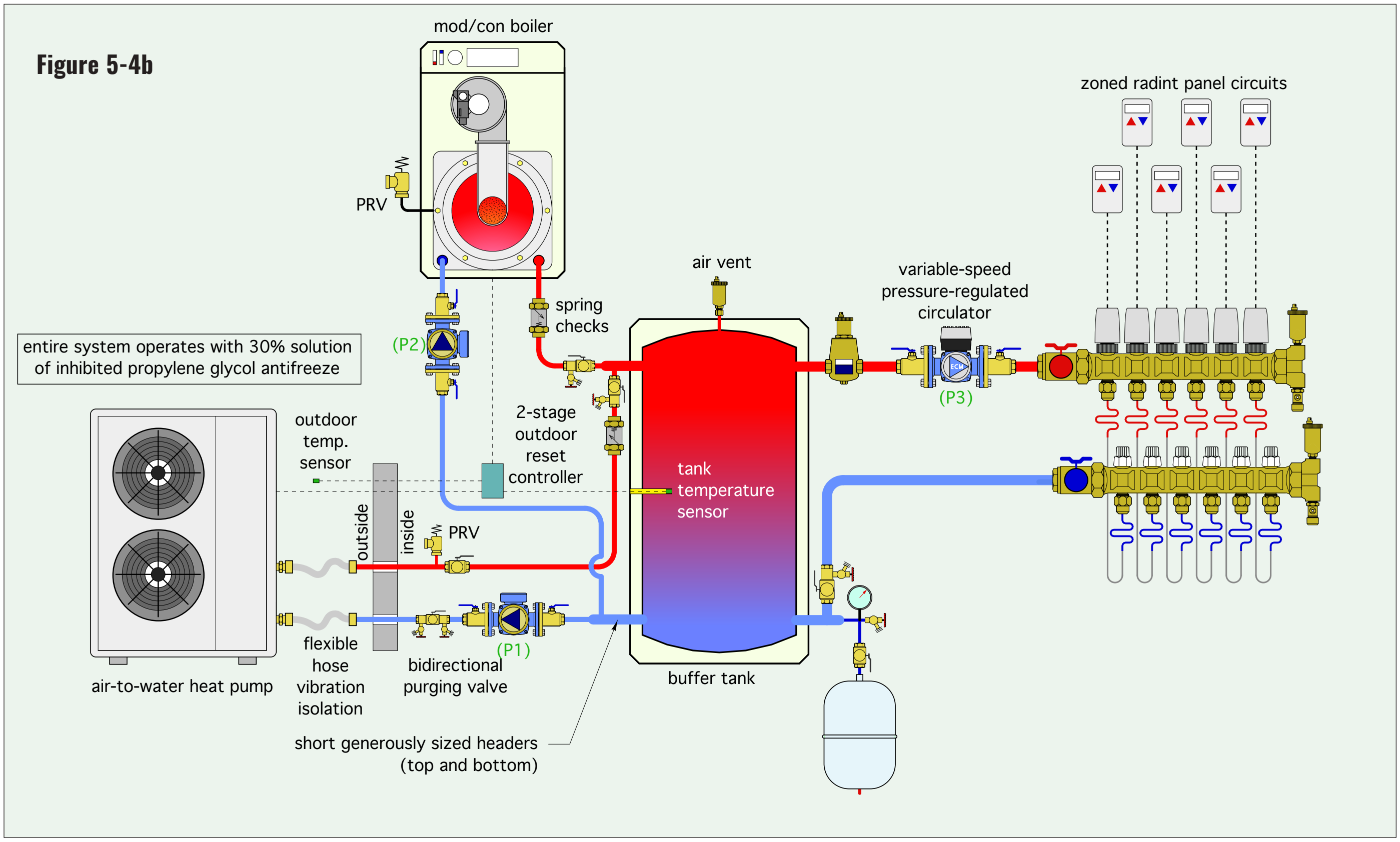



Figure 5-4b



Both heat sources are piped in parallel, and each can operate independently. Both heat sources connect to a buffer tank that moderates between the rate of heat production and heat dissipation by the highly zoned distribution system. A variable-speed pressure-regulated circulator automatically adjusts its speed in response to the number of active zones. The entire system operates with a 30% solution of propylene glycol antifreeze, which is necessary to protect the heat pump from freezing. Spring-loaded check valves prevent reverse thermosiphoning from the buffer tank, as well as flow reversal when only one heat source is operating. A 2-stage controller maintains the temperature of the buffer tank based on outdoor reset control, which reduces water temperature under part load conditions and improves the seasonal COP of the heat pump.

A 2-port purging valve allows the antifreeze solution to be pumped into the system through one port, while air exits through the other port.

Flexible reinforced hoses are used to reduce vibration transmission from the heat pump to the rigid piping.

## 5. WHAT'S WRONG: Unstable operation when high-mass and low-mass heat emitters are combined, a damaged heat source, flow reversal and noise from certain radiator valves.

This system is based on a design for a modest super-insulated home in a cold Northern climate. The home's design load is only 18,000 Btu/hr. The owners are planning to install a 12 KW solar photovoltaic electrical system, with the hopes of operating the house on a "net zero" basis. The local utility offers net metering, allowing surplus electrical power to be sent to the grid at full retail rate. Some of that "banked" electrical energy can be used during nighttime or on low solar gain days.

**Figure 5-5a**

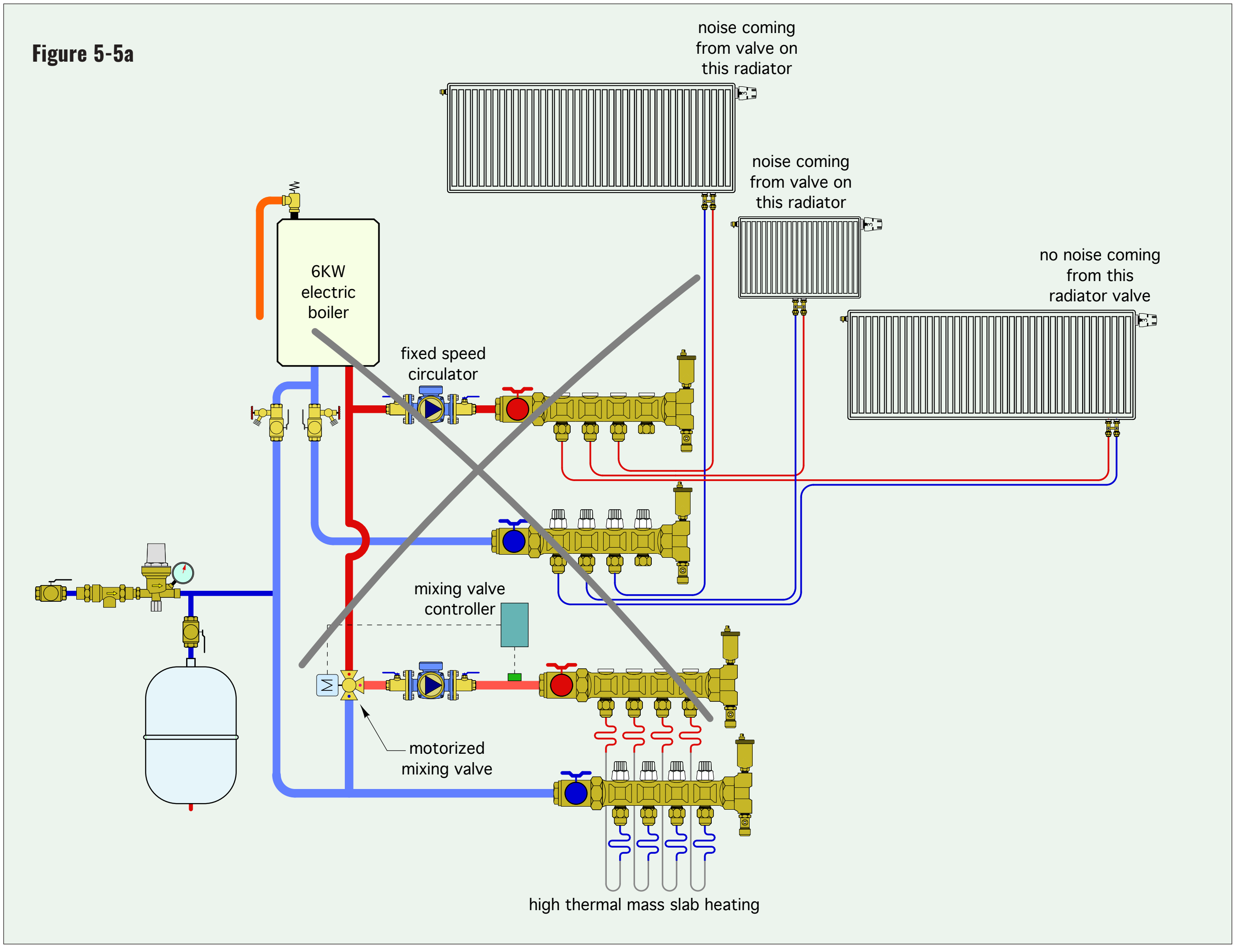
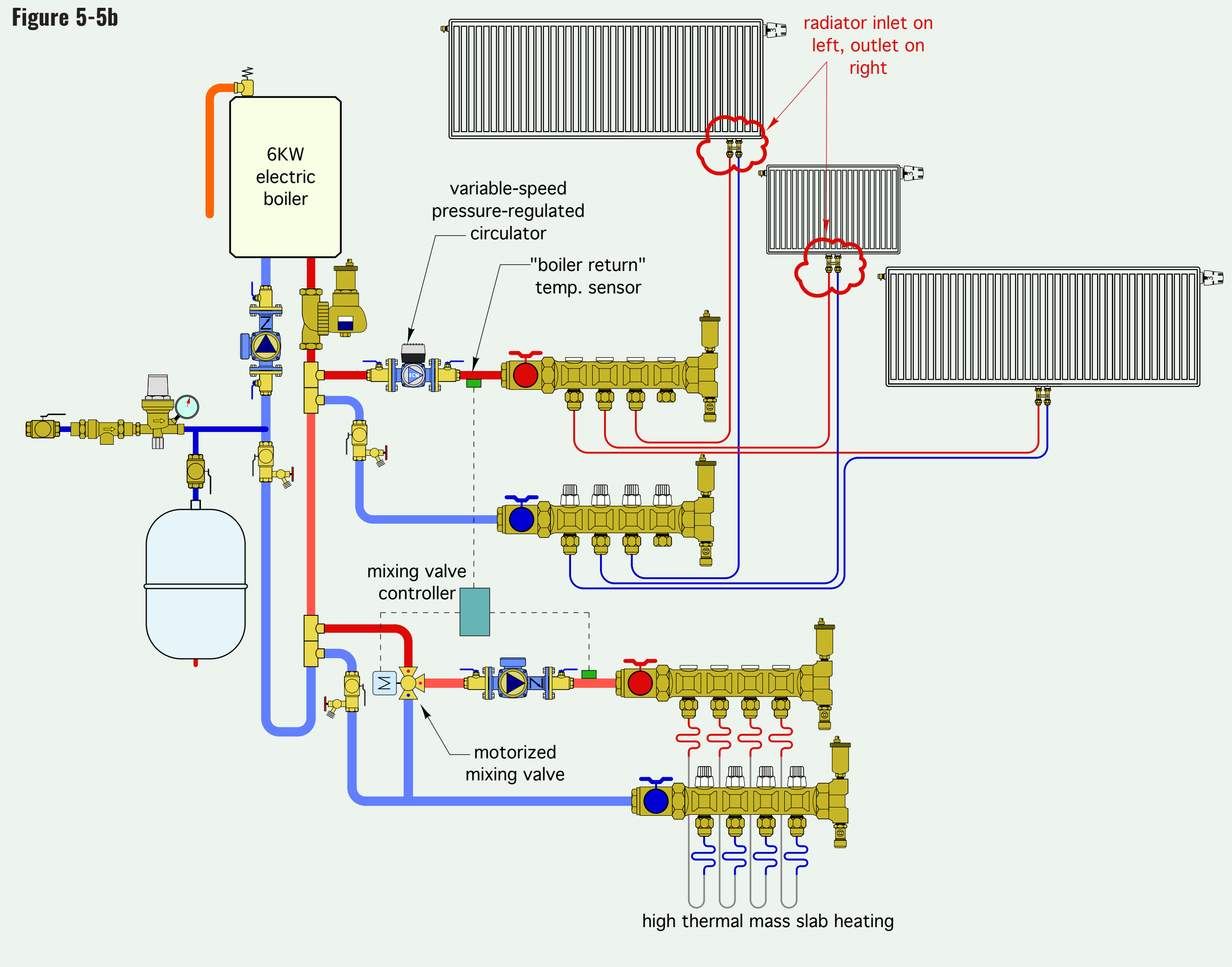


Figure 5-5b




The designer has selected a 6 KW (20,500 Btu/hr) electric boiler for the heat source. That boiler will supply floor heating in the basement slab, and three panel radiators on the main floor. The system was installed as shown in Figure 5-5a.

The owners report that, although the system is generally comfortable, they've noticed the main living room areas served by the panel radiators get cool and remain that way for two or three hours whenever they turn up the basement thermostat.

Other issues reported by the owners include having to replace some burned-out heating elements in the boiler, air noise in the system, occasional flow noise when only one panel radiator is operating and heat migrating into the floor heating portion of the system when the panel radiators are operating.

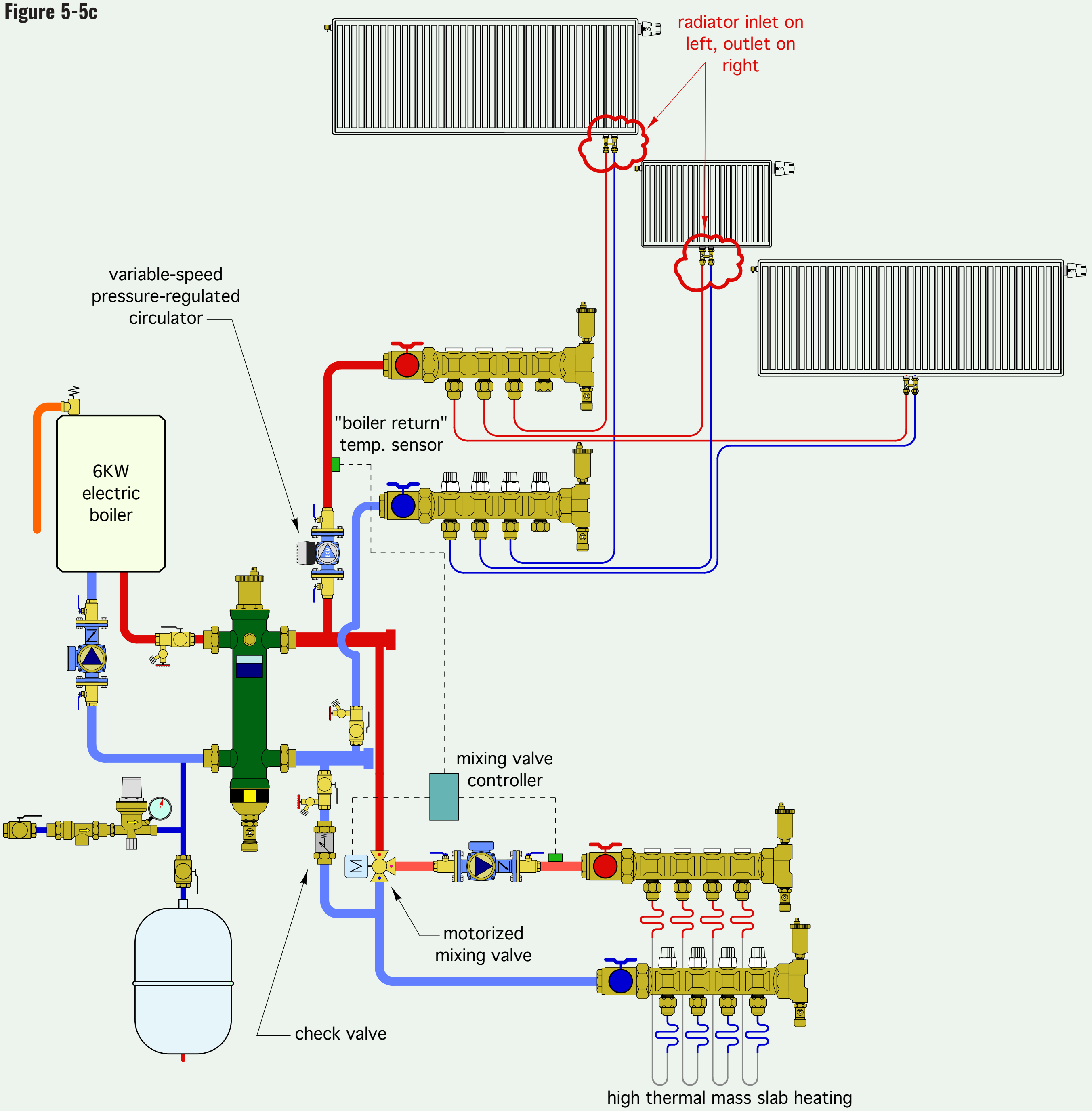
There are several issues with this system. They include:

• Electric boilers require a minimum flow rate whenever they operate to prevent their elements from overheating. If only one panel radiator is operating, it's likely that this minimum flow rate through the boiler would not be met, and hence the underlying reason for the burned-out elements.

• The use of a fixed-speed pump, in combination with the thermostatic valves on the radiators, requires some means of differential pressure control. Without this control, flow noise can occur at the thermostatic radiator valves when only one of the radiators is allowing flow, and thus, the fixed-speed circulator is operating at high differential pressure.

• This design places the panel radiator subsystem and the floor heating subsystem in parallel. Without check valves

**Figure 5-5c**




on the return side of both subsystems, flow reversal is possible whenever one subsystem is on and the other is off. This is likely the underlying reason for heat migration into an inactive subsystem when the other subsystem is operating.

• The drop in heat output from the radiators when the basement floor-heating thermostat is turned up is due to the high-thermal mass floor slab temporarily absorbing heat at a rate higher than the output of the boiler. This transient condition would eventually diminish but would reoccur each time the thermostat controlling the floor slab portion of the system is turned up, especially following a deep setback condition.

• The noise coming from two of the thermostatic radiator valves is due to a reversal of the supply and return piping connecting at the bottom of the radiator. This reversal causes flow to move backward through the radiator's valve, which can result in cavitation or "thumping" sounds when the valve plug is close to its seat. Most panel radiators have specific requirements on where the supply and return piping connect. The most common configuration has the supply on the left, and the return on the right, as viewed from the front of the radiator. Technicians should always verify that flow passes through radiator valves in the correct direction. Small details matter…

Figure 5-5b shows a modified design for the system.

The modified design uses a boiler loop with a dedicated circulator to ensure the necessary flow through the boiler whenever it operates. The loop is equipped with a Discal air separator, makeup water assembly and purging valve.

Both subsystems are connected to the boiler loop using closely spaced tees. These tees provide hydraulic separation between the circulators in the subsystems and the boiler circulator. The panel radiator subsystem is connected closest to the boiler to receive the higher available water temperature. A variable-speed pressure-regulated circulator provides flow and differential pressure control as the thermostatic valves on the radiators open and close.

*A key feature in the modified system is to use the "boiler return" temperature sensor to detect the water temperature supplied to the manifold station serving the panel radiators.* The mixing valve controller monitors the temperature of this "boiler return" sensor whenever the floor-heating subsystem is operating. If the supply temperature to the radiators drops below the minimum "boiler return" setting of the controller, the 3-way mixing valve begins to reduce the hot water portion of the mixed stream — as necessary — to maintain a minimum supply temperature to the radiators, and prevent a drop in heat output from the radiators when the floor slab is undergoing transient warm-up. The boiler would be operating at full output under such conditions, delivering heat to the building as fast as possible, but "favoring" heat output from the radiators as the slab warms to its nominal operating temperature.

All three radiators now have the supply pipe connecting on the left and the return pipe on the right. This provides the correct flow direction through the radiator valve, preventing cavitation or other sounds.

Figure 5-5c shows another possibility. This design uses a SEP4 hydraulic separator to eliminate the need for the closely spaced tees and air separator. It also likely reduces the piping and fitting count for the boiler loop, and provides dirt and magnetic particle separation, which was not provided in the previous designs. The short and generously sized headers on the load side of the separator ensure good hydraulic separation between the variable-speed pressure-regulated circulator supplying the panel radiators, and the fixed-speed circulator supplying the slab heating circuits.

The mixing valve controller still monitors the supply water temperature to the panel radiators using its "boiler return" sensor, and reduces hot water flow into the mixing valve, when necessary, to ensure adequate supply water temperature to the panel radiators.

## SUMMARY

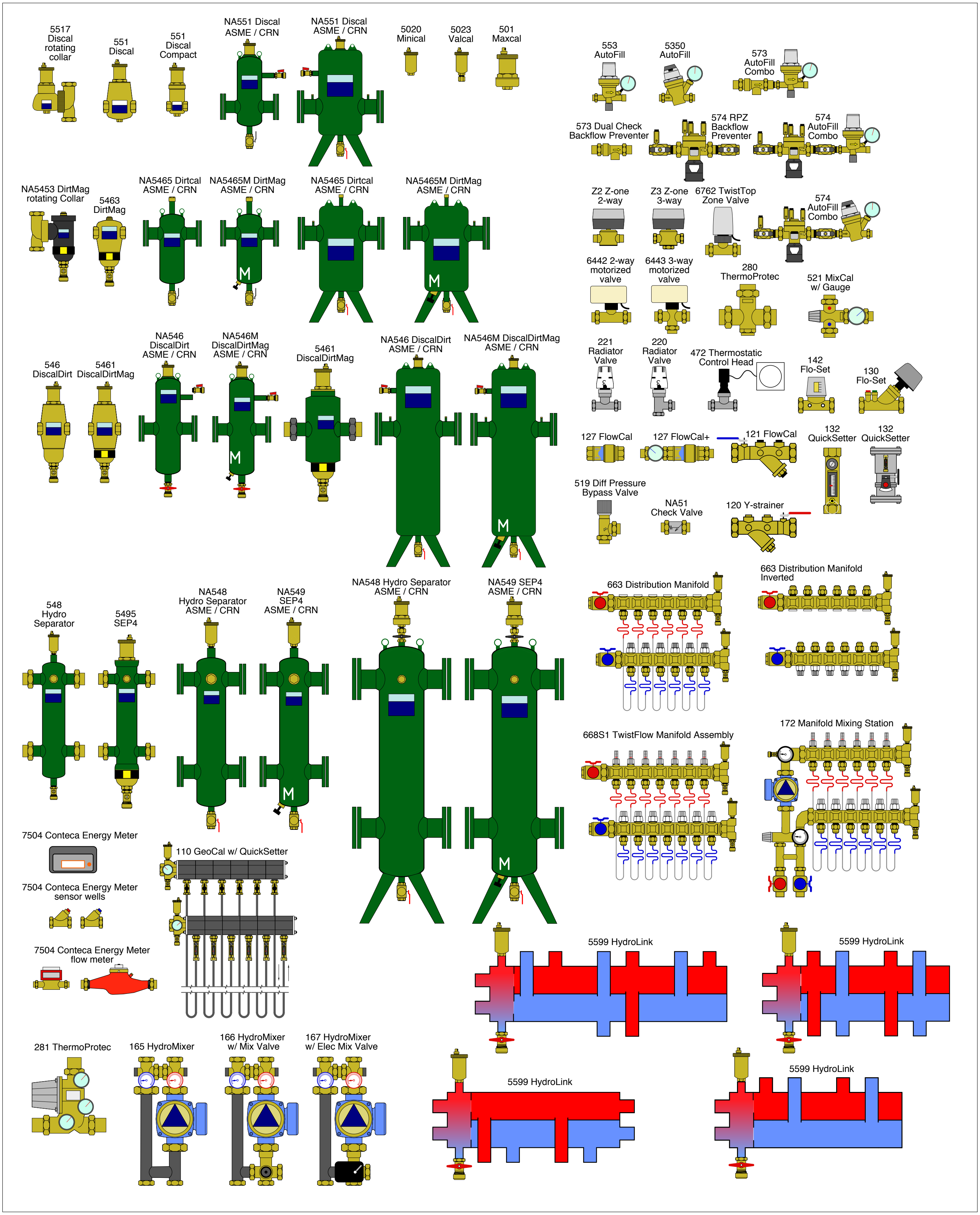
Troubleshooting hydronic heating and cooling systems, like any professional talent, is developed over time. Competence requires years of experience involving all stages of design, installation and service. The continuous introduction of new hardware, as well as the perseverance of legacy hardware, demands constant honing of troubleshooting skills.

This issue of *idronics* is not a substitute for such experience, but rather a guide to help novice technicians "zero in" on various generic performance issues based on a systematic approach and knowledge of commonly occurring symptoms.

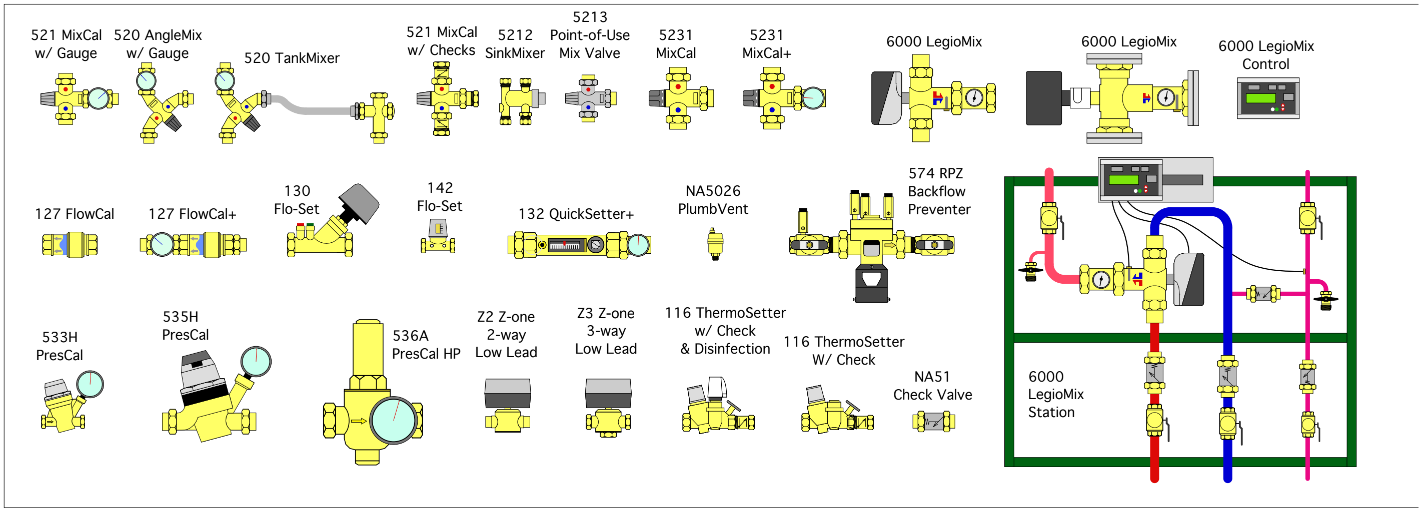
Technicians are encouraged to learn the intricacies of the specific heat sources and controls they will be working with, to supplement the information presented in this issue.

They are also encouraged to follow the many cited links to previous issues of *idronics* that provide broader coverage for a wide range of specific topics related to hydronic systems.

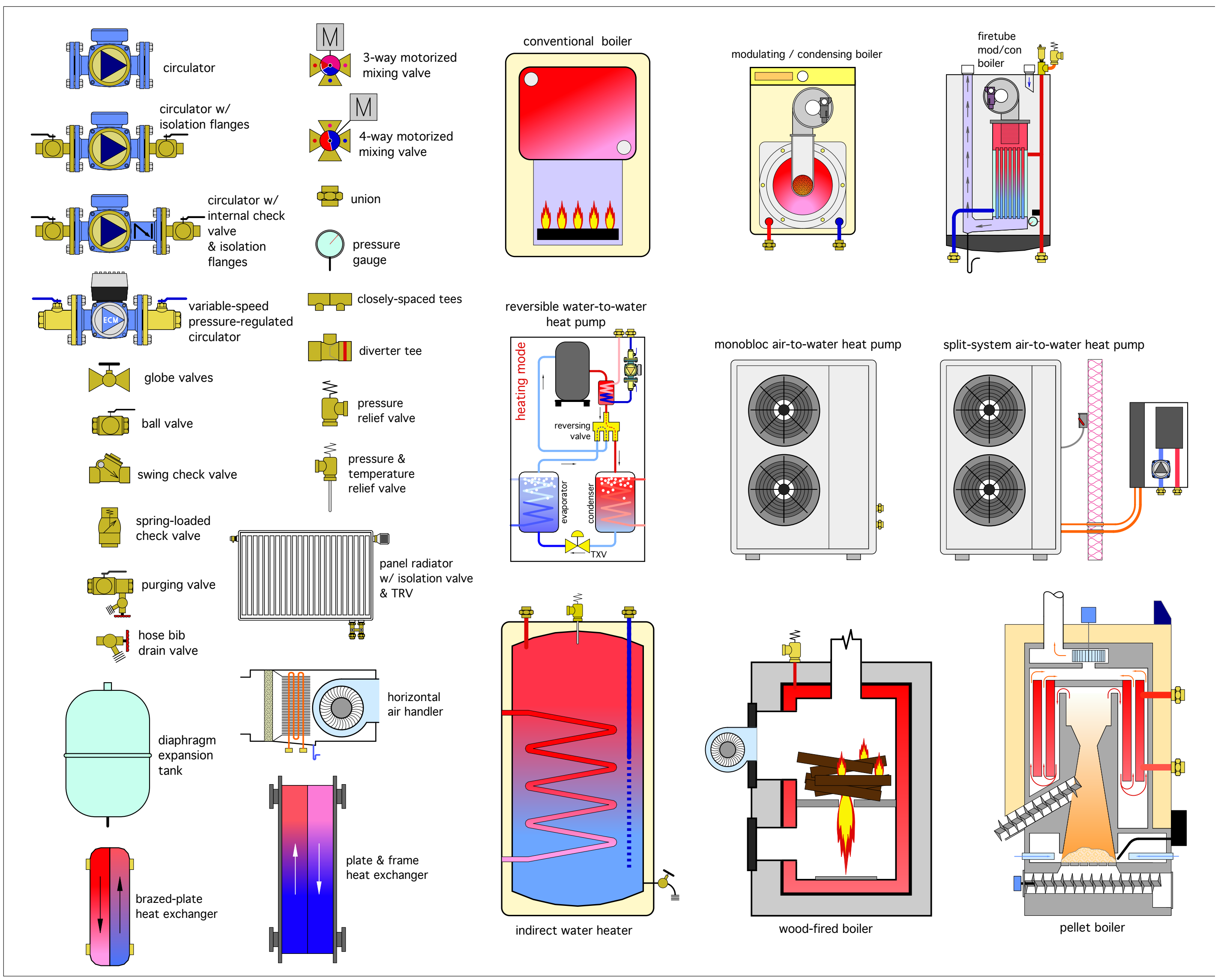
# APPENDIX A: CALEFFI HYDRONIC COMPONENTS



# APPENDIX B: CALEFFI PLUMBING COMPONENTS




# APPENDIX C: GENERIC COMPONENTS



# 132 QUICKSETTER™
# STATIC BALANCING VALVE WITH INTEGRAL FLOW METER

## FAST, EASY AND ACCURATE BALANCING

The Caleffi QuickSetter's built-in visual flow meter simplifies balancing by allowing the contractor to adjust flow while viewing flow rate directly on the valve itself. There is no need for time consuming differential pressure instruments that traditional static balancing valves require. Zone balancing is fast, easy and accurate with QuickSetter.

## PERFORMANCE

| | |
|---|---|
| MAX PRESSURE | 150 psi (10 bar) |
| WORKING TEMPERATURE RANGE | 14 — 230°F (-10-110°C) |
| MAX. PERCENTAGE OF GLYCOL | 50% |

## PRODUCT RANGE - Quicksetter 132 Series

| SIZES | FLOW SCALE: (GPM) | CV | CODE | |
|---|---|---|---|---|
| | | | NPT | PRESS |
| ½" | 0.5—1.75 | 3.0 | **132**432A | **132**436A |
| ¾" | 2.0—7.0 | 6.3 | **132**552A | **132**556A |
| 1" | 3.0—10.0 | 8.3 | **132**662A | **132**666A |
| 1¼" | 5.0—19.0 | 15.2 | **132**772A | **132**776A |
| 1½" | 8.0—32.0 | 32.3 | **132**882A | **132**886A |
| 2" | 12.0—50.0 | 53.7 | **132**992A | **132**996A |

All models supplied with pre-formed insulation shell

# PRODUCT FEATURES

### PULL-ADJUST-RELEASE:

Due to built-in direct reading flow meter, setting flow is as simple as: pulling ring, adjusting control stem until desired flow rate is reached, then releasing ring. Saves significant time compared to valves requiring use of a DP instrument or manometer.

### ALWAYS CLEAR FLOW SCALE:

Metal flow indicator ball travels within transparent isolated glass channel, attracted to the magnetic disc as it moves within the by-pass indicating GPM. Scale glass never clouds over. Provides clear, reading unlike traditional sight flow meters.

### PROTECTIVE BYPASS VALVE:

When not measuring or adjusting flow, by-pass valve stays closed thus preventing flow within by-pass channel. Protects potential debris from interfering with spring/magnetic disc mechanism.

### PRE-FORMED INSULATION SHELL:

Energy savings from conforming insulation shell. Prevents formation of condensation on body surface in cooling circuits.

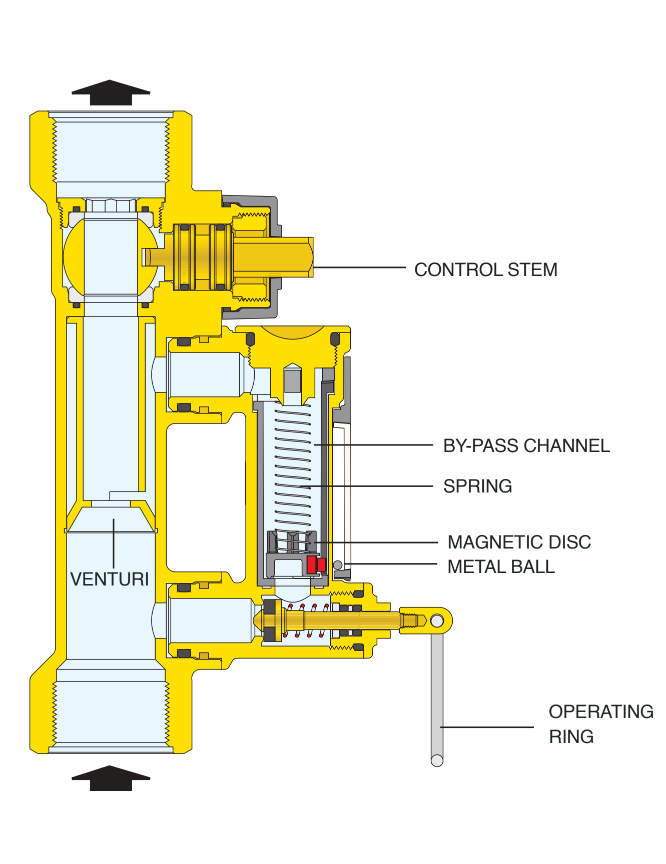
### MEMORY POINTER:

Sliding pointer on the scale provides flow rate memory indication.

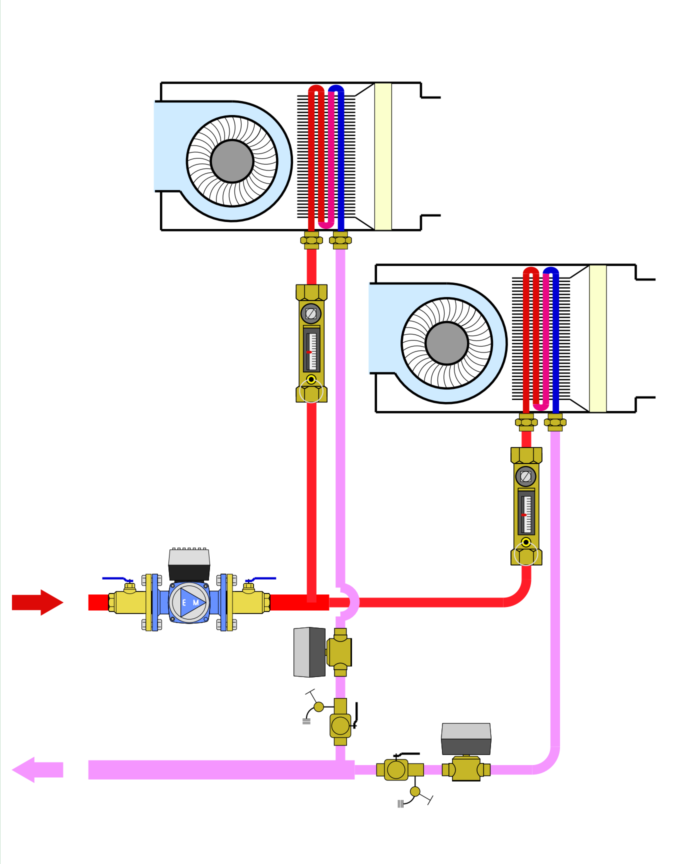
### SIMPLE SERVICING:

By-pass channel easily detaches for cleaning.

## SECTION VIEW




## APPLICATION DIAGRAM



# 5463 SERIES DIRTMAG® PRO
# DIRT SEPARATOR WITH DUAL MAGNETIC FIELDS

## HIGH PERFORMANCE DIRT SEPARATION WITH TROUBLE-FREE BLOWDOWN

The DIRTMAG® PRO incorporates patented technology and features dual magnetic fields that increase ferrous debris removal efficiency by 40%. The concentric pattern collision media inside the low-velocity zone efficiently separates non-ferrous debris. All debris is quickly purged from system via the blow down valve. No disassembly or scraping of magnetite from wetted magnets is required, which means clean hands and fast easy servicing.


## PERFORMANCE

| | |
|---|---|
| MAX. WORKING PRESSURE | 150 psi (10 bar) |
| WORKING TEMPERATURE RANGE | 32 — 250°F (0 - 120°C) |
| MAX. PERCENTAGE OF GLYCOL | 50% |
| PARTICLE SEPARATION CAPACITY | 5 microns (0.2 mil) |
| FERROUS IMPURITIES SEPARATION EFFICIENCY | up to 100% |

## PRODUCT RANGE - DIRTMAG PRO 5463 Series

| SIZES | MAX. FLOW RATE: (GPM) | CODE | | |
|---|---|---|---|---|
| | | FNPT | SWEAT | PRESS |
| 1” | 9 | **5463**06AM | **5463**28AM | **5463**66AM |
| 1¼” | 15 | **5463**07AM | **5463**35AM | **5463**67AM |
| 1½” | 24 | **5463**08AM | **5463**41AM | **5463**68AM |
| 2” | 36 | **5463**09AM | **5463**54AM | **5463**69AM |

Patent No. US 9,925,543 B2

# PRODUCT FEATURES

## DOUBLE THE PROTECTION:

Captures two forms of debris that can damage or shorten the life of heat exchangers, circulators, valves and polymers: **ferrous debris** such as magnetite, and **non-ferrous debris** such as copper shavings, solder, lime-scale fragments, silica and pipe compound.

## CONCENTRIC PATTERN COLLISION MEDIA:

Unique dirt collision media uses low-flow velocity, deflection and gravity to separate dirt particles as small as 5 microns from flow stream. Concentric pattern design has low flow resistance resulting in 85% less pressure drop compared to same size y-strainer.

## UNIQUE DUAL MAGNETIC FIELDS:

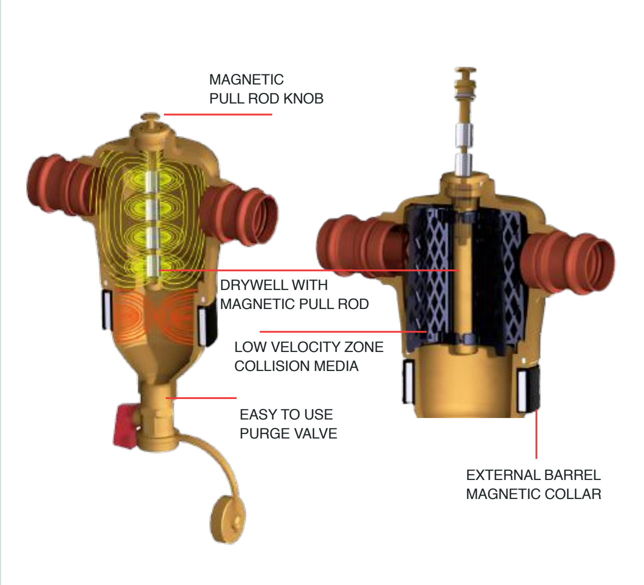
Two powerful neodymium rare-earth magnetic fields attract and capture ferrous oxide impurities and allow simple blowdown - no disassembly required.

## FAST AND EASY CLEAN HANDS PURGING:

Pull out the magnetic rod from drywell on top, unclip the external barrel magnetic collar and open the purge valve to simply release the captured magnetic impurities and purge all dirt.

## SECTION VIEW

## APPLICATION DIAGRAM




## INCREASED POWER:

Powerful magnetic pull rod mounted inside drywell and positioned directly in fluid flow path, external magnetic barrel collar and collision media function together to increase magnetic debris removal efficiency by 40%.


DIRTMAG PRO
CALEFFI
DISCAL
CALEFFI