july 2014
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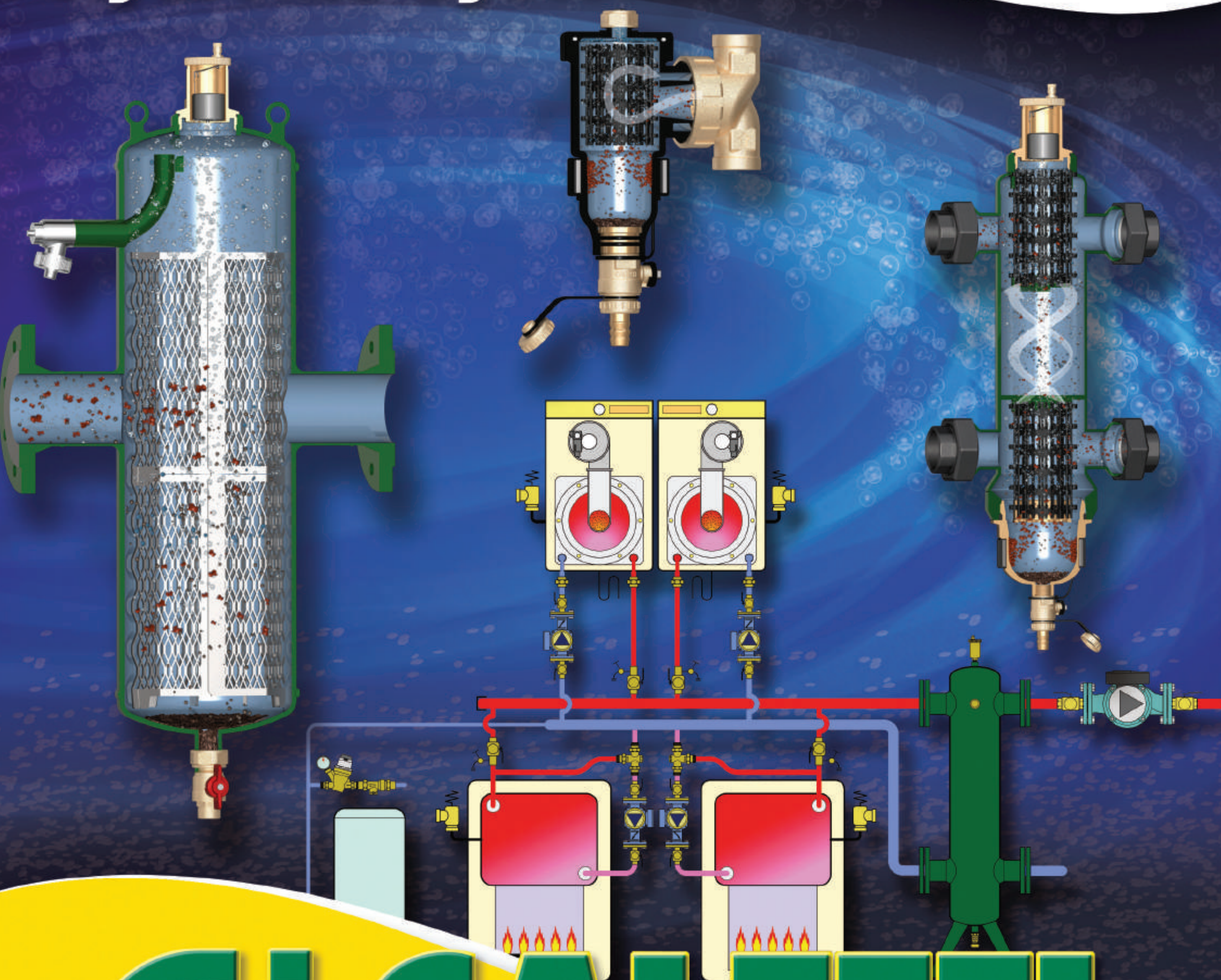
idronics™

JOURNAL OF DESIGN INNOVATION FOR HYDRONIC PROFESSIONALS

Separation in Hydronic Systems



CALEFFI

A Technical Journal
from
Caleffi Hydronic Solutions

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To receive future idronics issues
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Printed: Milwaukee, Wisconsin USA

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Dear Hydronic and Plumbing Professional,

Twelve years after Caleffi North America was established, air issues, dirt issues and hydraulic separation issues continue to be frequent topics in the technical support calls we receive. Some of these calls are from contractors trying to correct problems in existing systems. Others are from designers looking for the best way to apply our products in a new system. Some callers simply ask: "Can you explain how this device works?"

These calls confirm that an understanding of air & dirt separation, as well as hydraulic separation, is critically important to those who design, install or maintain hydronic systems. Those who comprehend these topics well are more capable of creating and maintaining the modern, energy-efficient systems today's marketplace demands.

This 15th edition of idronics combines the topics discussed in our 1st and 2nd issues from 2007, and updates those topics to reflect several new products now available from Caleffi. Some of these new products combine the functions previously performed by single components. Others expand the range of application from residential jobs through large commercial systems that provide heating and cooling.

From time to time, we receive photos showing installations of Caleffi products. We sincerely appreciate these submittals. They help us show and explain the best way to apply and install specific products. This issue includes several such photos. We sincerely thank all those who have sent us these photos and encourage you to continue sharing them with us.

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

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Mark Olson

Mark Olson

General Manager & CEO

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Separation in Hydronic Systems

1. INTRODUCTION

To "separate" means to disconnect or segregate. The word separate has several meanings in the context of hydronic heating or cooling systems. This issue of *idronics* examines three distinctly different forms of separation within such systems. They are:

1. Air separation
2. Dirt separation
3. Hydraulic separation

All of these are desirable characteristics that exist in well-planned hydronic systems.

AIR SEPARATION:

The ideal fluid in a hydronic heating or cooling system is water without any impurities, air bubbles or dissolved gases such as oxygen and nitrogen. However, every hydronic system starts out with air in all of its components. A well-planned system will quickly enable this air to be gathered and removed from the system. It will also reduce the dissolved air gases in the water to levels where they are of no concern. The system should then maintain the water at a very low level of dissolved air content over its entire life. Any small amounts of air that may enter the system during component maintenance should be quickly captured and ejected.

DIRT SEPARATION:

A newly assembled hydronic system usually contains dirt or remnants of oils used during manufacturing, transportation or installation. It may also contain pieces of joint sealing tape, rubber particles or ferrous metal particles. The latter is common when cast iron or steel components such as circulators, panel radiators or cast iron sectional boilers are used in the system.

Dirt or metal particles are undesirable in hydronic systems. Fine particles of dirt can interfere with the operation of moving parts within valves or circulators. They can also coat the internal surfaces of both heat sources and heat emitters, decreasing rates of heat transfer. Metal particles such as iron oxides can collect in circulators due to the magnetic fields they create. All well-planned and properly commissioned hydronic systems should contain very little dirt. What dirt the system does contain should be captured and removed. The state-of-the-art dirt separators discussed in this issue of *idronics* can remove particles as small as 5 microns in diameter.

HYDRAULIC SEPARATION:

Many hydronic systems contain multiple circulators, some of which need to operate at the same time. Ideally, the operation of any one of these circulators will not create any change in the flow or head produced by any other circulator in the system that also happens to be operating. When this is achieved, the circulators are said to be hydraulically separated from each other.

There are several methods by which hydraulic separation can be achieved. This issue of *idronics* discusses each of them, along with their strengths and limitations.

For many applications, it makes sense to combine the three fundamental forms of separation into a single device. In other applications, or for retrofit situations, this may not be possible or practical.

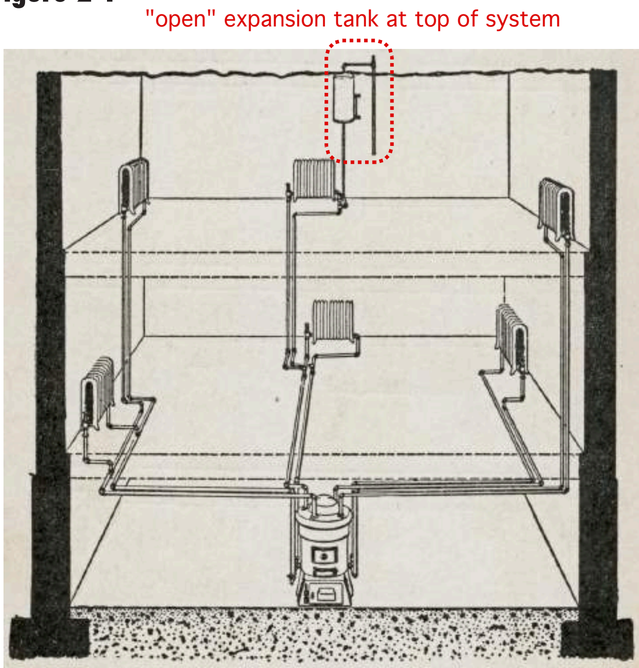
A thorough understanding of the principles involved in each type of separation equips designers to select the best products and installation locations for the system at hand. This issue of *idronics* was written to provide this understanding.

2. AIR SEPARATION

Air control within hydronic systems has always presented challenges. It began with the earliest hydronic systems that did not have circulators. Water flow was created by the buoyancy difference between hot water in the boiler and cooler water returning from the heat emitters. These systems used large-diameter piping and operated at very low flow velocities. Air removal was mostly a matter of waiting for air pockets to form and then releasing this air through manually operated valves located at high points in the system where the air accumulated.

Most of these early systems were "open-loop" rather than closed-loop systems. An expansion tank vented to the atmosphere was located at the high point of the

Figure 2-1



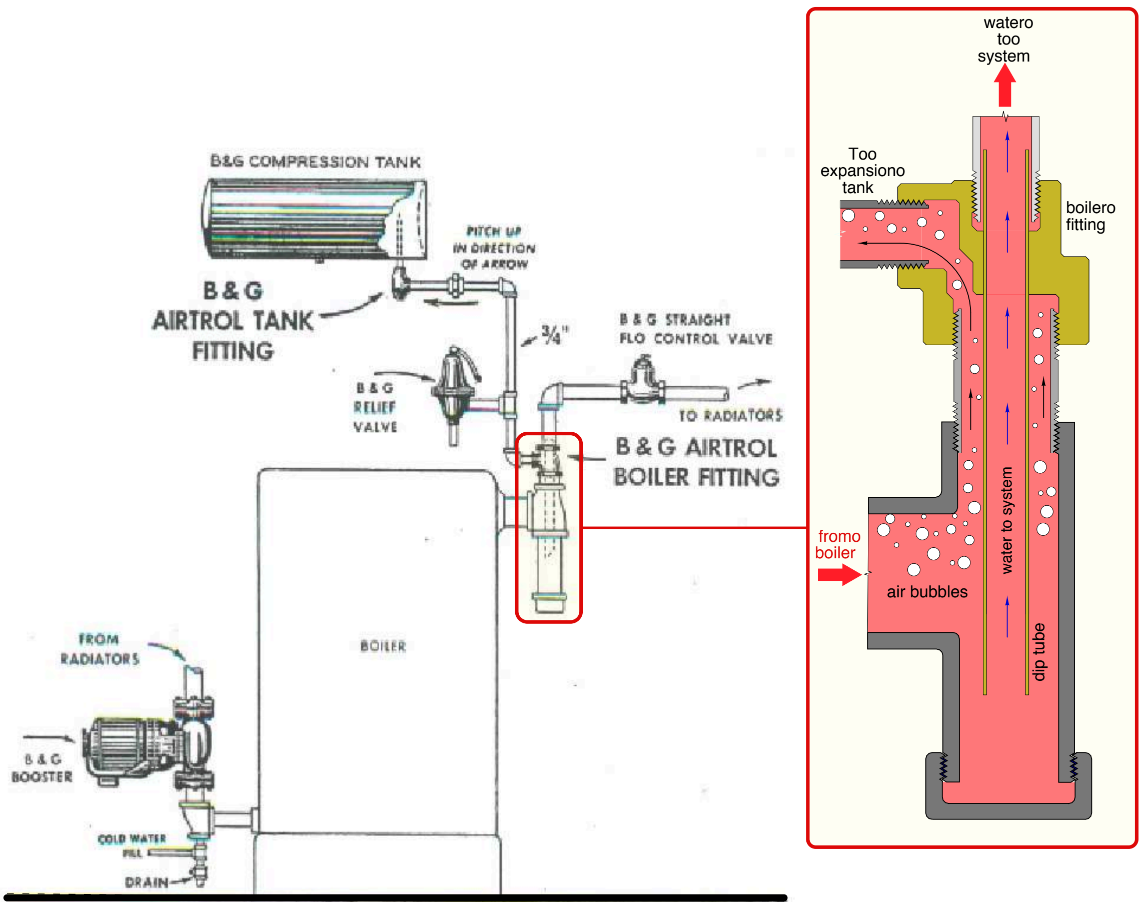
system—usually in the attic or upper floor, as seen in Figure 2-1, which appeared in a heating design manual published in 1906.

Although air could leave this tank as the water in the system was heated and expanded, it could also reenter the tank as the water cooled. This allowed a constant presence of dissolved oxygen molecules within the water, which often sustained oxygen-based corrosion within these systems constructed of iron and steel piping.

Occupants in buildings got used to “bleeding” the air from the system when its presence caused a drop in heat output or an annoying noises in the system.

During the 1940s, engineers began designing closed-loop hydronic systems. They created devices to help capture air and separate it from the circulating water. A system of this vintage typically used a standard expansion tank that was supported above the boiler, as shown in Figure 2-2.

Figure 2-2



Courtesy of Bell & Gossett

Air bubbles rising from the boiler were captured by a special "boiler fitting," and directed through a pipe to the expansion tank. Another special "tank fitting" was used to minimize the absorption of air within the expansion tank into the system water. The overall process is best described as *air control* rather than air elimination. Although some of these systems are still in operation, they do not represent modern technology. Very few systems are now installed using this approach.

Even when closed-loop hydronic systems became standard, industry veterans can attest that air elimination, especially during system commissioning, often remained a challenge. Significant time went into ridding systems of air, especially in large, complex piping systems. Keeping the air out of those systems also required frequent attention.

This is partially because closed-loop hydronic systems are not 100% sealed against air entry. Although such systems appear to hold pressure reasonably well for months, and seldom have visible water leaks, they are not perfectly sealed. Small amounts of the gases that make up air can enter closed-loop hydronic systems in a variety of ways, especially if those systems are poorly designed. Examples include air weepage at valve packings and circulator flange gaskets, as well as molecular oxygen diffusion directly through the walls of non-barrier PEX or other types of polymer tubing. Air can even be sucked into hydronic circuits through devices intended to expel it. This occurs when improper design, improper component placement or maintenance allow the pressure in the piping where the devices are located to drop below atmospheric pressure.

AIR-RELATED PROBLEMS:

Problems due to air in hydronic systems can be frustrating to occupants as well as heating professionals. If these problems are not fully understood, the attempted solution often produces only temporary correction. Eventually, those trying to remedy the situation may give up, thinking that the system is incapable of operating air-free. This is unfortunate and unnecessary, because every properly designed modern hydronic system can quickly rid itself of air and maintain itself essentially air-free for years.

The following problems can arise due to air in hydronic systems:

- Noises in the piping and heat emitters that annoy occupants
- Inadequate flows due to a mixture of water and air in circulators
- Poor heat transfer by heat emitters when all heat transfer surfaces are not wetted

Figure 2-3

- Accelerated corrosion due to oxygen in contact with ferrous metals
- Improper lubrication of circulator bushings due to air in flow
- Improper performance of balancing valves
- Complete loss of flow and heat output due to large air pockets

Noise: One benefit provided by a properly designed and installed hydronic system is the near-silent conveyance of heat. Building occupants should not hear water as it travels through tubing and heat emitters. Properly deaerated water traveling through piping at velocities of 4 feet per second or less produces sound levels that are virtually undetectable by human ears. However, a mixture of water and air is much more acoustically active.

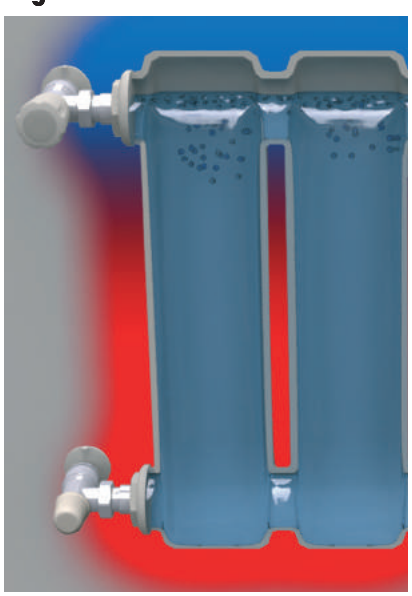
Figure 2-4

Entrapped air sounds often become noticeable as flow begins to disturb stationary air pockets. Air-filled cavities within piping and radiators act as acoustic amplifying chambers, especially if water enters a component which has trapped a large pocket of air. Noise is also generated when dissolved gases within water are released due to a sudden drop in pressure. This is called gaseous cavitation, and it often occurs at the orifice of valves or the inlet of circulators.

Inadequate Flow: Circulator impellers are designed to transfer mechanical energy called "head" to incompressible liquids. A mixture of water and air is not an incompressible liquid. Although most circulators can maintain flow when the liquid passing through contains some entrained air, mechanical energy transfer is not as efficient as when the liquid is fully deaerated. This decreases circulator efficiency and reduces the rate of heat conveyance by the system. Noise is also present as a mixture of liquid and air bubbles pass through a circulator.

Poor Heat Transfer: Air has much lower heat transfer properties than water. A given volume of water can absorb almost 3500 times more heat than the same volume of air. When air displaces water away from heat transfer surfaces within heat sources or heat emitters, the rate of heat transfer can be significantly reduced. "Cool spots" on radiators usually indicate entrapped air, as shown in Figure 2-5.

Figure 2-5



Accelerated Corrosion: Air is about 23% oxygen, and oxygen in contact with ferrous metals such as steel and cast iron causes corrosion. Many improperly deaerated hydronic systems that experience chronic air problems are constantly allowing air to enter the system. This resupplies oxygen that furthers the corrosion reaction. Poorly deaerated hydronic systems can fail prematurely due to such corrosion. Corrosion of internal surfaces can lead to leakage in thin steel components such as panel radiators or expansion tank shells. Corrosion on other surfaces can eventually break off as ferrous oxide particles that can be carried throughout the system and possibly become trapped in components such as circulators or heat exchangers.

The following chemical reactions can occur in hydronic systems containing ferrous (iron-containing) components.

$$O_2 + Fe + 2H_2O \rightarrow Fe(OH)_2 + H_2$$

OXYGEN — IRON IONS — WATER — FERROUS HYDROXIDE — HYDROGEN

$$3Fe(OH)_2 \rightarrow Fe_3O_4 + H_2 + H_2O$$

FERROUS HYDROXIDE — MAGNETITE — HYDROGEN — WATER

The compound Fe_3O_4 is called magnetite and appears as a dark gray sludge within the system. Magnetite is also attracted to magnetic fields created by circulators, especially those containing powerful permanent magnets. Circulator manufacturers have developed improved methods of forestalling magnetite or other ferrous metal particles from reaching the rotating inner parts of their circulators, but the potential for some magnetite entry into such parts still exists.

Figure 2-6

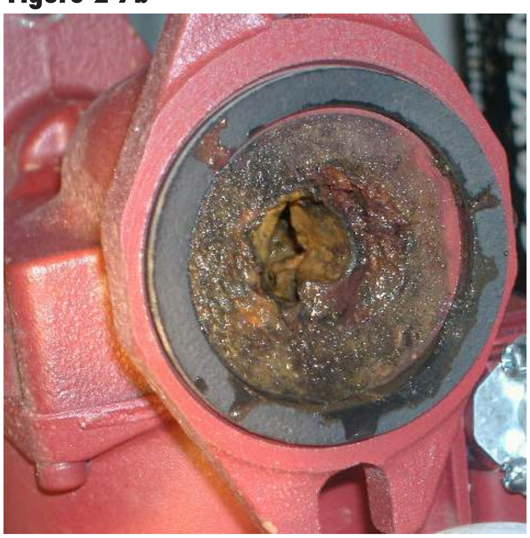
If oxygen continues to be present in the system, magnetite will be converted to hematite (Fe_2O_3), which can cause pitting corrosion throughout the system.

Figure 2-7 shows a pipe and circulator with accumulated iron oxide sludge. Consider the effect such accumulation would have on flow rate.

Figure 2-7a

Courtesy of Tony Hillard

Figure 2-7b



Courtesy of Heatboy

Circulator Damage: Modern wet-rotor circulators have ceramic bushings that depend on system water for lubrication. Due to its lower density, air tends to accumulate near the pump shaft and these bushings. The presence of air bubbles or air pockets can displace lubricating water and hence create premature bushing failure. The likely result is replacement of the entire circulator.

Circulators installed in vertical piping with upward flow and having spring-loaded check valves near their discharge are especially susceptible to large pockets

Figure 2-8

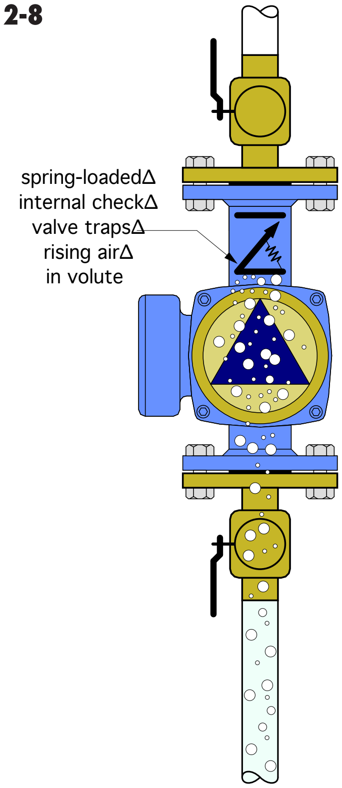
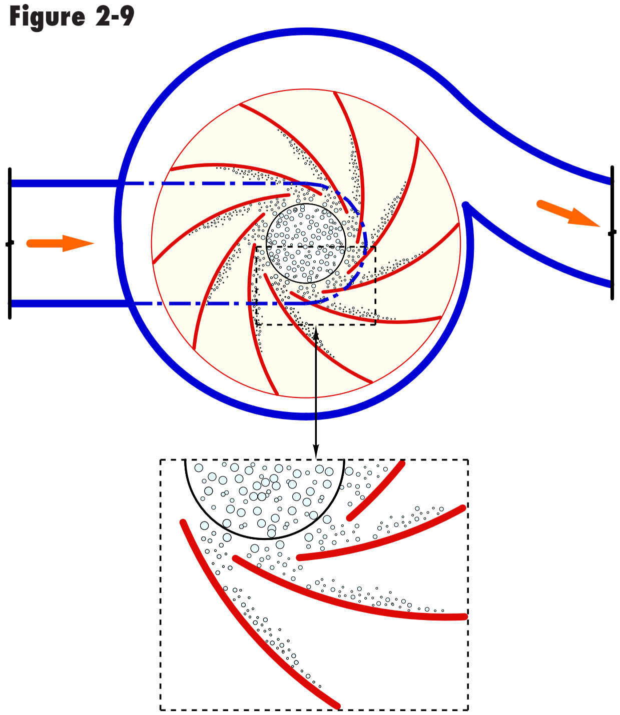


Figure 2-9



of air. If a sufficient volume of air enters the volute and displaces water in the impeller, the circulator may be unable to clear itself and will quickly be running without lubrication. Failure is almost certain.

Gaseous cavitation occurs within circulators when the pressure at the eye of the impeller drops below the saturation pressure of gases such as oxygen or nitrogen in solution with the water. The dissolved gas molecules instantly form bubbles that interfere with circulator performance, as depicted in Figure 2-9.

Sediments formed by oxidation within the system can be deposited on the impeller and volute of circulators, lowering their performance or causing total blockage (see Figure 2-6).

Improper Performance of Balancing Valves: Hydronic balancing valves are precision devices designed to perform within tight specifications when conveying liquids. The presence of air in the water changes the pressure drop versus flow rate characteristics of the valves, allowing flow rates to drift away from desired settings. This in turn can lead to improper heat delivery in various portions of the system. Highly throttled balancing valves can also experience gaseous cavitation when water with a high dissolved air content passes through them. Such cavitation can lead to annoying noises, especially in valves located within or near occupied spaces.

Complete Loss of Flow: If a stationary air pocket is large enough, and the piping system is tall enough, the system's circulator cannot generate sufficient lift to force water over the top of the system. Under such circumstances, there will be complete loss of flow in the circuit. Even if the circulator can establish some flow over the top of the system, that flow may not be sufficient to entrain air and help dislodge the air pocket.

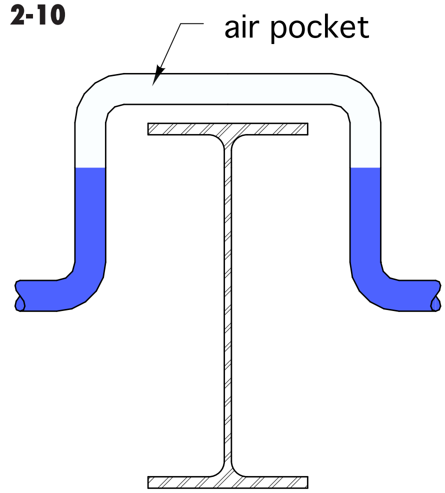
FORMS OF ENTRAPPED AIR

Air exists in three distinct forms within hydronic systems:

- Stationary air pockets at high points
- Entrained air bubbles
- Gases dissolved within water

Every hydronic system is completely filled with air at the start of its commissioning. As water enters the lower portions of the system, air rises upward. However, some components or improper piping configurations may not allow all the air initially contained in the system to rise to the top where an air venting device may be present. This results in trapped air pockets. These pockets can form at the top of heat emitters, boiler sections, unvented tanks, inverted diaphragm-type expansion tanks or heat exchangers. Air pockets can also form in horizontal piping that eventually turns downward or piping that is routed above obstacles in its path, as shown in Figure 2-10.

Figure 2-10



As water enters the system, these locations can trap air, especially if water approaches them from both directions. Slow water movement during the filling process also enhances air pocket formation.

Stationary air pockets can also reform when air bubbles merge and migrate toward high points. This is especially likely in components with low flow velocities, where slow-moving fluid is unable to push or drag the air along with it. Examples of such components include large heat emitters, large diameter piping and storage tanks.

ENTRAINED AIR BUBBLES:

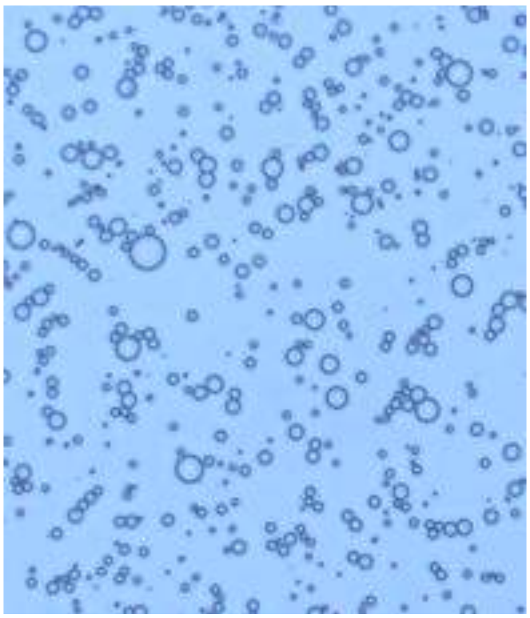
A moving fluid may be able to carry air bubbles along with the flow (e.g., entrain them). This is desirable from the standpoint of moving air bubbles from remote parts of the system back to a central air-separating device, where they can be captured and expelled. However, if the fluid's flow velocity through the air-separating device is too high, the entrained air cannot be efficiently separated and could end up passing through the separator many times.

The ability of a fluid to entrain air can be judged by its ability to move bubbles vertically downward, against their natural tendency to rise. If the fluid moves downward faster than a bubble can rise, it will pull the bubble along. A minimum flow velocity of 2 feet per second is needed to entrain air bubbles within downward-flowing pipes.

MICROBUBBLES:

Air can also exist in hydronic systems as microbubbles. Individually, most microbubbles are too small to be seen by the human eye. However, dense collections of microbubbles can make otherwise clear water appear cloudy. A common place to see temporary clouds of microbubbles is in a drinking glass just filled with water from a faucet having an aerator device. Figure 2-11 shows a visually enhanced microscopic view of microbubbles.

Figure 2-11



Source: www.urmc.rochester.edu

In hydronic systems, microbubbles form when water with dissolved gases such as oxygen and nitrogen is heated in a boiler or other heat source. In chilled-water cooling systems, it is possible for microbubbles to form within terminal units as the water absorbs heat under low water pressure conditions. They can also form when water passes through a component that creates a sudden and significant pressure drop, such as a valve that is almost closed.

Microbubbles have extremely low rise velocities and are easily entrained by moving fluids. This characteristic makes them more difficult to capture compared to larger bubbles. Some hydronic systems, especially older systems, have air-separating devices that do not provide sufficiently low flow velocities or suitable internal detailing to allow efficient microbubble separation. While larger bubbles are more easily captured due to their greater rise velocities, microbubbles are often swept through older style air-separating devices without being captured. The result can be a system that takes days, or sometimes weeks, to reduce its air content to acceptable levels.

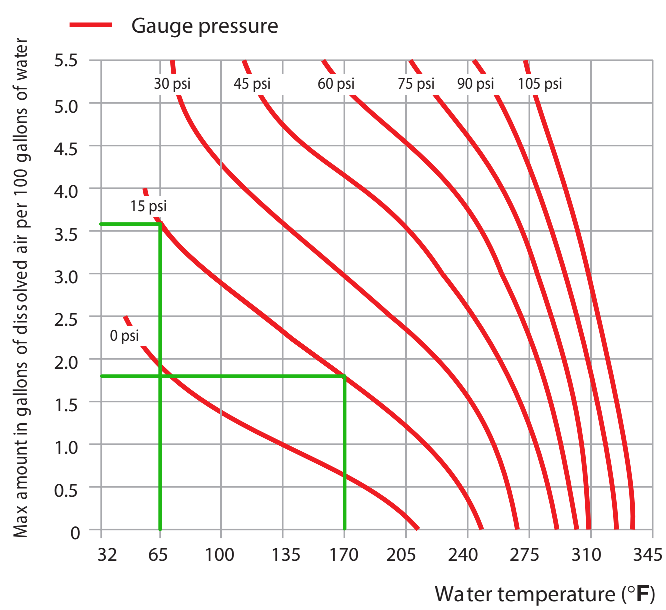
DISSOLVED AIR:

Molecules of the gases that make up air (nitrogen, oxygen, carbon dioxide and some other compounds) can exist "in solution" with water molecules. Since molecules are too small to be seen, water that appears perfectly clear and free of bubbles can still contain a significant amount of dissolved gases that ultimately need to be removed from the system.

The amount of dissolved gases that water can hold depends on the water's temperature and pressure. At higher temperatures, the ability of water to contain dissolved gases decreases, and vice versa. As the pressure of the water increases, so does its ability to hold dissolved gases in solution.

The contours in Figure 2-12 show the maximum amount of dissolved air gases contained in water over a range of temperatures and pressures (expressed as a percentage of total volume). For example, at 15 psi gauge pressure and a temperature of 65ºF, up to 3.6% of the molecules in a container of water can be dissolved gases (oxygen, nitrogen and other trace gases). However, if the water's temperature is raised to 170ºF while maintaining the same pressure, its ability to hold dissolved gas is reduced to 1.8% of its volume, half the previous level. Such a change in temperature would be typical of cold water heated within a boiler and illustrates the "degassing" effect of increased temperature.

Figure 2-12



As the pressure of the water is lowered, so is its ability to hold dissolved gases in solution. Figure 2-12 shows that reducing the pressure of 170ºF water from 15 to 0 psi gauge pressure reduces the amount of dissolved gas it can contain from 1.8% to about 0.6% of its volume. This explains why air bubbles are more likely to form in the upper portions of a multi-story hydronic system. Lower static pressure in the upper portions of the building makes it easier for dissolved air to come out of solution. Higher static pressure near the bottom of the system tends to keep gases in solution.

Temperature also affects the solubility of dissolved gases in water. Figure 2-13 shows a simple piping system with representative temperatures and gauge pressures at four locations.

The graph to the right of the piping schematic shows the combination of temperature and *gauge pressures* at these four locations. Notice that point A is the lowest of the four points, and thus represents the lowest solubility of air in water of the four locations. The lower the solubility, the more likely microbubbles are present; thus point A is the preferred location for the Caleffi Discal air separator.

Water can repeatedly absorb and release gases as its temperature and/or pressure changes. This can affect hydronic systems in several ways—some good and some not so good.

For example, the ability of water to absorb air as it cools helps reduce the volume of stationary pockets in areas of the system where flow is slow. This absorbed air can be carried back to a high-efficiency separating device where it is then captured and ejected from the system. The ability of water to absorb air can also cause an undesirable condition called “water logging” in older style expansion tanks without diaphragms or bladders.

It’s always desirable to minimize the dissolved air content of the system’s water. This is accomplished by establishing conditions that encourage dissolved gases to come out of solution (e.g., high temperatures and low pressures), and placing an effective air separating device at a location where such conditions occur.

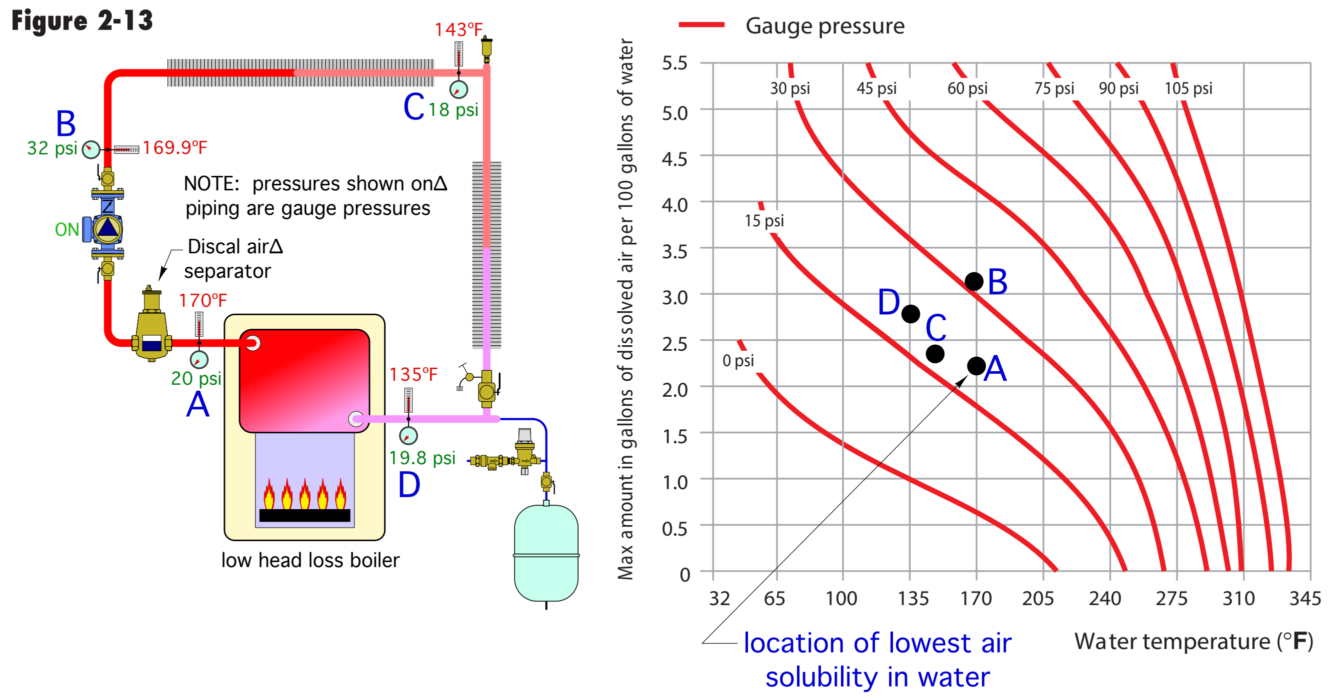
AIR REMOVAL DEVICES:

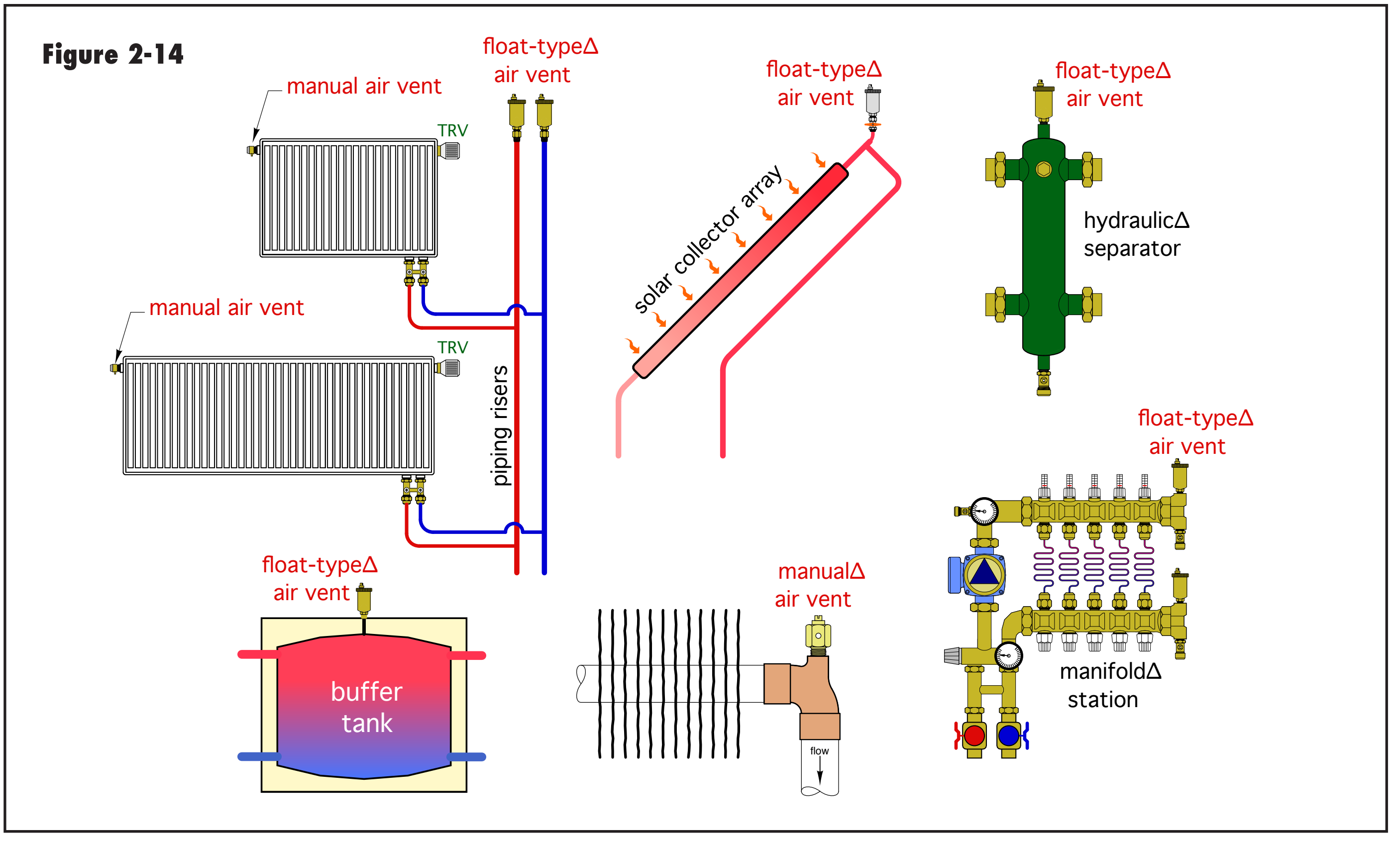
Most air removal devices used in hydronic systems can be classified as either:

1. High-point vents
2. Central air separators

High-point vents release air from one or more high points in the system where it tends to accumulate. Typical locations for high-point vents are the top of each heat emitter, the top of distribution risers, the top of tanks or hydraulic separators, or wherever piping turns downward following an upward or horizontal run. Figure 2-14 shows some examples.

Figure 2-13





A central air separator is used to remove entrained air from a flowing fluid, as well as to maintain the system at the lowest possible air content.

MANUAL AIR VENTS:

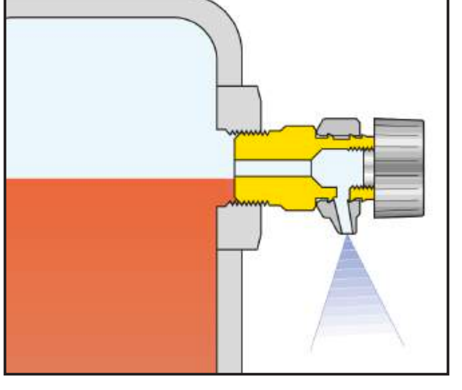
The simplest type of high-point venting device is a manual air vent. These components are essentially small valves that thread into 1/8-inch or 1/4-inch FPT tappings, and are operated with a screwdriver or square head key. When opened, air moves through the valve seat and exits through a small side opening.

Manual air vents are commonly installed at the top of each heat emitter. An example of a manual air vent installed at the top of a panel radiator is shown in Figure 2-15. Such vents are opened to release air that rises to the high point as fluid enters lower in the system. When the fluid level reaches the manual air vent, a small stream of water will flow out the side of the vent. A small piece of flexible tubing can be used to guide this stream into a can or pail. It's important to capture this water and not allow it to stain carpets or otherwise damage surrounding materials. When a steady stream of water has been flowing from the vent for several seconds, it should be closed. After air has been removed from the system, be sure to check that the system has adequate static water pressure.

Manual air vents can also be mounted on a special fitting called a baseboard tee, an example of which is shown in Figure 2-16a. These

Figure 2-15a

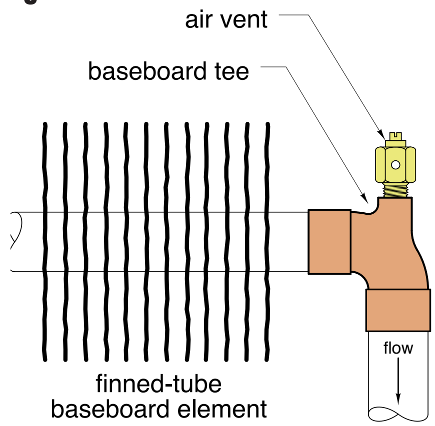
Figure 2-15b



fittings resemble a 90° elbow, but with an extra port having either 1/8" or 1/4" FPT threads. They are typically installed at high points where piping changes from vertical to horizontal. Their name comes from a common application in which they are mounted on the outlet of a fin-tube element within a baseboard convector, as seen in Figure 2-16b.

Figure 2-16a

Figure 2-16b



HYGROSCOPIC AIR VENTS:

Another type of small high-point venting device is called a hygroscopic air vent. An example of such a device is shown in Figure 2-17a. Figure 2-17b shows this device installed at the top of a cast iron radiator.

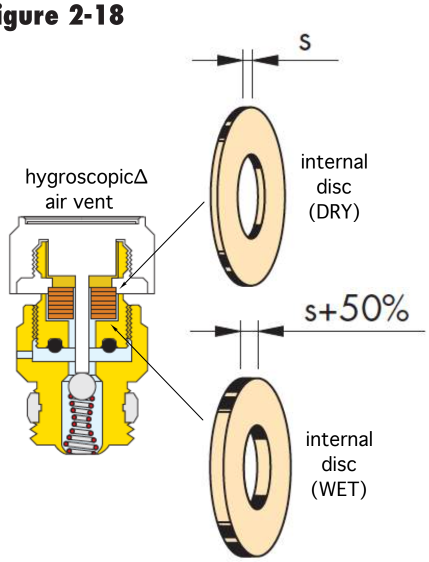
Figure 2-17a

Figure 2-17b

Hygroscopic air vents contain a special cellulose fiber disc that, when dry, allows air to pass through it and exit the vent. When moisture reaches the disc, it expands very quickly to stop further flow from the device. The location and thickness of the fiber disc is illustrated in Figure 2-18.

Hygroscopic air vents can be used in either automatic or manual mode. When the knob is opened one turn from its fully closed position, as shown in Figure 2-19a, it operates the same as a manual air vent. Any pressurized air at the base of the vent exits through a small hole at the side of the vent's brass body.

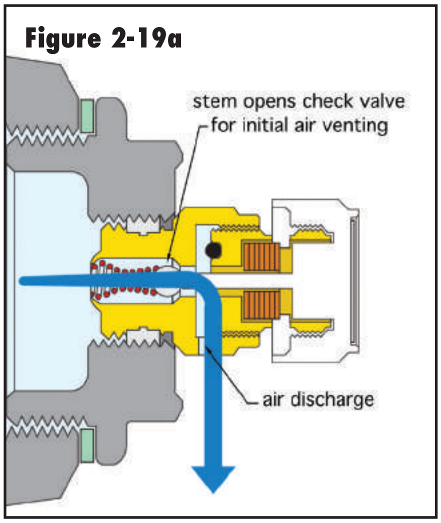
Figure 2-18

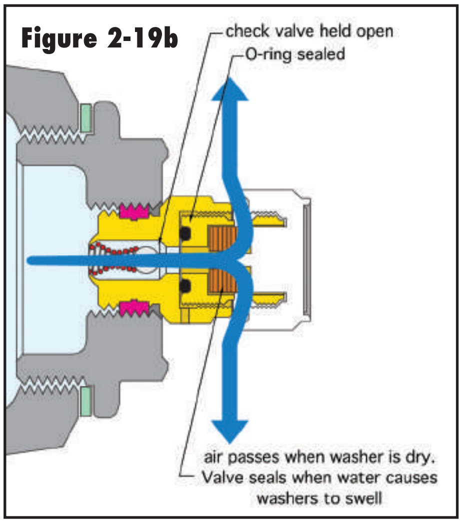


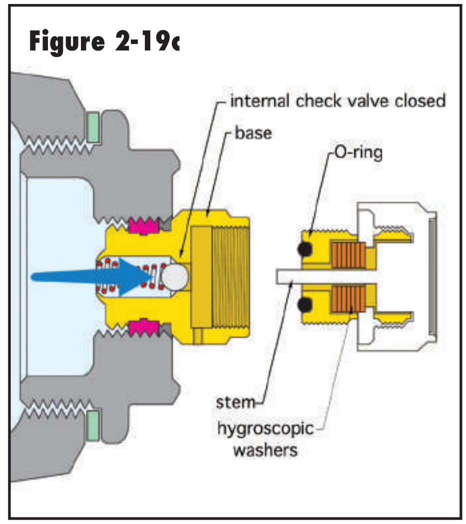
When the knob is fully closed, an internal O-ring seals off the side port. However, if air is present at the vent, the fiber discs will dry and allow air to pass through them. This air is discharged under the vent's knob, as shown in Figure 2-19b. Once the air has been vented and water reaches the fiber discs, they swell very quickly to seal off any further discharge.

Minerals or sediment in the system water can interfere with the operation of the internal hygroscopic disc. It is generally recommended that these discs be replaced every three years. Caleffi hygroscopic air vents contain an internal spring-loaded check valve that closes whenever the upper portion of the vent body is removed, such as when changing the fiber discs. This is illustrated in Figure 2-19c.

Although hygroscopic air vents are automatic, they can be manually opened and are therefore not recommended in locations where tampering is possible. A float-type air vent is a preferred choice in such locations.

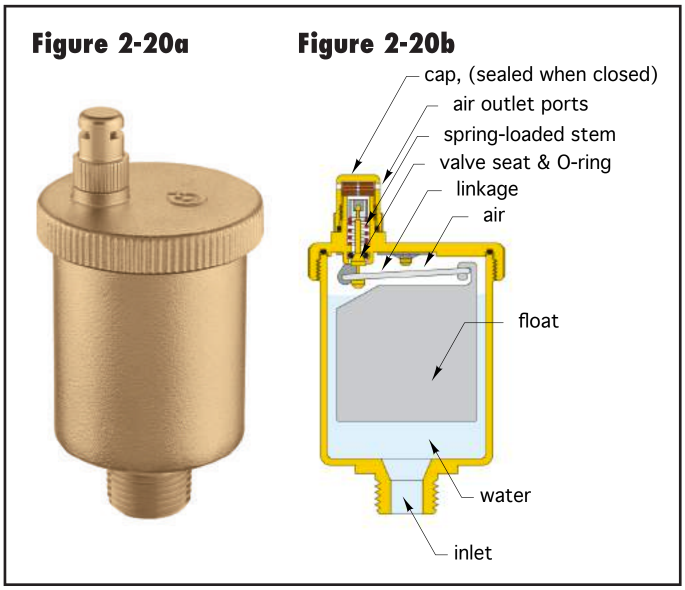






FLOAT-TYPE AIR VENTS:

A float-type air vent provides fully automatic air release and instantaneous response to the presence of water. An example of such a device is shown in Figure 2-20.



It contains an air chamber, a float assembly and an air valve. As air accumulates within the chamber, the float descends. A linkage attached to the float eventually opens the valve mechanism at the top of the unit. As air is released, water flows into the chamber and lifts the float to close the valve. Some Caleffi float-type vents are equipped with hygroscopic caps that seal the vent from water leakage, and thus provide secondary leak protection if the vent's internal valve mechanism does not operate properly.

Most float-type air vents are equipped with a cap that protects the valve mechanism from debris. It's important that this cap is loosened when the vent is put into operation. If the cap is fully closed, the vent cannot operate. Caleffi vents can be equipped with Caleffi-specific "anti-siphon" caps that prevent airflow into the vent if the pressure at the vent location drops below atmospheric pressure.

Float-type air vents are available in different sizes and shapes. Compact designs allow mounting within the enclosures of heat emitters, such as fin-tube convectors or fan-coils. Larger "high-capacity" vents are available for use at the top of central air separators, storage tanks, or other locations where high-volume air venting is needed.

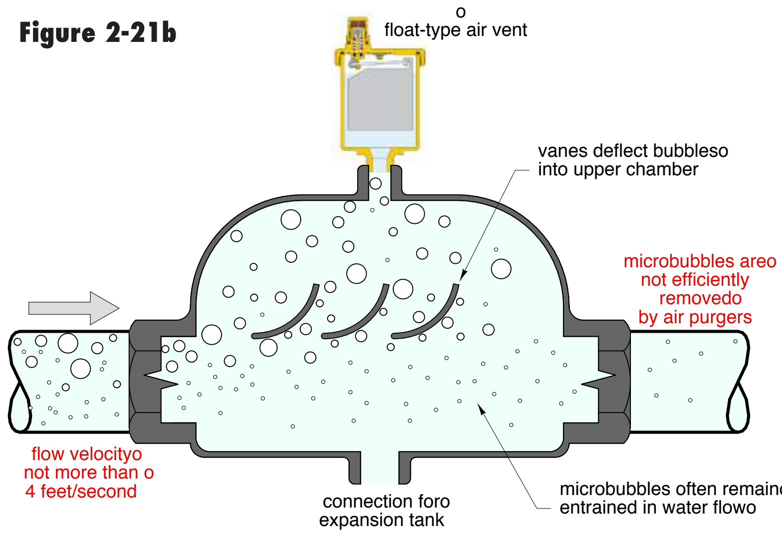
It's important to remember that some float-type air vents can also allow air to enter the system if the system pressure at their installed location drops below atmospheric pressure. This can happen as a result of improper placement of the expansion tank relative to the circulator. It can also be caused by low static pressure in the system. *Caleffi anti-siphon vent caps are designed to prevent this intake of air.*

It's good practice to design and commission all closed-loop hydronic systems so there is at least 5 psi of positive static pressure at the top of the system. This ensures that float-type vents will always be able to expel any air that accumulates.

It's also important to verify that the pressure rating of float-type air vents is suitable for the conditions and locations where they will be located in the system. Hydronic systems that have piping installed over several building stories can generate high static pressure in the lower portions of the system, where such vents may be located at the top of tanks, heat exchangers, hydraulic separators, boilers or other devices.

Figure 2-21a

Figure 2-21b



CENTRAL AIR SEPARATORS:

The ability to maintain very low air levels within a closed-loop hydronic system is vital to quiet, efficient and reliable operation. The key component in providing this function is a central air separator. Such devices can be categorized as either air purgers or microbubble air separators.

Figure 2-21a shows an example of a cast iron air purger. These relatively simple devices encourage well-formed air bubbles to rise into a collection chamber and then pass out through a float-type air vent at the top of that chamber. They rely heavily on the buoyancy of well-formed bubbles as the means of separation. To achieve proper operation, the velocity of the flow stream entering the separator must be kept below 4 feet per second. Lower velocities increase the air removal efficiency of these devices, albeit at the cost of larger and more expensive hardware. Air purgers are not designed to capture microbubbles, and as such, cannot lower the dissolved air content of the system as well as separators specifically designed for this purpose. A cutaway illustration of a typical air purger is shown in Figure 2-21b.

MICROBUBBLE AIR SEPARATORS:

Due to their small size and low buoyancy, microbubbles are more difficult to capture relative to well-formed bubbles or large air pockets. Doing so requires surfaces upon which microbubbles can cling and eventually merge into larger bubbles. This process is called coalescence and is critically important to attaining and maintaining minimum air levels in hydronic systems.

Figure 2-22a

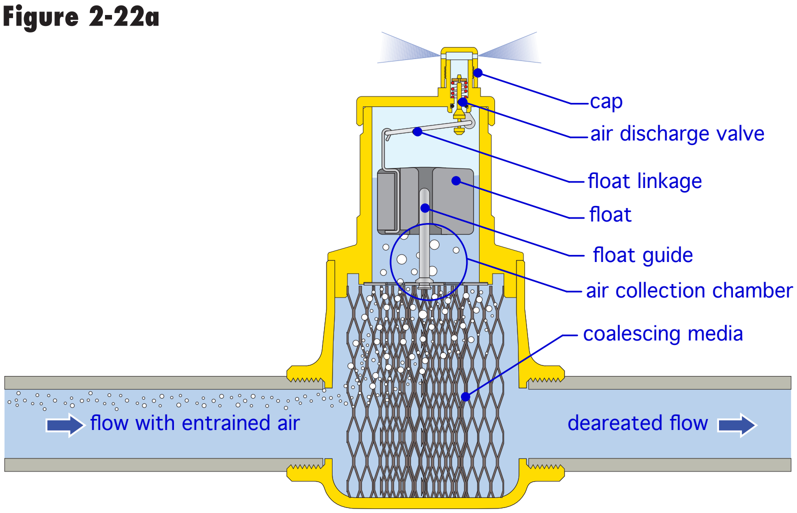


Figure 2-22b

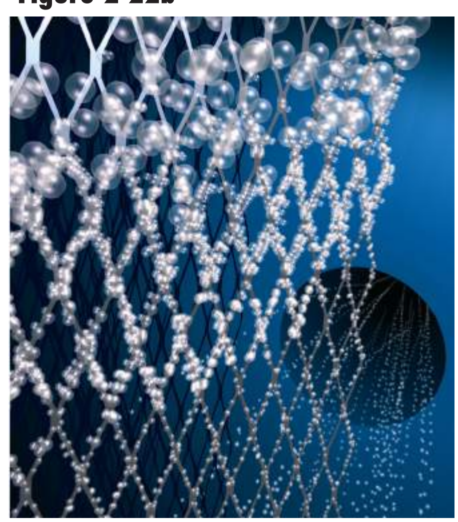
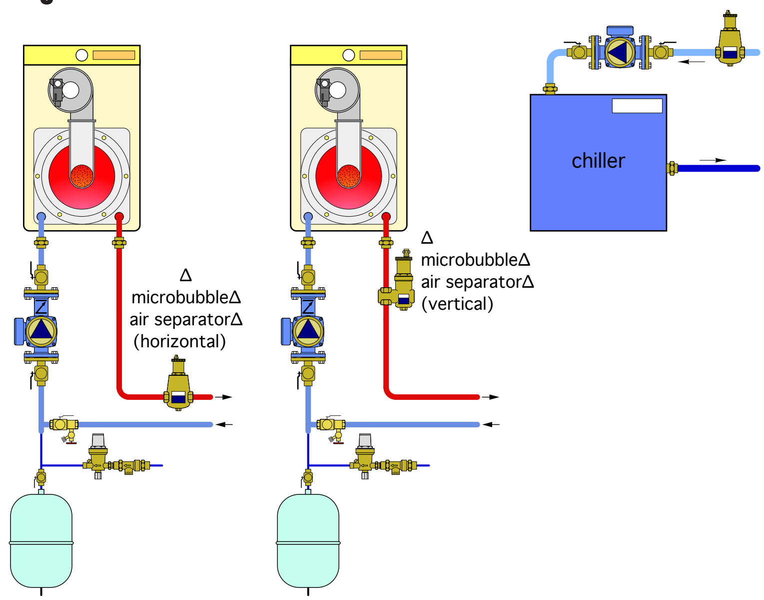


Figure 2-23



The surface on which microbubbles coalesce is called the "coalescing media." Some microbubble air separators use metal meshes for this media, while others use special polymers. In either case, the coalescing media must provide high surface contact area, enhancement of vertical bubble movement and a relatively low pressure drop.

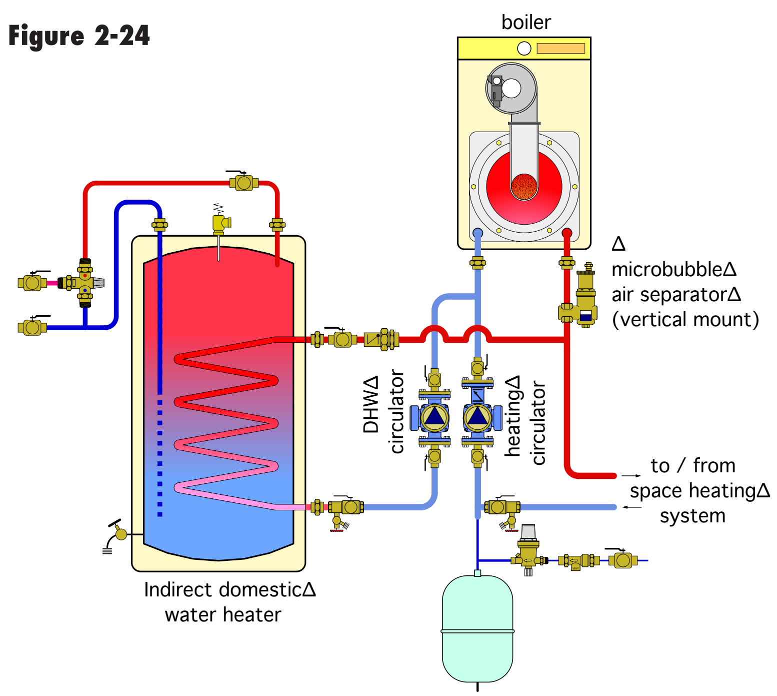
As microbubbles coalesce together, they form larger bubbles. Eventually, the bubbles attain a volume large enough that buoyancy forces overcome the adhesion forces holding them to the coalescing surface. The bubbles then rise along the coalescing surfaces to a chamber above the main flow stream where they can be collected and expelled through a float-type air vent. The concept of coalescence inside such a separator is illustrated in Figure 2-22b.

PLACEMENT OF CENTRAL AIR SEPARATORS

Central air separators work best when located where the solubility of dissolved gases within the system water is lowest. In heating systems, they should be mounted near the outlet of the heat source (see Figure 2-23). In cooling systems, they should be mounted on the inlet side of the chiller (e.g., where water temperatures are warmer).

In some situations, it is convenient to use a central air separator that can mount in a vertical pipe. Figure 2-24 shows an example of such an application. Notice how the air separator placement allows flow through it during space-heating as well as domestic water-heating operating modes. The greater the number of times system water passes through the heat source and central air separator, the better the latter device can "scrub" dissolved gases from the water and expel them.

Figure 2-24



The ability of a microbubble air separator to lower the water's dissolved gas content allows that water to absorb air back into solution as it cools. A common example of this is water cooling within piping and heat emitters during an off-cycle. Think of this cooling water as a "sponge" that soaks up molecules of air gases with which it comes in contact. Since these molecules are pulled into and held in solution under these conditions, they will eventually be carried back to the heat source when flow resumes. Upon heating, they will be released from solution as microbubbles and captured by the microbubble air separator. This process is ongoing and can eventually bring the dissolved air content of the water to approximately 0.4% of system volume. In this state, the water can provide efficient and virtually silent conveyance of heat, and its very low oxygen content discourages corrosion.

AIR MANAGEMENT

There are some situations in which it is not desirable to eject air from a closed-loop hydronic system. Instead, the air in the system needs to be maintained in part of the system.

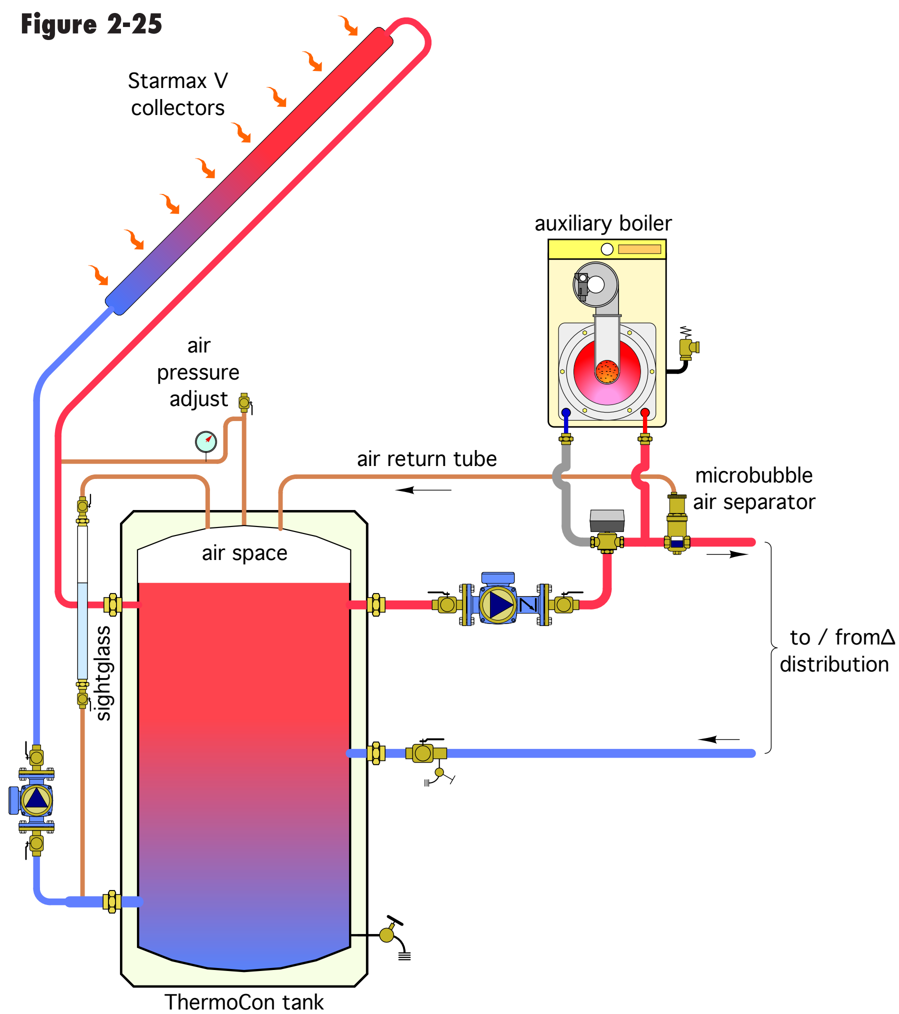
A closed-loop solar thermal system using drainback freeze protection is one such situation. Consider the closed-loop, drainback protection solar combisystem shown in Figure 2-25.

For drainback freeze protection to work, there must be air in the collectors and any exposed piping whenever the collector circulator is off. Total air elimination, as previously discussed, would defeat the purpose of drainback freeze protection. However, the air in the collectors and upper portion of the storage tank should not be allowed to find its way into the distribution system where it could potentially cause problems such as noise, poor circulator performance or trapped air pockets. Thus, the air in the system must be "managed."

Air management maintains the internal air volume in its proper location within the system. In the system shown in Figure 2-25, any air that is captured by the microbubble air separator is returned to the air-filled portion of the system rather than being ejected from the system. This allows the pressurized closed-loop system to maintain its initial pressurization, since air is not being expelled from it. Likewise, when the collector circulator turns off, air from the top of the tank moves back through the air return tube, and then up into the collector array. At the same time, water within the collector array and exposed piping flows back down to the tank. No air is ejected from the system.

Notice that there is no automatic makeup water assembly on this system. Such an assembly, if present, would eventually allow the system to fill with water should there be an air leak at any point.

Figure 2-25



Also note that there is no expansion tank in this system. The captive air volume at the top of the storage tank, if properly sized, provides the volume needed to accommodate the expansion volume of the system's water and serve as the drainback space.

Figure 3-1

Figure 3-2

Figure 3-3

Photo courtesy of Ken Shockley

3. DIRT SEPARATION

There are many ways dirt can enter a hydronic system. Perhaps the most common is through repeated handling of piping and system components from manufacturing through transportation and installation. Piping and components stored on-site can accumulate wind-blown dust or even larger dirt particles if dragged over the ground or dirty floor surfaces. Insects can nest in piping stored in warehouses or on jobsites.

Sediment can also be present in hydronic systems, especially older systems containing steel or iron piping and cast iron radiators. This is especially true for systems that originally operated with steam and are being converted to hot water circulation.

Even new cast iron boilers or radiators can contain residue associated with their manufacturing. Metal chips from reaming copper or iron piping often lodge inside pipes during installation. Access solder often forms small pellets inside piping. Welding slag grains are also common in systems using steel pipe.

DIRT-RELATED PROBLEMS:

The ideal hydronic heating or cooling system would be dirt-free. The presence of dirt can have serious consequences, including:

• Damage to rotating components in circulators, especially impeller and bushing surfaces. Figures 3-1 and 3-2 show two examples of circulators with clogged impellers caused by debris and iron oxides within hydronic systems.

• Reduced heat transfer due to “fouled” surfaces in heat sources, such as the cast iron boiler section seen in Figure 3-3. Fouling due to dirt accumulation is especially problematic in boilers or other heat sources with compact heat exchangers.

Fouling due to dirt accumulation can also drastically affect the thermal and hydraulic performance of heat exchangers. Figure 3-4 shows an example of a heavily fouled plate from a plate & frame heat exchanger.

Figure 3-4

Similar fouling can occur with chillers and heat exchangers in chilled-water cooling systems.

Dirt in the flow stream can also exasperate internal erosion of copper tubing, as shown in Figure 3-5. The higher the flow velocity, the more aggressive the erosion.

Figure 3-5

Courtesy of Illinois State Water Survey

Dirt in systems, especially very fine particles, can eventually collect on transparent surfaces such as those used in sightglasses, rotameter flow meters or flow meters built into manifold stations. This can make it difficult or impossible to read the flow level in the sightglass or the flow rate through the meter. Figures 3-6 and 3-7 show two examples.

Figure 3-6

With sufficient accumulation, dirt buildup can cause the moveable parts in the flow meter to jam, rendering the meter useless.

Dirt can also cause erosion and/or clogging of relief valves, balancing valves, check valves, venting valves and thermostatic radiator valves, as depicted in Figures 3-8 and 3-9.

Figure 3-7

Figure 3-8

Figure 3-9

DIRT SEPARATION METHODS:

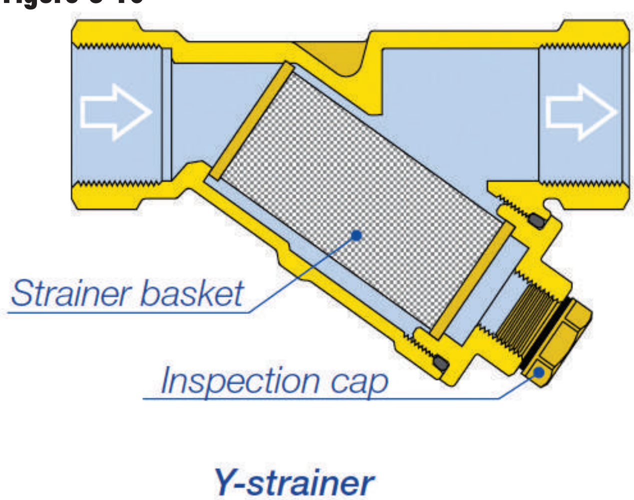
There are three common methods for capturing and expelling dirt from hydronic systems:

1. Use of chemical "flocculants" to wash the inside of the system.
2. Use of basket strainers.
3. Use of low-velocity-zone particle separators.

Chemical flocculants act as detergents within piping systems. They provide the chemical reactions necessary to dislodge certain types of accumulated sediments and assist in bonding fine particles together so that they can be entrained in a flowing stream. A typical system cleaning procedure involves adding the flocculants to the system, then operating it at elevated temperatures for several hours so that accumulated sediment or corrosion residuals can be dislodged and carried along by the flow. The system is then drained and flushed with clean water to expel as much of the sediment as possible. This procedure can be done when the system is first commissioned or as a remedial measure for systems in which sediment or corrosion scale has decreased performance. Some flocculants also coat the inside of piping and components with a residual film to protect against corrosion.

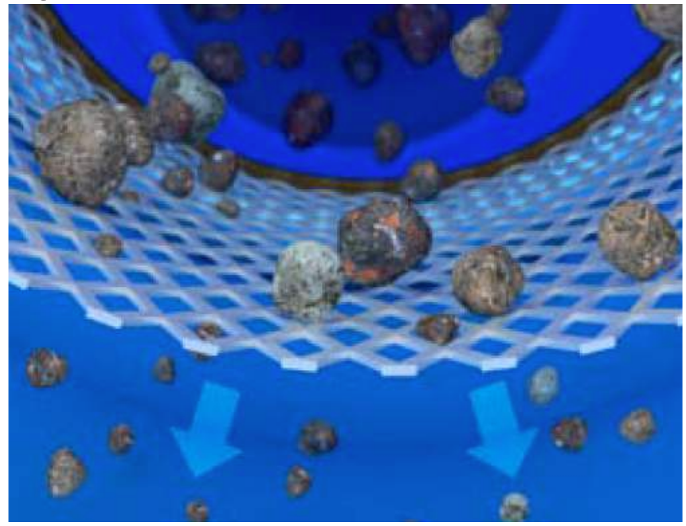
Basket strainers, also known as Y-strainers, entrap dirt within a "basket" made of stainless steel or brass mesh. The cross section of a typical Y-strainer is shown in Figure 3-10.

Figure 3-10



Y-strainers work similarly to the strainer inside the neck of a funnel. All system flow passes through the strainer and particles larger than the mesh size of the basket are trapped. Particles smaller than the mesh size may pass through the basket, as shown in Figure 3-11.

Figure 3-11



As debris collects inside the strainer's basket, it impedes flow. This results in increased pressure drop and hence higher head loss. If the strainer basket is not properly maintained, such head loss can be excessive. Figure 3-12 shows an example of a heavily loaded basket from a Y-strainer.

Figure 3-12

Flow reductions due to dirt accumulation in Y-strainers will reduce heat conveyance by the system. When restricted strainers are present near the inlet of circulators, they can induce vapor cavitation due to significant pressure drop. This can severely damage a circulator if not corrected.

Experimental testing of Y-strainers in which 70% of the free area of the basket screen is covered with debris have shown a pressure drop 450% higher than the same Y-strainer with a clean basket screen. Figure 3-13 compares the pressure

Figure 3-13

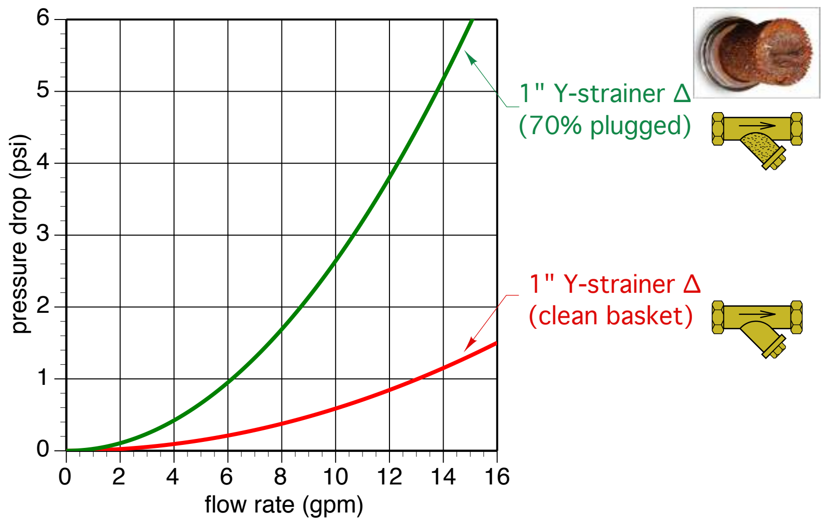


Figure 3-15

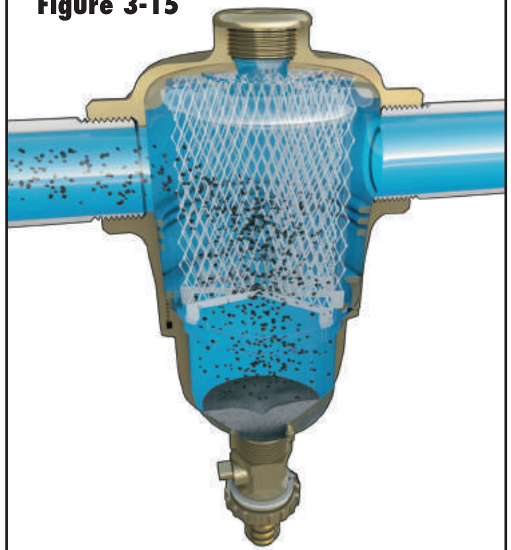
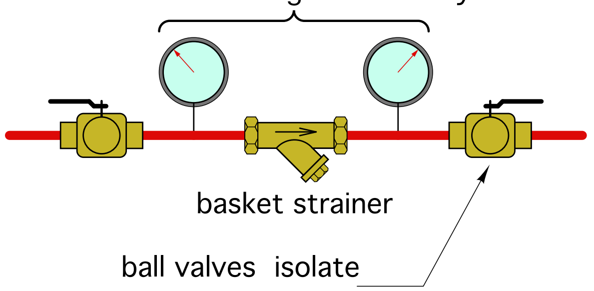


Figure 3-14



drop of two 1" pipe size Y-strainers: one with a clean basket, and the other with the basket 70% plugged with debris.

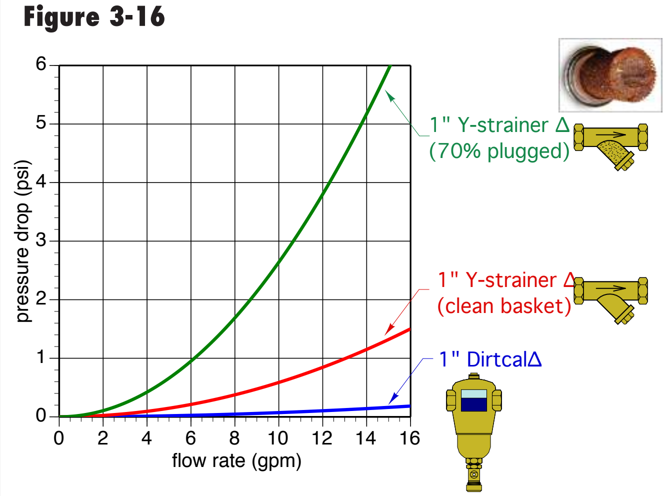
In most systems, the pressure drop across a basket strainer is monitored to determine when cleaning is necessary. A pressure drop of 5% or more of the differential pressure across the circulator is a reasonable indication that the strainer should be cleaned. Ball valves are installed to isolate the strainer so its basket can be removed without significant fluid loss, as shown in Figure 3-14. Flow through the system must be stopped during this cleaning procedure.

LOW-VELOCITY-ZONE DIRT SEPARATORS

Low-velocity-zone dirt separators allow gravity and deflection to separate dirt particles from the flow stream. The velocity of the flow stream entering such a separator is reduced, often by a factor of 9 or more. The reduced velocity makes it difficult for the flow stream to continue entraining the dirt particles. A specially designed media within the low-velocity-zone dirt separator further impedes dirt entrainment. The dirt particles drop out of the active flow region of the separator and collect in the bowl at the bottom of the separator. When a valve at the bottom of this bowl is opened, the accumulated dirt is "blown down" (e.g., expelled) to a hose or bucket. An example of a Caleffi Dirtcal low-velocity-zone dirt separator is shown in Figure 3-15.

A low-velocity-zone dirt separator has much lower head loss and pressure drop compared to the same size Y-strainer with a clean screen. Figure 3-16 compares the pressure drop of a 1" pipe size Caleffi Dirtcal separator to that of a 1" pipe size Y-strainer with a clean basket, as well

Figure 3-16



as the same Y-strainer with a basket that is 70% plugged.

Lower head loss and pressure drop reduces the circulator power required for a given flow rate. This reduces long-term system operating cost.

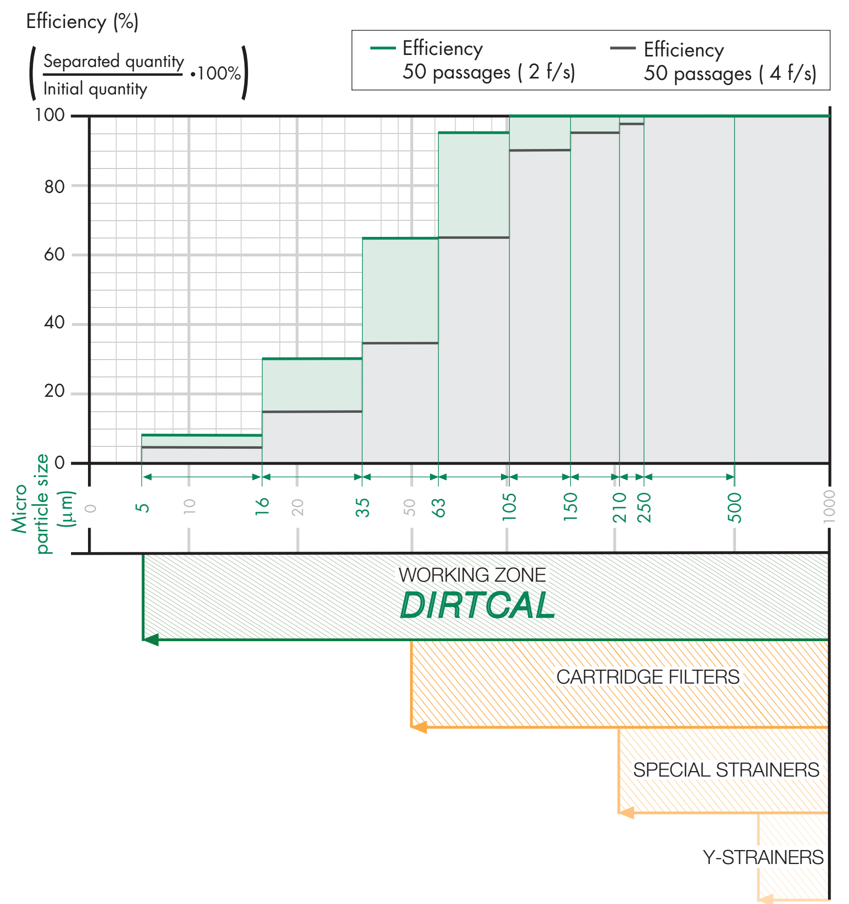
Because sediment accumulates below the flow stream, low-velocity-zone dirt separators can operate for relatively long periods between blowdowns. Furthermore, flow through the system does not need to stop during the blowdown procedure.

As with air separation, flow velocity through a low-velocity-zone dirt separator affects performance. The maximum flow velocity through such a device is 4 feet per second.

EFFICIENCY OF DIRT SEPARATION

No dirt separator or Y-strainer can capture 100% of the dirt in a flow stream during a single pass through the device. This is especially true of very small particles, such as iron oxide, which are easily entrained with flow. The smaller the particles, the greater the number of cycles required to remove them. Figure 3-17 shows the results of a particle separation test performed on a Caleffi low-velocity-zone dirt separator. Results reflect particle size, flow velocity and the number of passes (e.g., number of times the entire system volume has passed through the separator).

Figure 3-17



Testing has shown that Caleffi low-velocity-zone separators can remove nearly 100% of small sand particles in sizes greater than 100 micrometers (approximately 0.004 inches) when operating with flow rates up to 4 feet per second. Eventually these separators can remove particles as small as 5 micrometers (approximately 0.0002 inch). This dimension is less than 1/10th the diameter of a human hair, and much smaller than the particle size that can be captured by a typical Y-strainer.

MAGNETIC DIRT SEPARATORS

Many hydronic systems contain cast iron or steel components. The presence of these ferrous metals creates the opportunity for iron oxides to form. The greater the presence of oxygen, and the more conductive the water, the faster these oxides form. It follows that iron oxides are a common type of debris that could be present in many hydronic systems.

Figure 3-18

Iron oxide particles are attracted to magnetic fields. The most common location of such fields within hydronic systems is near a circulator's motor. Manufacturers of wet-rotor circulators have continually improved the ability of their circulators to isolate such particles from the fluid-filled space between the rotor and stator poles. Still, circulators installed in systems with high iron oxide content are more likely to experience eventual accumulation of these particles within the rotor can. In severe cases, this accumulation can jam the rotor within the

Figure 3-19

rotor can, preventing the circulator from operating.

The high-efficiency wet-rotor circulators that are increasingly used in hydronic systems contain very strong rare earth magnets within their rotors, as demonstrated in Figure 3-18. They may also use closer spacing between the rotor can and rotor to improve magnetic coupling between the rotor and stator, which improves motor efficiency.

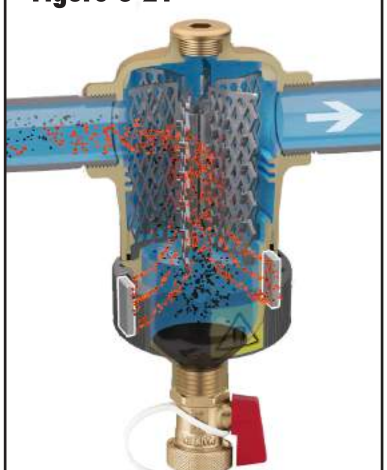
Evidence suggests that the long-term wire-to-water efficiency of these circulators can decrease by 20% or more due to accumulation of iron-based particles within the circulator, as seen in Figure 3-19. Although the circulator may still operate, it does so at reduced flow and head relative to when first installed. In other cases, the circulator can be completely stalled by the accumulation of such particles.

One way to help ensure that high-efficiency circulators maintain good performance is to trap iron oxide particles, as well as other debris, before they can accumulate within the circulator. This is possible using magnetically enhanced, low-velocity-zone dirt separators.

The ability of a low-velocity-zone dirt separator to capture iron oxide particles is enhanced by installing powerful rare-earth magnets on or within the separator. Iron oxide particles are attracted to these magnets, improving the capture efficiency of the separator. When the magnetic portion of the separator is removed, the iron oxide particles along with other debris can be flushed out from the lower bowl of the separator.

Figure 3-20

Figure 3-21



Figures 3-20 and 3-21 show external and internal views of a Caleffi DirtMag magnetic dirt separator. Notice the black collar near the bottom of the separator's bowl. This collar contains powerful rare earth magnets that attract ferrous metal particles and hold them against the side of the brass body, which is nonmagnetic.

The permanent magnets used in this collar maintain their full strength over time, allowing the separator to constantly attract and capture ferrous particles as they form in the system.

Figure 3-22

Figure 3-23

Figures 3-22 and 3-23 shows another variation on a magnetic dirt separator. In this case, the separator's body is made of engineered polymer. The body connects to a rotatable brass base fixture that allows the body to remain vertical regardless of the orientation of the pipe to which it is attached. This separator also contains a media that helps separate dirt from the flow stream. The magnetic collar can be seen at the lower end of the body.

Figure 3-24 shows a DirtMag separator being drained. Notice that the magnetic collar has been removed during the drainage process. This allows the captured ferrous metal particles to drop into the lower bowl and be flushed out with other debris.

Figure 3-25 shows how a magnet attracts iron containing dirt particles that have been captured in the effluent flushed from the DirtMag separator.

Figure 3-24

Figure 3-25

Figure 3-26

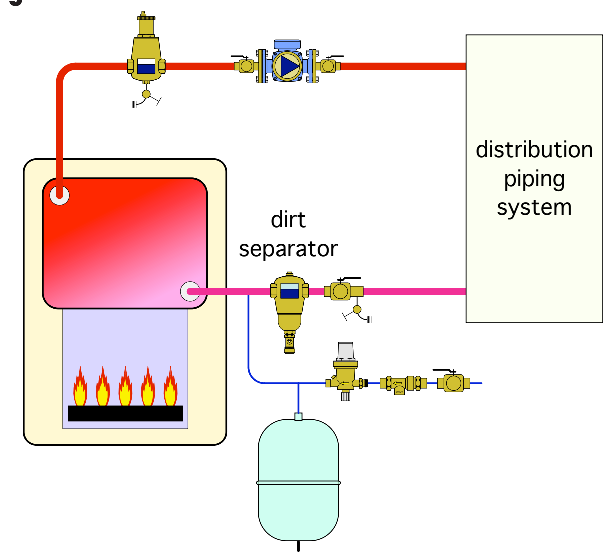
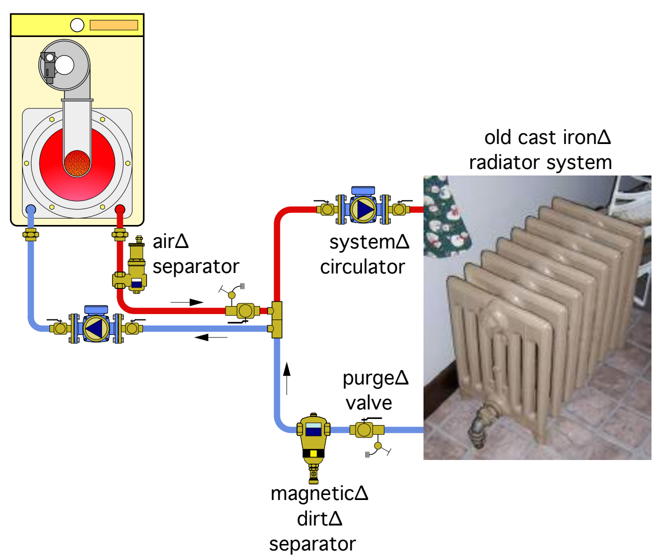


Figure 3-27



PLACEMENT OF DIRT SEPARATORS:

Because most dirt particles have a density greater than water, they tend to migrate toward the lower portions of the system. Thus, it makes sense to separate and capture them in this area. It also makes sense to continually route system flow through a dirt separator to increase the number of passes the system volume makes through the device in a given amount of time.

Dirt separators are commonly placed on the inlet side of boilers, heat exchangers and other heat sources, as shown in Figure 3-26. This is especially important in systems using boilers or other heat sources with compact heat exchangers. It's also very important in systems where a new boiler is installed in a system containing older piping and/or cast iron radiators, as shown in Figure 3-27.

The dirt separator is placed on the return side of the distribution system to capture particles that might otherwise flow through the new boiler. A magnetic dirt separator is especially appropriate for such systems given the higher potential of iron oxide particles in the flow stream.

Notice that purging valves have been located just upstream of the dirt separator. This allows some of the dirt in the system to be flushed out during initial filling and purging. This, in turn, decreases the amount of dirt the separator will eventually have to capture.

When possible, it's also desirable to place the dirt separator upstream of circulators. This helps extract dirt before flow passes through the circulator. When doing so, allow at least 12 pipe diameters of straight pipe between the outlet of the air separator and inlet of the circulator.

Some systems use multiple circulators to push flow from different circuits into the boiler. In this case, the compromise is to place the dirt separator upstream of the boiler, as shown in Figure 3-28.

Figure 3-28

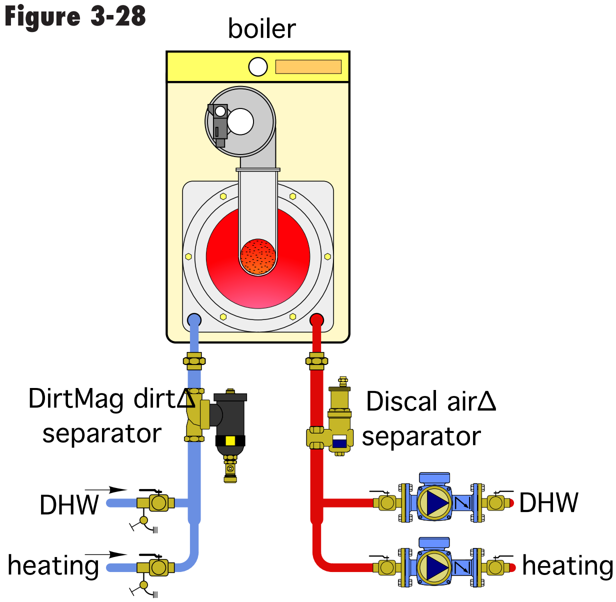
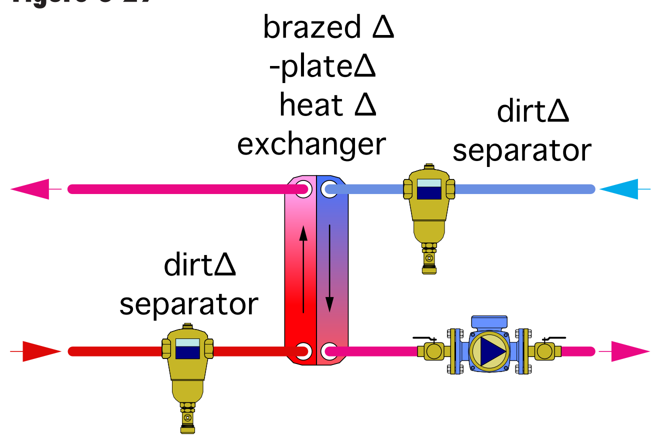


Figure 3-29



In systems with a main mixing valve, it's best to place dirt separators in the return line from the distribution system ahead of the valve. This increases flow through the separator and better protects the mixing valve from dirt.

With all installations, be sure to plan sufficient space to connect a drain hose or place a bucket under the dirt separator to capture the expelled fluid and dirt.

Low-velocity-zone dirt separators are also well-suited to protect the small fluid passageways within plate-type heat exchangers from dirt accumulation. Separators should be installed near the inlets of both the primary and secondary sides of the heat exchanger, as shown in Figure 3-29.

Figure 4-1

Figure 4-2

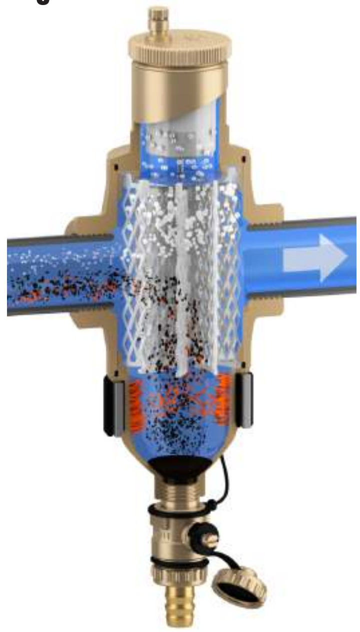
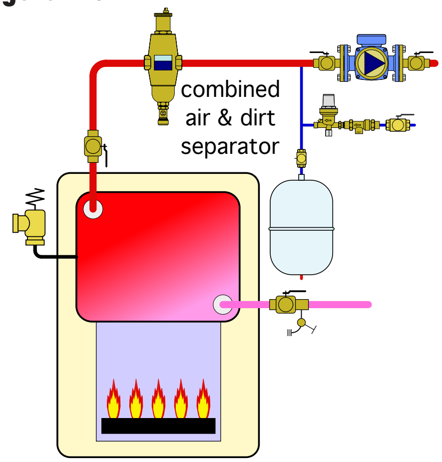


Figure 4-3



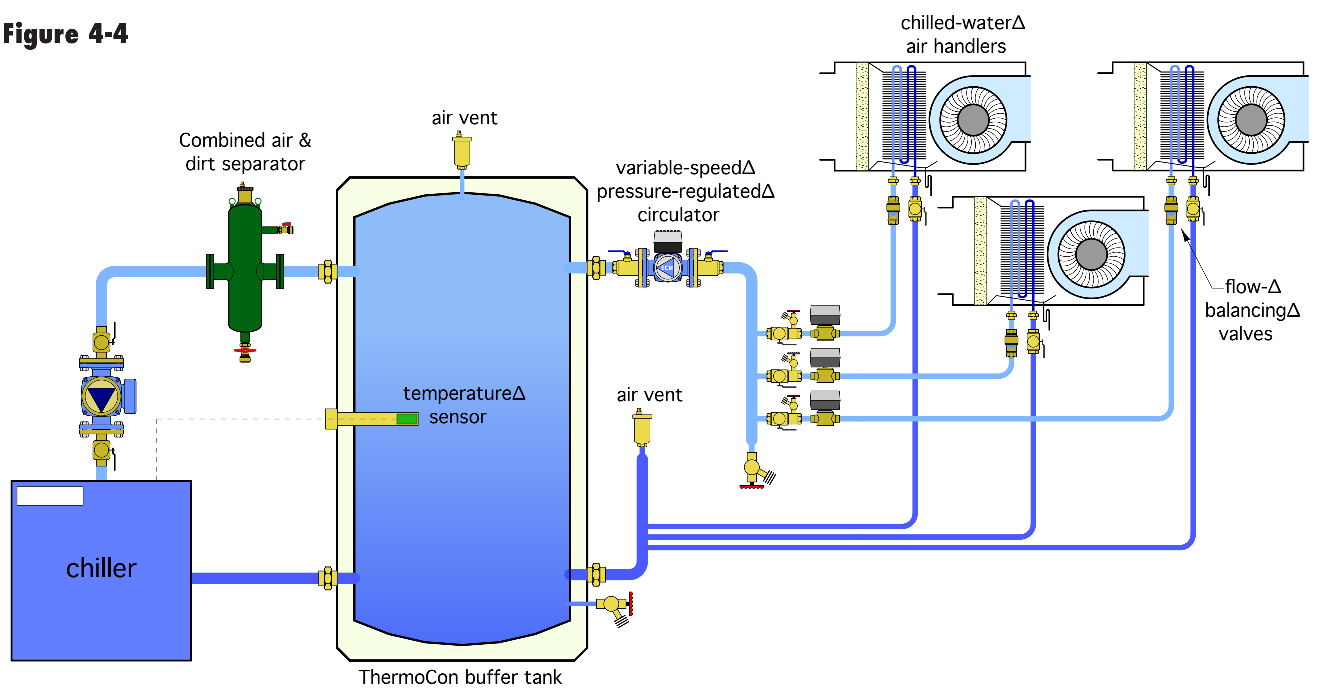
4. COMBINED AIR & DIRT SEPARATION

Some designers prefer to combine the function of air separation and dirt separation into a single device. This approach saves space, especially in tight mechanical rooms. It also reduces cost relative to installing two individual separators.

Combined air & dirt separators use the same principles of microbubble air separation in the upper portion of the separator body, combined with low-velocity-zone dirt separation in the lower portion of the separator body. They have a float-type automatic air vent at the top of the body and a drainage valve at the bottom, as seen in Figure 4-1.

Caleffi also offers combined air & dirt separators with magnetically enhanced separation of ferrous particles. A cross section of one such separator is shown in Figure 4-2.

Figure 4-4



PLACEMENT OF COMBINED AIR & DIRT SEPARATORS

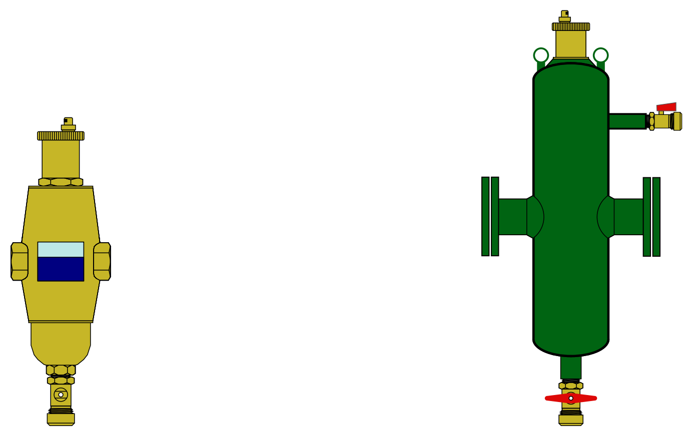
The preferred placement of a combination air & dirt separator depends on the application and system piping. In heating systems, preference should be given to air separation. The preferred placement of the combined air & dirt separator is near the outlet of the heat source, as shown in Figure 4-3. This creates conditions favorable to air separation (e.g., higher fluid temperature and lower pressure).

In cooling systems, the preferred placement of the air & dirt separator is near the *return* to the chiller plant, as shown in Figure 4-4. Water at this location has a slightly higher temperature compared to water leaving the chiller. This improves the conditions under which microbubbles can form. It also places the dirt separating function on the inlet to the chiller plant, which reduces the potential of dirt accumulation within the chiller.

SIZING AIR & DIRT SEPARATORS:

The ability of an air separator, dirt separator or a combined air & dirt separator to remove the undesired materials from a stream of water depends on the flow velocity of that stream. Slower flow velocities improve separation efficiency. For optimum performance, the pipe size for any of these separators should limit flow velocity to 4 feet per second. Higher flow velocities of up to 10 feet per second are possible but will decrease the efficiency of air and dirt separation. Separation will still occur, but over a longer time. Figure 4-5 lists the nominal pipe size of separators along with the flow rates corresponding to flow velocities of 4 feet per second and 10 feet per second.

Figure 4-5



		BRASS			STEEL								
	size	3/4"	1"	1.25"	2"	2.5"	3"	4"	5"	6"	8"	10"	12"
4 ft/sec	flowrateΔ GPM	8.0	9.3	10.0	37.3	63	95	149	259	380	625	980	1410
10 ft/sec	flowrateΔ GPM	19.0	22.1	25.0	88.8	150	227	355	616	904	1570	2450	3530

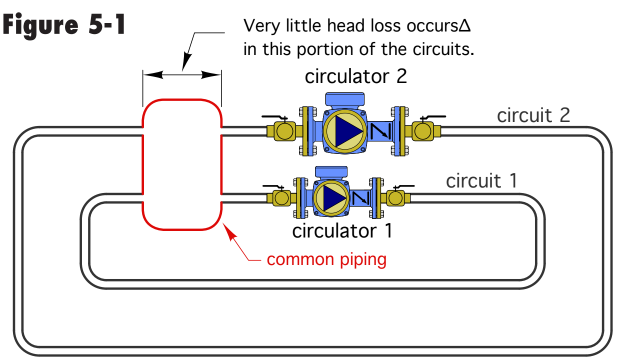
5. PRINCIPLES OF HYDRAULIC SEPARATION

Many hydronic systems contain multiple independently controlled circulators. These circulators can vary widely in their flow and head characteristics. Some may operate at fixed speeds, while others will operate at variable speeds.

When two or more circulators operate simultaneously in the same system, they each attempt to establish differential pressures based on their own pump curves. *Ideally, each circulator in a system will establish a differential pressure and flow rate that is unaffected by the presence of another operating circulator within the system.* When this desirable condition is achieved, the circulators are said to be **hydraulically separated** from each other.

Conversely, the lack of **hydraulic separation** can create very *undesirable* operating conditions in which circulators interfere with each other. The resulting flows and rates of heat transport within the system can be greatly affected by such interference, often to the detriment of proper heat delivery.

Figure 5-1

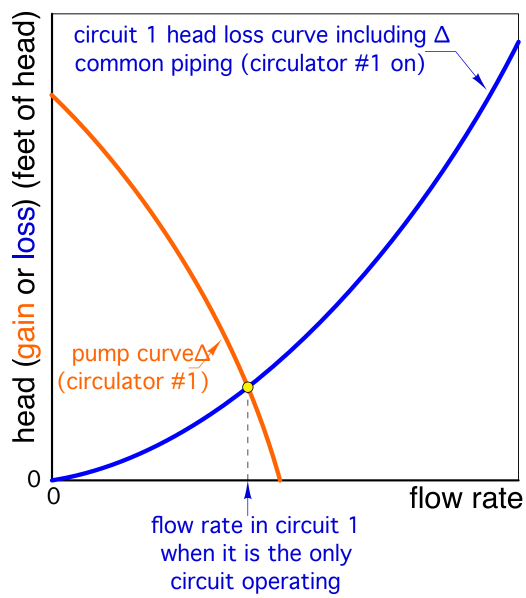


The degree to which two or more operating circulators interact with each other depends on the head loss within the piping path they have in common. This piping path is called the **common piping**, since it is shared by both circuits. *The lower the head loss of the common piping, the less the circulators will interfere with each other.*

Consider the system shown in Figure 5-1. In this system, both circuits share common piping. The "spacious" geometry of this common piping creates very low flow velocity through it. As a result, very little head loss can occur across it.

Assume that circulator 1 is operating, and circulator 2 is off. The blue circuit head loss curve shown in Figure 5-2 applies to this situation. The point where the blue circuit head loss curve crosses the orange pump curve for circulator 1 establishes the flow rate in circuit 1.

Figure 5-2



Next, assume circulator 2 is turned on, while circulator 1 remains on. The flow rate through the common piping increases, and so does the head loss across it. However, because of its spacious geometry, the increase in head loss across the common piping is very small. The system head loss curve that is now "seen" by circulator 1 will steepen, but very slightly. It is shown as the green curve in Figure 5-3.

Figure 5-3

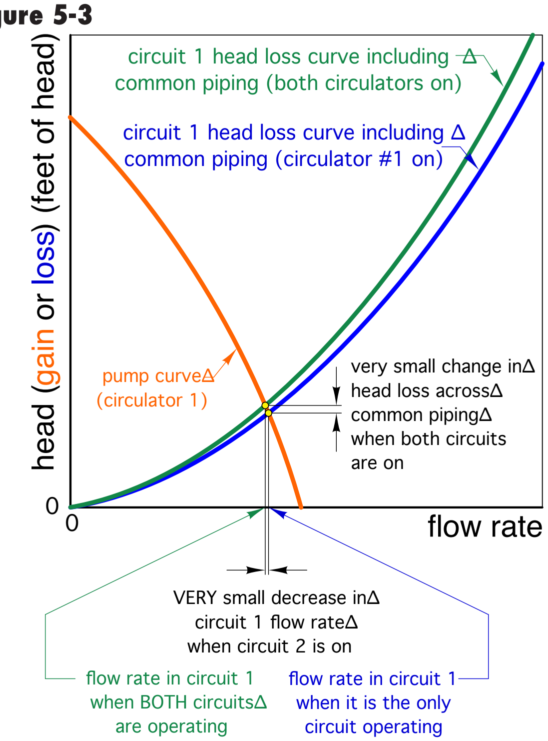
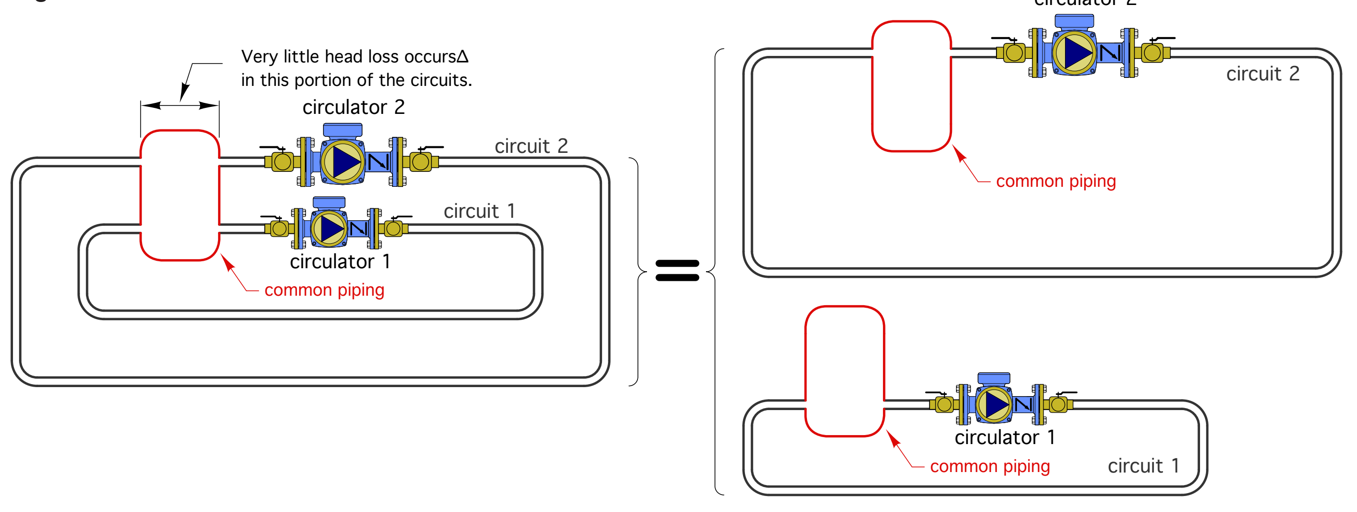


Figure 5-4



The operating point of circuit 1 has moved very slightly to the left and slightly upward. This implies that the flow rate through circuit 1 has decreased very slightly. This very small change in flow rate is indicated in Figure 5-3. Such a small change in circuit flow rate will have virtually no effect on the ability of circuit 1 to deliver heat. Thus, the interference created when circulator 2 was turned on is of no consequence. Therefore, this situation provides acceptable hydraulic separation between the two circulators.

One could imagine a hypothetical situation in which the head loss across the common piping was zero, even with both circuits operating. Because no head loss occurs across the common piping, it would be impossible for either circulator to have any effect on the other circulator. Such a condition would represent "perfect" hydraulic separation and would be ideal. Fortunately, *perfect* hydraulic separation is not required to ensure that the flow rates through independently operated circuits, each with their own circulator, and each sharing the same low-head-loss common piping, remain reasonably stable, and thus capable of delivering consistent heat transfer. In animated terms, the two simultaneously operating circulators cannot "sense" each other's presence within the system, and thus operate as if they were each in an independent circuit.

One can think of (and design) circuits that are known to have a high degree of hydraulic separation, as if they were completely independent of each other, as illustrated in Figure 5-4.

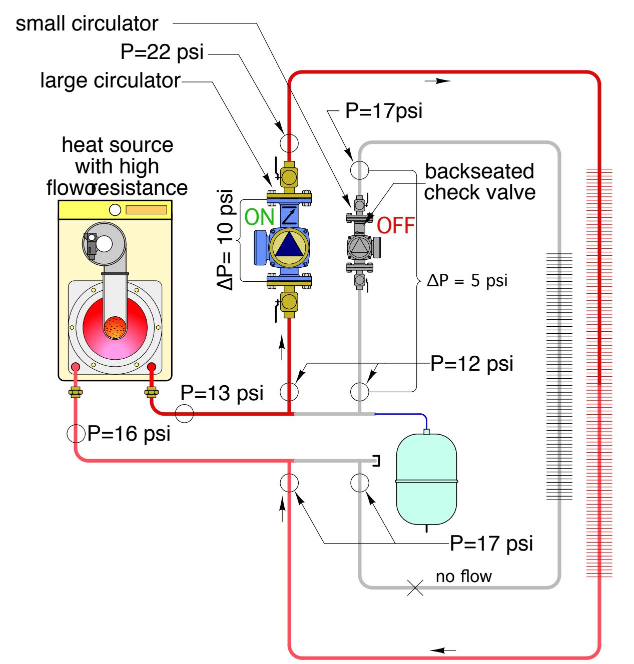
The required hydraulic performance of each circuit can be determined as if it were a standalone circuit, unaffected by the other circuits in the system. This is a very powerful concept that simplifies design and troubleshooting.

LACK OF HYDRAULIC SEPARATION:

Having stressed that hydraulic separation is desirable, it is worthwhile to consider a situation in which hydraulic separation is *NOT* present and observe the consequences.

Consider the horizontal piping system shown in Figure 5-5. The larger circulator is sized to move sufficient flow through the higher flow-resistance circuit including the high-flow-resistance heat source. When operating, the flow created by the large circulator creates a pressure drop of 5 psi between the supply and return headers connected to the heat source.

Figure 5-5



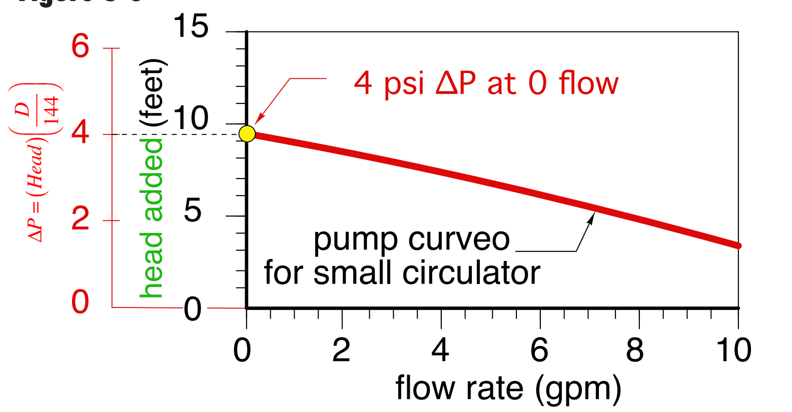


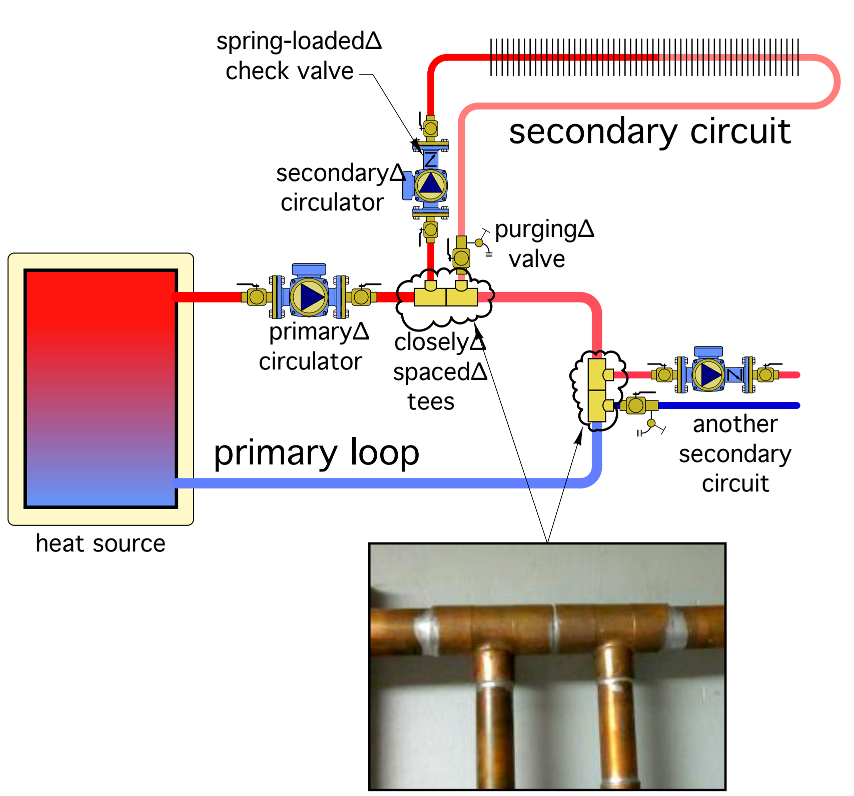
Figure 5-6 shows the pump curve for the smaller circulator. Notice that the maximum possible differential pressure this circulator can create is 4 psi.

Because the reverse differential pressure of 5 psi is greater than the maximum forward differential pressure of 4 psi, the circulator cannot create flow, even though its impeller is spinning at normal speed. Its internal check valve remains closed. Under this condition, the circulator is said to be "deadheaded." It will dissipate its full input power as heat. This heat will be absorbed by the water in the circulator's volute, as well as be dissipated by the circulator's body. Although this is not a condition that should be allowed by proper design, small wet-rotor circulators can usually withstand such operation for several hours. Such situations can be avoided by creating hydraulic separation between the circuits.

The pressures shown in Figure 5-5 are those established when the large circulator is operating and the small circulator is off. Because there is no flow in the circuit containing the small circulator, the 17 psi pressure at the return end of this circuit is present around the circuit. Hence, there is a 17 psi pressure at the discharge port of the smaller circulator. This creates a *reverse* pressure differential of (17-12) = 5 psi across the small circulator, which forces its internal check valve closed.

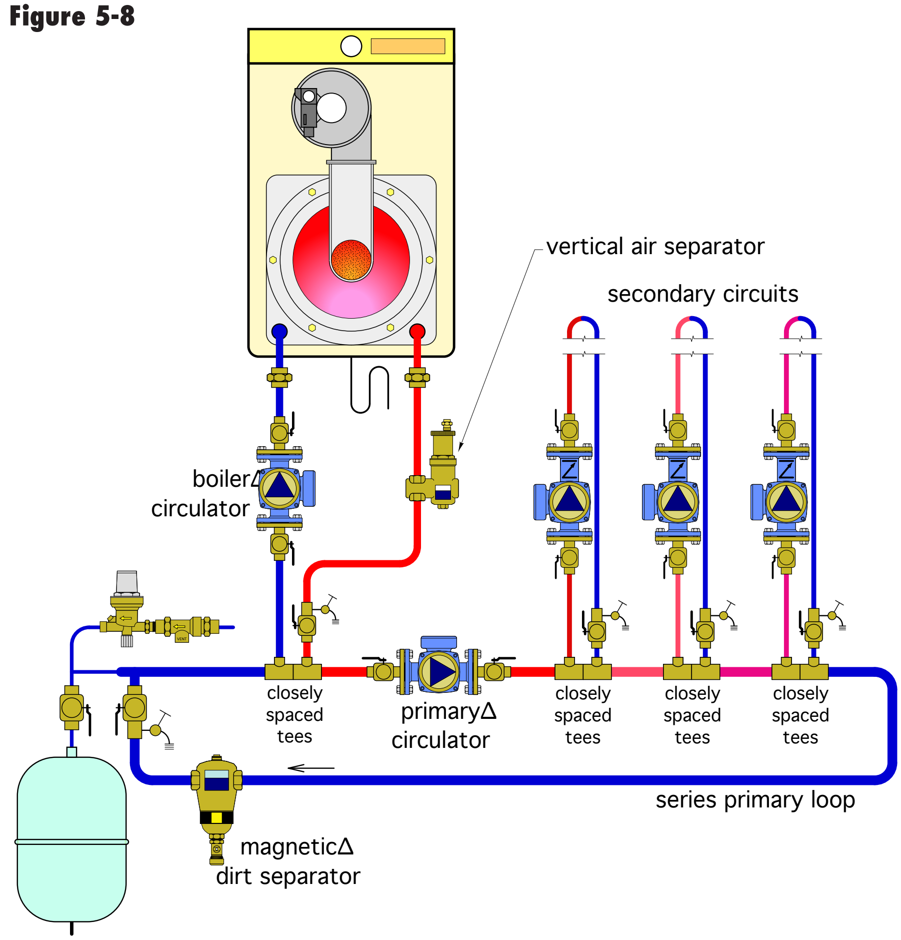
EVOLUTION OF HYDRAULIC SEPARATION:

Although the term *hydraulic separation* is relatively new to the North American hydronics industry, the principle of avoiding interaction between simultaneously operating circulators in the same system is not. During the 1950s, the concept of primary/secondary piping was introduced in North America. It was promoted as a way to provide stable on/off flow control in multiple independently controlled circuits, each with its own circulator. It is based on the use of two very closely spaced tees, as shown in Figure 5-7.



Because the tees are very close together, the pressure drop between them due to head loss is almost zero. Hence, the pressure at the side port of each tee is almost exactly the same. Since there is virtually no pressure differential between the tees, there is very little tendency for flow to develop in the secondary circuit, even though flow is passing through the tees in the primary circuit. However, it is still good practice to install a spring-loaded check valve on the supply side of every secondary circuit to prevent buoyancy-driven flow from developing. The intended flow rate in the secondary circuit is achieved when

Figure 5-8



the secondary circulator operates. Because the flow created by the primary circulator does not induce flow in the secondary circuit, nor does it have any significant effect on the flow in the secondary circuit when its secondary circulator is operating, these two circuits are hydraulically separated from each other.

This concept can be extended to multiple secondary circuits served by a common primary loop, as shown in Figure 5-8. Each secondary circuit, including the secondary circuit through the boiler, is joined to the primary circuit using a pair of closely spaced tees to provide hydraulic separation.

The configuration shown in Figure 5-8 is more precisely called a *series* primary/secondary system. With this approach, all secondary circuits are arranged in a sequence around the common primary loop.

Although hydraulic separation exists between all circuits, so does an often-undesirable effect—*a drop in supply water temperature from one secondary circuit to the next whenever two or more of the secondary circuits are operating simultaneously.* Although there are situations in which this temperature drop doesn't present a problem, it does add complications that designers must assess and compensate for.

One way to overcome the series temperature drop effect associated with series primary loops is to create a *parallel* primary loop, as shown in Figure 5-9.

A parallel primary loop is divided into two or more "crossover bridges." A pair of closely spaced tees within each crossover bridge provides hydraulic isolation between each secondary circuit and the parallel primary loop.

Unlike a system with a series primary loop, a system with a parallel primary loop provides essentially the same supply water temperature to each secondary circuit, regardless of which secondary circuits are operating. This benefit is achieved through more complicated and costly piping. Notice that each crossover bridge contains a flow-balancing valve. These valves are needed to set the flow through each crossover bridge in proportion to the thermal load served by the secondary circuit supplied from that bridge. If these valves are not present and properly adjusted, there may be problems such as inadequate flows through the crossover bridges located farther away from the primary circulator.

Another important consideration is that both series and parallel primary/secondary systems require a primary circulator. This circulator adds to the installed cost of the system. More importantly, it adds to the system's operating cost over its entire life. Even one small primary loop circulator in a system can have operating costs that total more than $1,000 over a typical 20-year design life. Larger primary loop circulators can have life-cycle operating costs of several thousand dollars.

For example: Consider a primary loop circulator that must produce a flow rate of 50 gpm, with a corresponding head of 15 feet (which is evidenced by a pressure gain of 6.35 psi across the circulator). Assume the circulator is a typical wet-rotor design and has a wire-to-water efficiency of 25% at these operating conditions. The estimated input power to operate this circulator is:

$$W = \frac{0.4344 \times f \times \Delta P}{0.25} = \frac{0.4344 \times 50 \times 6.35}{0.25} = 552 watts$$

If this primary loop circulator were to operate for 3000 hours each year, and the local cost of electrical energy was \$0.10/kWhr, the annual operating cost would be:

$$\text{1st year cost} = \left(\frac{3000hr}{yr}\right)\left(\frac{552w}{1}\right)\left(\frac{1kwhr}{1000whr}\right)\left(\frac{\$0.10}{kwhr}\right) = \$165.60$$

Furthermore, if the cost of electricity were to inflate at 4% each year, the total operating cost of this circulator over a 20-year period would be:

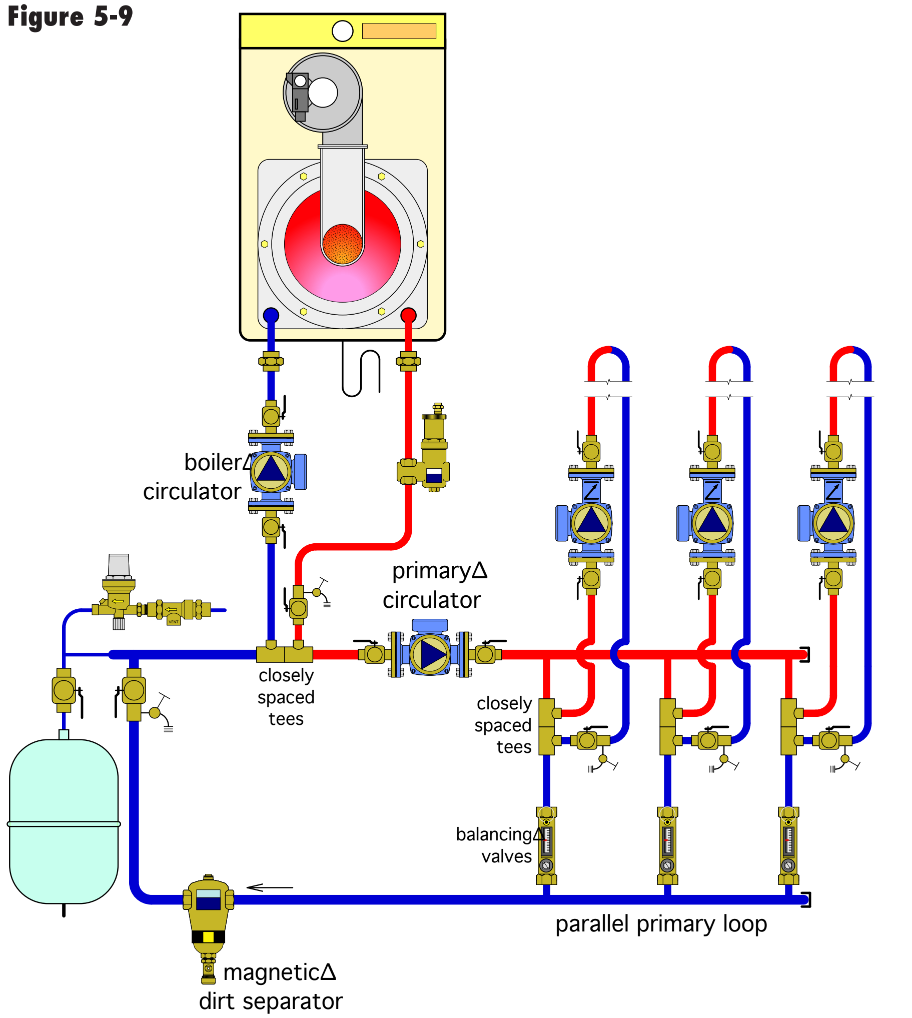
$$c_T = c_1 \times \left(\frac{(1+i)^N - 1}{i}\right) = \$165.60 \times \left(\frac{(1+0.04)^{20} - 1}{0.04}\right) = \$4{,}931$$

This cost is only for operation of the primary loop circulator. It does not include purchase, installation or maintenance of that circulator over time.

Imagine a situation in which the hydraulic separation benefits of primary/secondary piping, as well as the equal supply water temperatures provided by a parallel primary loop, could be provided without having to construct a primary loop or use a dedicated primary loop circulator.

There are now several modern methods for achieving these benefits without need of constructing primary/secondary piping systems. They are discussed in the next section.

Figure 5-9



6. MODERN METHODS OF HYDRAULIC SEPARATION

Any component or combination of components with very low head loss, and common to two or more hydronic circuits, can provide hydraulic separation between those circuits.

One way to create low head loss is to keep the flow path through the common piping very short. Another way to create low head loss is to significantly reduce the flow *velocity* through the common piping.

Examples of devices that use these principles include:

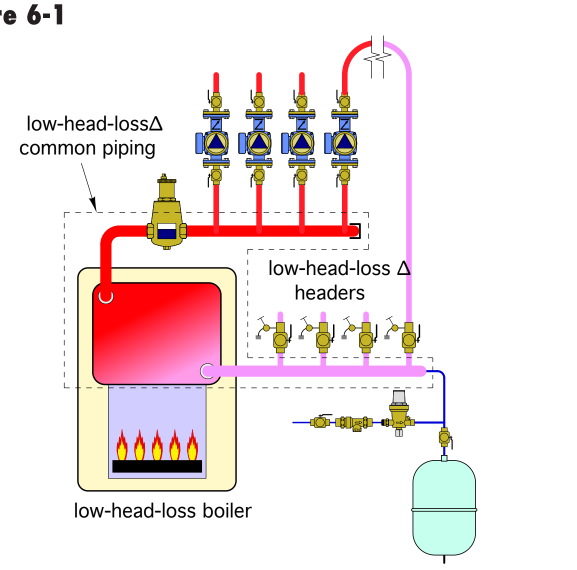
1. A heat source that has very low head loss
2. A pair of closely spaced tees
3. A buffer tank with specific piping arrangement
4. A hydraulic separator
5. Specialty components such as a Caleffi HydroLink

Each of these methods can provide hydraulic separation between simultaneously operating circulators, as well as equal supply water temperature to each load circuit.

LOW-HEAD-LOSS HEAT SOURCE:

Figure 6-1 shows an example of a system with a single cast iron sectional boiler supplying 4 zone circulators. Many North American hydronic systems were once piped similar to this. Although the term hydraulic separation was not used at that time to describe the inherent advantage of this approach, these systems performed well with minimal interference between simultaneously operating circulators.

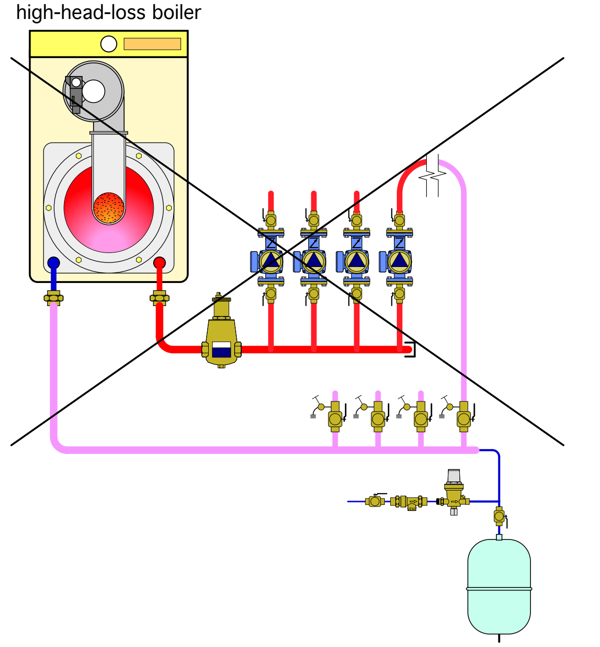
Figure 6-1



Nearly all cast iron sectional boilers have large chambers through which water moves very slowly as it passes from the boiler's inlet to its outlet. These slow internal velocities create very low head loss through the boiler, even when all the zone circulators are operating. If this type of boiler is combined with low-head-loss header piping, as discussed in the previous section, the resulting combination creates low-head-loss common piping for the zone circuits. This, along with a very simple piping arrangement, provides the necessary conditions for hydraulic separation.

When modulating/condensing boilers were first introduced to North America, many of them used compact internal heat exchangers that created much higher head loss in comparison to traditional cast iron boilers. Some of these boilers were installed using the same piping arrangement that was common practice with cast iron boilers, as shown in Figure 6-2.

Figure 6-2



The high head loss of the mod/con boiler significantly increased the overall head loss of the common piping and largely negated the hydraulic separating characteristic attained in systems using the older style, low-head-loss boilers. This created many problem installations, since installers and manufacturers did not immediately recognize the source of the resulting flow problems.

Eventually, the source of the flow problems was traced back to the high head loss of the new style boilers with

Figure 6-3

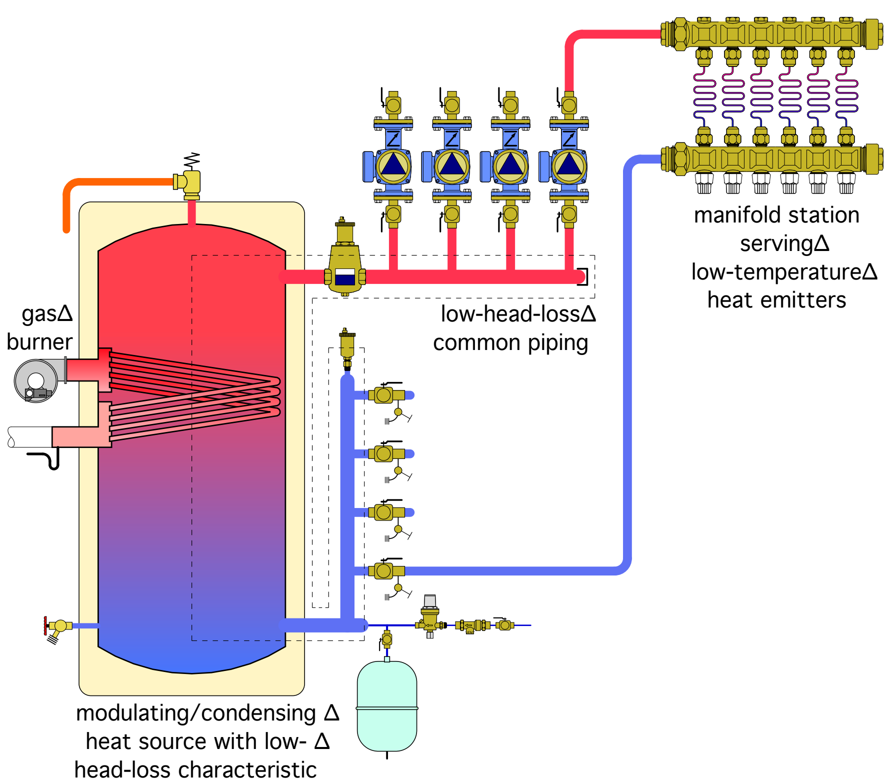
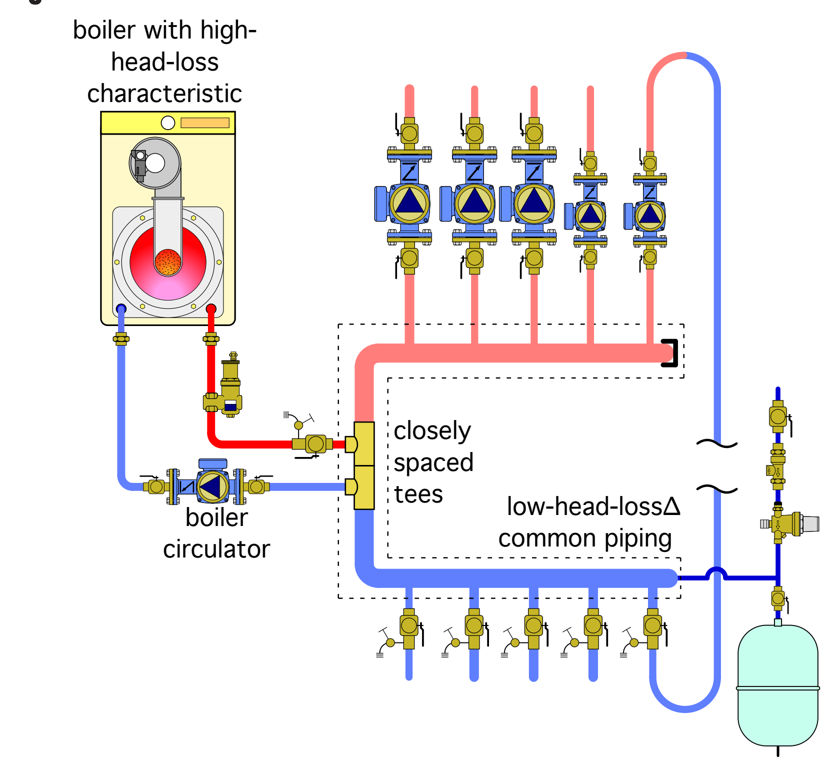


Figure 6-4



their compact heat exchangers. Piping methods were modified to correct this problem. These methods will be discussed shortly.

Today, there are modulating/condensing boilers available with low-head-loss characteristics. When combined with low-temperature distribution systems, they provide the benefit of high thermal efficiency, as well as the benefit of simple piping that provides excellent hydraulic separation between the circulators. Figure 6-3 shows an example of such a system.

HYDRAULIC SEPARATION USING CLOSELY SPACED TEES:

Heat sources such as mod/con boilers with compact internal heat exchangers or water-to-water heat pumps tend to have high-head-loss characteristics. Because of this, they should not be part of a common piping assembly that is supposed to have low head loss.

One solution is to couple such heat sources to a generously sized header system using a pair of closely spaced tees, as shown in Figure 6-4.

Because they are positioned as close to each other as possible, there is virtually no head loss between the tees. They form the common piping between the boiler circuit and the headers, and thus provide hydraulic separation between the boiler circulator and any of the circulators on the supply header. The headers have also been sized for low head loss. As such, they provide hydraulic separation between any two or more of the circulators connected to the headers.

A suggested guideline is to size headers for a flow velocity in the range of 2 to 4 feet per second when all the circulators supplied by the header are operating. Low

Figure 6-5

Tube/pipe size	Flow rate at 2 ft/sec	Flow rate at 4 ft/sec
1" M copper	5.5 gpm	10.9 gpm
1.25" M copper	8.2 gpm	16.3 gpm
1.5" M copper	11.4 gpm	22.9 gpm
2" M copper	19.8 gpm	39.6 gpm
2.5" M copper	30.5 gpm	61.1 gpm
3" M copper	43.6 gpm	87.1 gpm
4" M copper	75.9 gpm	152 gpm
5" M copper	118 gpm	236 gpm
6" schd. 40 steel	180 gpm	361 gpm
8" schd. 40 steel	312 gpm	624 gpm
10" schd. 40 steel	492 gpm	984 gpm
12" schd. 40 steel	699 gpm	1397 gpm

flow velocity creates minimum head loss, while also allowing for air bubble entrainment. The latter is useful when air bubbles need to be forced downward in a vertical header during system commissioning.

Figure 6-5 lists the flow rates corresponding to flow velocities of 2 feet per second and 4 feet per second for type M copper tubing in sizes from 1-inch to 5-inch, and in schedule 40 steel for larger pipe sizes. For other piping materials or sizes, the flow rate corresponding to a given flow velocity can be calculated using Formula 6-1.

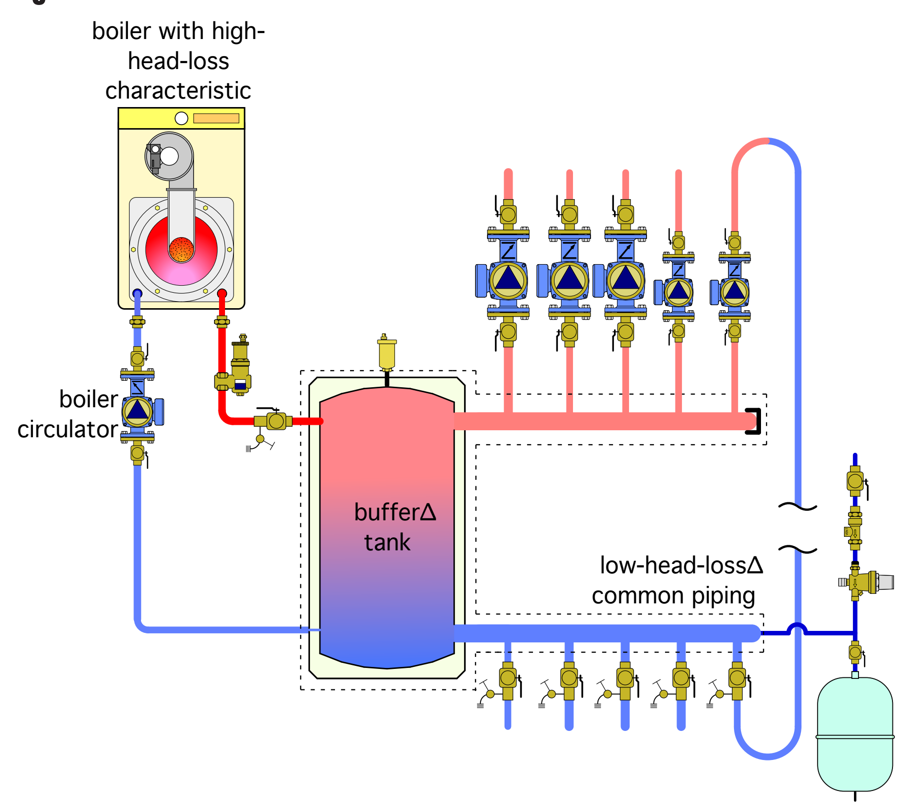
Formula 6-1:

$$f = v\left(\frac{d_i^2}{0.408}\right)$$

Where:
v = average flow velocity (ft/sec)
f = flow rate (gpm)
di = exact inside diameter of pipe (inches)

With proper hydraulic separation, such as shown in Figure 6-4, it is possible to combine circulators with significantly different pump curves on the same header system. It is also possible to combine fixed-speed and variable-speed circulators on the same low-head-loss headers.

Figure 6-6



HYDRAULIC SEPARATION USING A BUFFER TANK:

Figure 6-6 shows a buffer tank and generously sized headers serving as the low-head-loss common piping that provides hydraulic separation between the heat source circulator and each of the distribution circulators. This demonstrates that hydraulic separation can sometimes be accomplished as an ancillary function to the main purpose of the device (e.g., hydraulic separation is not the main function of the buffer tank).

Figure 6-7 shows an example of a Caleffi ThermoCon tank serving as both a buffer tank and hydraulic separator between a water-to-water geothermal heat pump, a modulating/condensing auxiliary boiler and the associated distribution system.

Figure 6-7

Courtesy of Harvey Youker and Danny Gough

HYDRAULIC SEPARATION USING A HYDRAULIC SEPARATOR:

Another method of providing hydraulic separation is by installing a device appropriately called a hydraulic separator. Although relatively new in North America, hydraulic separators have been used in Europe for many years. Figure 6-8 shows a hydraulic separator installed in place of the buffer tank in Figure 6-6. Note the similarity of the piping connections between the systems.

Figure 6-8

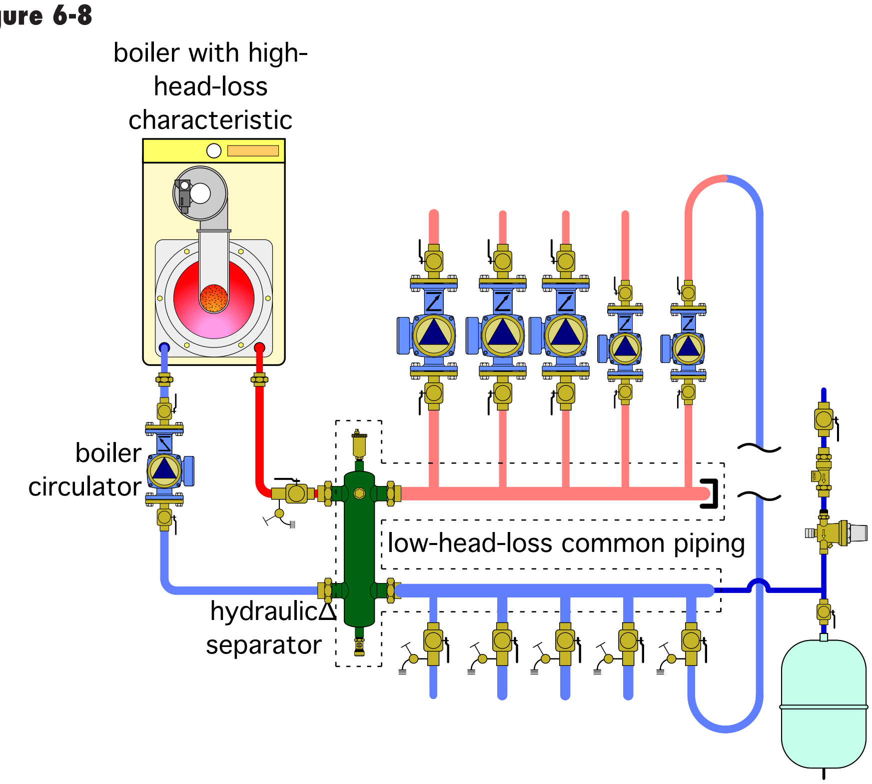


Figure 6-9 shows the external appearance of several Caleffi hydraulic separators. The front portion of the insulation shell has been removed from the two smaller separators. The large, self-supporting hydraulic separator is awaiting site-installed insulation.

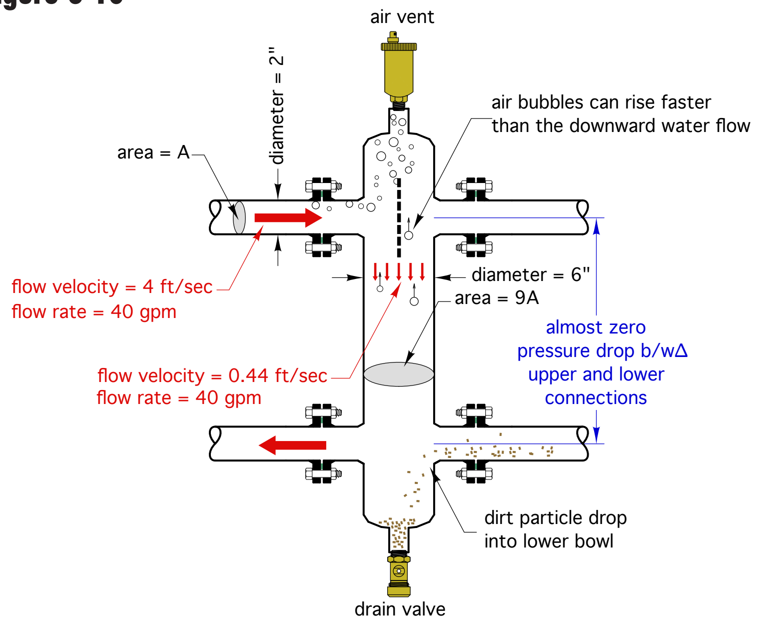
Hydraulic separators are sometimes also called **low loss headers** or "**decouplers.**" They create a zone of low flow velocity within their vertical body. The diameter of the body is typically three times the diameter of the connected piping. This causes the vertical flow velocity in the vertical body to be approximately 1/9th that of the connecting piping, as shown in Figure 6-10. Such low velocity creates very little head loss and very little dynamic pressure drop between the upper and lower connections. Thus, a hydraulic separator provides hydraulic separation in a manner similar to a buffer tank, only smaller.

The reduced flow velocity within a hydraulic separator allows it to perform two additional functions. First, air bubbles can easily rise upward within the vertical body and be captured in the upper chamber. When

Figure 6-9

Installed separator photo courtesy of Rathe Associates

Figure 6-10



sufficient air collects at the top of the body, the float-type air vent allows it to be ejected from the system. Thus, a hydraulic separator can provide air separation.

Second, the reduced flow velocity inside the hydraulic separator allows dirt particles to drop into a collection chamber at the bottom of the body. A valve at the bottom can be periodically opened to flush out any accumulated dirt. Thus, the hydraulic separator also serves as a dirt removal device.

The efficiency of both air and dirt separation is enhanced through use of a *coalescing media* in the active flow zones, which are in line with the side ports of the separator. These are shown in Figure 6-11.

High-performance hydraulic separators, such as the Caleffi HydroCal, provide three functions:

1. Hydraulic separation
2. High-performance air separation (equivalent to a Caleffi *Discal* air separator)
3. High-performance dirt separation (equivalent to a Caleffi *Dirtcal* dirt separator)

This multifunctional ability allows a single high-performance hydraulic separator to provide hydraulic separation, as well as replace a high-performance air separator and high-performance dirt separator, as illustrated in Figure 6-12.

Figure 6-11

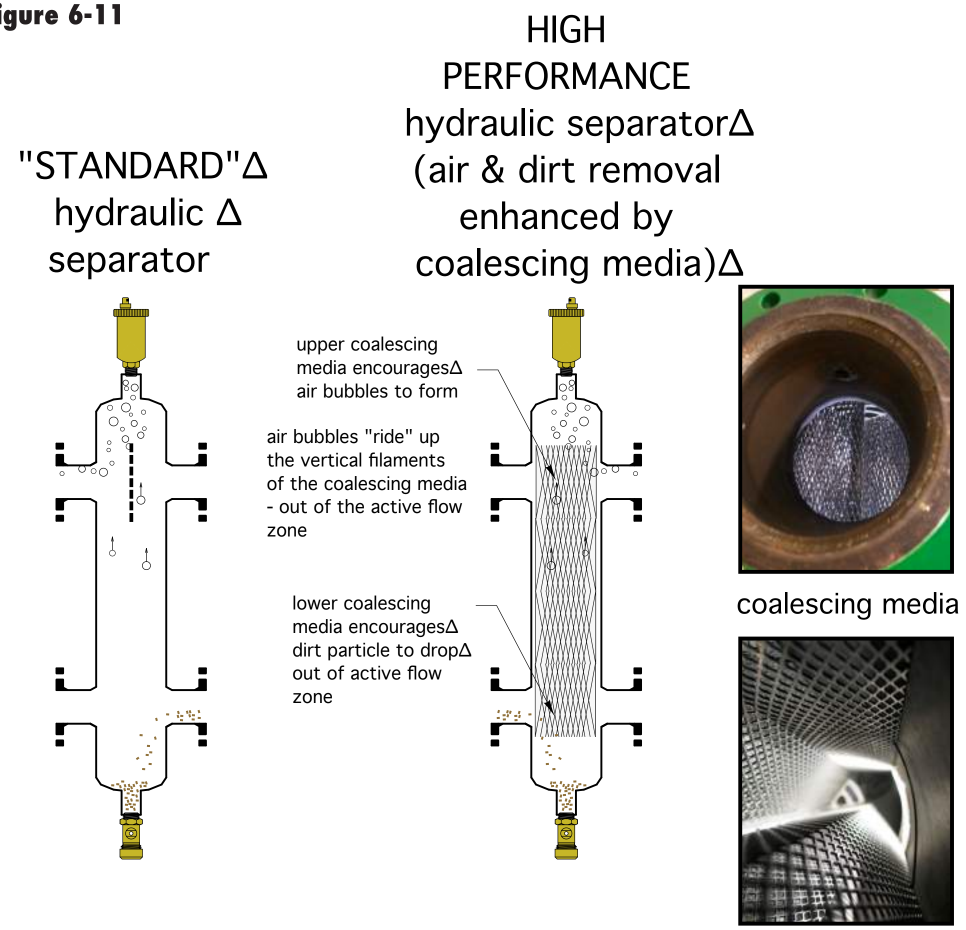
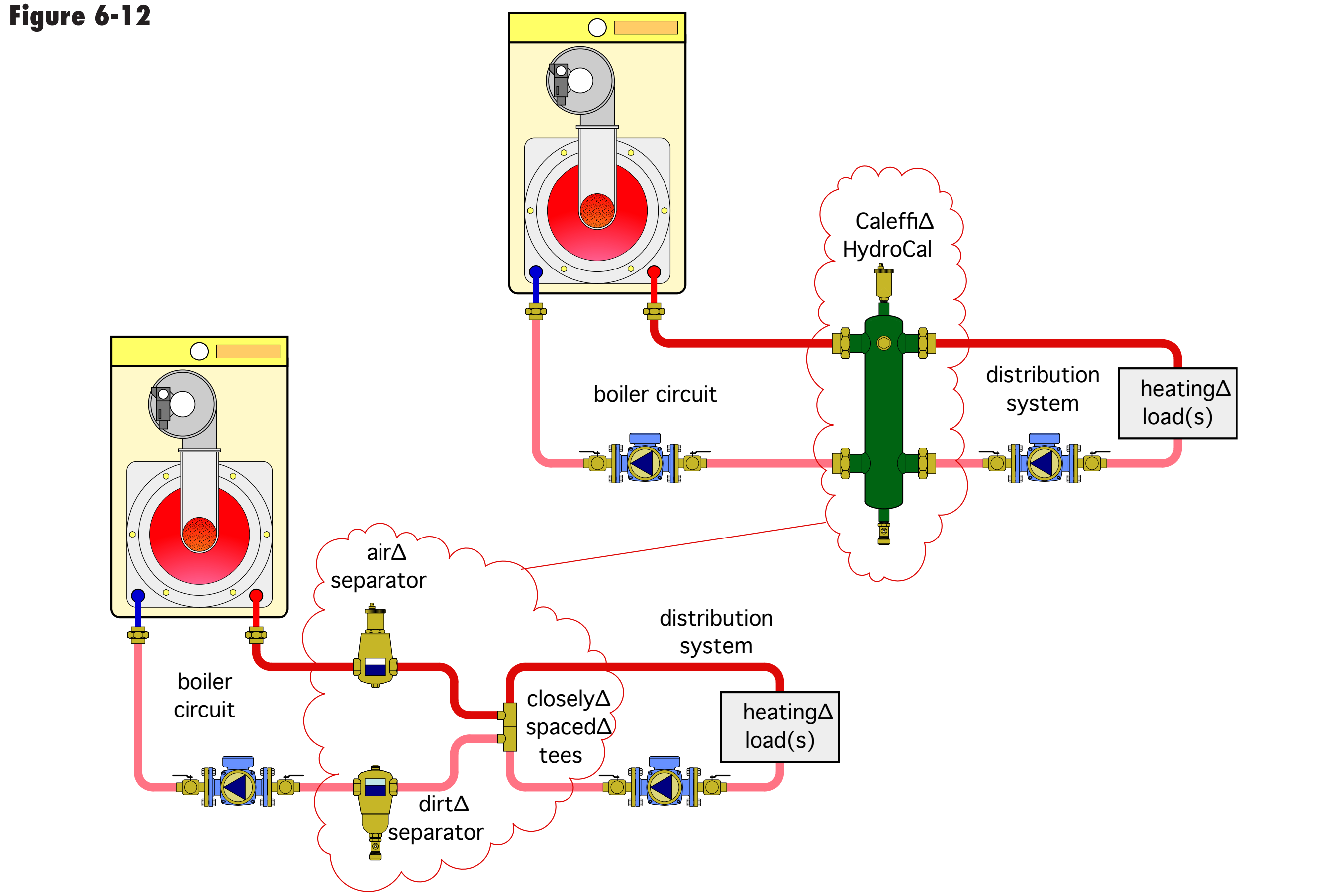


Figure 6-12



MAGNETICALLY ENHANCED PARTICLE SEPARATION:

The latest enhancement for high-performance hydraulic separators is the addition of magnetic particle separation. Figure 6-13 shows the Caleffi SEP4 separator, which uses a collar containing strong rare earth magnets in combination with a brass sediment bowl to add the fourth function (e.g., magnetic particle separation) to the product.

The addition of magnetic particle separation makes the SEP4 hydraulic separator especially useful for applications in which an older distribution system—one that may have some accumulated ferrous metal sludge—is connected to a new heat source. Figure 6-14 shows a concept for how a SEP4 hydraulic separator is used to interface the new boiler and high-efficiency circulator to an older distribution system serving cast iron radiators. Notice that each radiator has been equipped with a thermostatic valve that allows for individual heat output control.

Figure 6-13a

Figure 6-13b

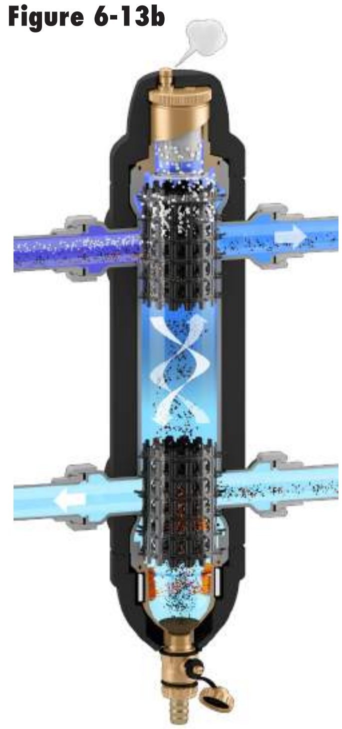


Figure 6-14

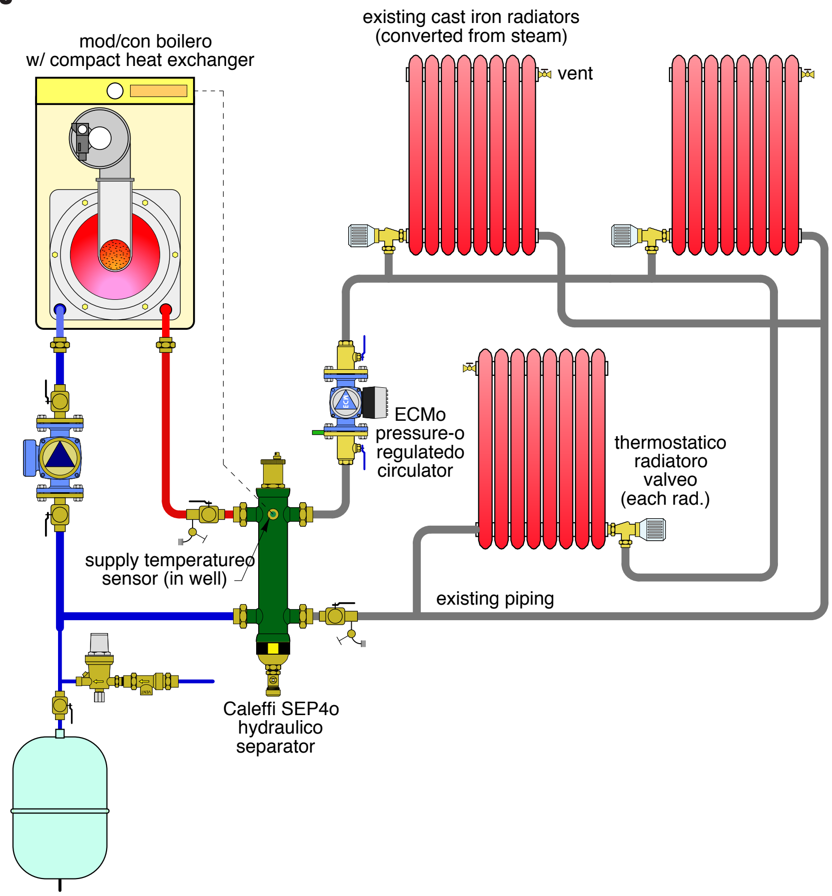


Figure 6-16

Courtesy of Tweet / Garot Mechanical, Inc., Greenbay, Wisconsin

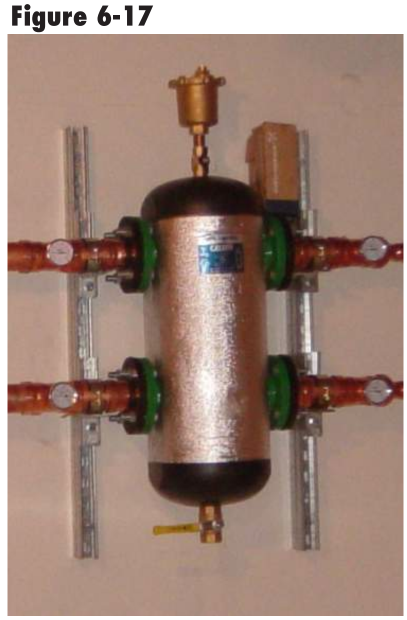
Given the surface area of their bodies, *hydraulic separators should always be insulated* to minimize heat loss to their surroundings. This is especially true of larger hydraulic separators, which may have more surface area than a modestly sized radiator, and without insulation, would needlessly overheat the mechanical room. Figure 6-15 shows the insulation shell supplied with a Caleffi SEP4 separator installed on the device. Figure 6-16 shows onsite fabricated insulation covering a large hydraulic separator in an industrial heating system.

Figure 6-15 shows another example of a SEP4 circulator providing magnetically enhanced dirt separation in a system using a high-efficiency permanent magnet circulator.

Figure 6-15

Courtesy of Osborne Company

Figure 6-17



Courtesy of Dan Schlicher

Hydraulic separators should also be properly supported. Small units can typically be supported by channel strut, as seen in Figure 6-17, or by using clevis hangers. Large hydraulic separators are designed to be self-supported at their base.

Hydraulic separators are available in pipe sizes from 1-inch to over 12-inch. The “size” of a hydraulic

Figure 6-18

union connections: 1" – 2"

flange connections: 2" – 12"

pipe size	1"	1.25"	1.5"	2"	2.5"	3"	4"	5"	6"	8"	10"	12"
max flow rate (gpm)	11	18	26	37(union) 40(flange)	80	124	247	300	484	792	1330	1850

separator refers to the nominal pipe size of the 4 side-wall connections.

Selecting an appropriate-size hydraulic separator is easy. It is based on choosing a size that allows the maximum anticipated flow rate into either side of the separator, without exceeding a preferred flow velocity of 4 feet per second. Limiting the flow velocity to this value maintains highly efficient air and dirt separation. The table in Figure 6-18 can be used as a reference.

For example, if the maximum flow rate on the primary side of the hydraulic separator was 290 gpm, and the maximum flow rate on the secondary side of the separator was 400 gpm, the higher flow rate would be the limiting case. Figure 6-16 indicates that a 6" size separator can handle flow rates up to 484 gpm, and thus would be an appropriate selection for this situation.

MIXING AT THE POINT OF HYDRAULIC SEPARATION: Mixing can occur within any component or group of components that provides hydraulic separation. The results of the mixing can be predicted by considering the principles of:

1. Conservation of mass
2. Conservation of thermal energy

In essence, the first of these principles states that the total flow rate of an incompressible fluid such as water entering the separator has to equal the total flow rate exiting the separator. The second principal implies that, under steady-state operating conditions, the total thermal energy entering the separator has to equal the total thermal energy leaving the separator.

The temperatures at the two outlet ports of a hydraulic separator (e.g., ports 2 and 3 in Figure 6-19) depend on the temperatures at the two inlet ports (e.g., ports 1 and 4 in Figure 6-19), as well as the flow rates in both the boiler circuit and distribution system.

Figure 6-19

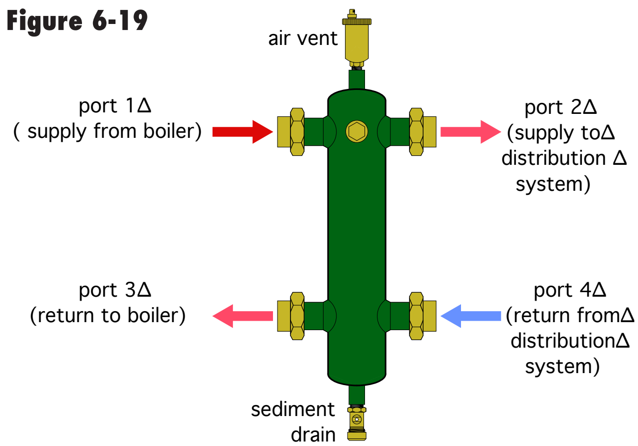
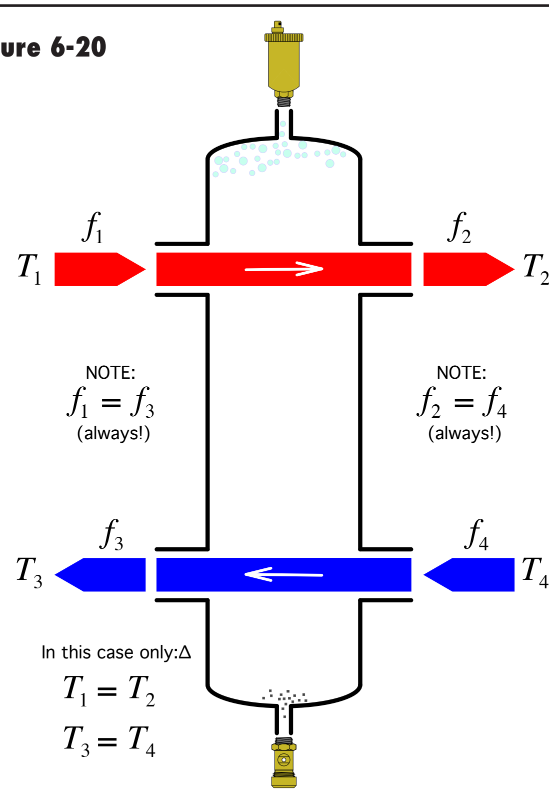


Figure 6-20



There are three possible cases:

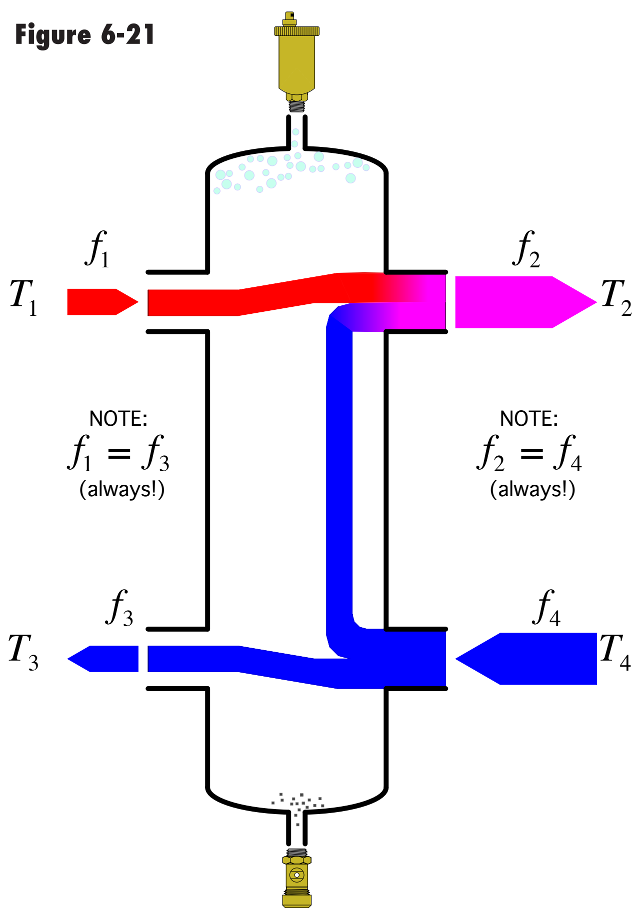
1. Flow in the distribution system is equal to flow in the boiler circuit
2. Flow in the distribution system is greater than flow in the boiler circuit
3. Flow in the distribution system is less than flow in the boiler circuit

Case #1. Distribution flow equals boiler flow: This situation tends to be the exception rather than the norm. It is illustrated in Figure 6-20.

The flow and temperature leaving port 2 of the hydraulic separator is the same as the temperature of the hot water entering port 1. Very little internal mixing occurs because the flows are balanced. Because of its buoyancy, the hot water entering port 1 remains near the top of the hydraulic separator. Most of the air bubbles carried into port 1, or that form within the hydraulic separator, rise to the top of the unit and are ejected through the air vent.

A similar situation exists at the lower ports of the separator. Since the flows are balanced, the outlet temperature returning to the heat source from port 3 equals the temperature returning from the distribution system into port 4. Again, very little mixing takes place within the separator. Dirt particles carried into the separator at port 4 will settle to the bottom of its body, where they can be periodically flushed out through the drain valve.

Figure 6-21



If a conventional boiler (e.g., one that is not intended to operate with sustained flue gas condensation) is used, the designer should verify that the water temperature on the return side of the distribution system is high enough to prevent sustained flue gas condensation within the boiler. The use of a hydraulic separator in itself does not guarantee that the water temperature entering the boiler will be high enough to prevent sustained flue gas condensation.

Case #2. Distribution system flow is greater than boiler flow: Since the flow rates in the boiler circuit and distribution system are not the same, mixing occurs within the hydraulic separator. In this case, a portion of the cooler water returning from the distribution system moves upward through the separator and mixes with the hot water entering from the boiler, as shown in Figure 6-21.

This mixing reduces the water temperature supplied to the distribution system. This is not necessarily a bad thing, but the designer needs to realize it can occur and plan accordingly.

Formula 6-2 can be used to calculate the mixed temperature (T_2) supplied to the distribution system under these conditions.

Formula 6-2

$$T_2 = \left(\frac{(f_4 - f_1)T_4 + (f_1)T_1}{f_4} \right)$$

Where:
f_4 = flow rate returning from distribution system (gpm)
f_1 = flow rate entering from boiler (gpm)
T_4 = temperature of fluid returning from distribution system (ºF)
T_1 = temperature of fluid entering from boiler (ºF)

Formula 1 is valid for both water and other system fluids, provided all fluid entering and leaving the hydraulic separator is the same. It can also be used with any consistent set of units for flow and temperature.

Suppose, for example, that a distribution system containing several operating circulators has 25 gallons per minute of total flow. Water returns from the distribution system at 120ºF and enters port 4 of the hydraulic separator. At the same time, the boiler flow rate is 10 gallons per minute, and the water temperature supplied to port 1 is 160°F. Determine the mixed water temperature leaving port 3. Also, what is the water temperature returning to the boiler?

The mixed water temperature is found using Formula 6-2:

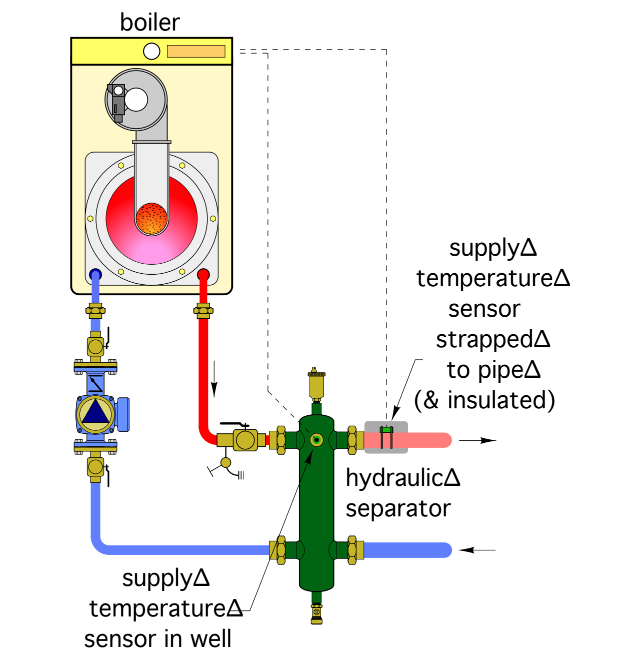
$$T_2 = \left(\frac{(f_4 - f_1)T_4 + (f_1)T_1}{f_4} \right) = \left(\frac{(25-10)120 + (10)160}{25} \right) = 136^o F$$

Notice that the water temperature supplied to the distribution system (136°F) is substantially lower than the water supplied from the boiler (160°F). This is the result of mixing within the hydraulic separator.

Since no mixing occurs in the bottom portion of the separator, the water temperature returning to the boiler is the same as that returning from the distribution system (e.g., 120°F).

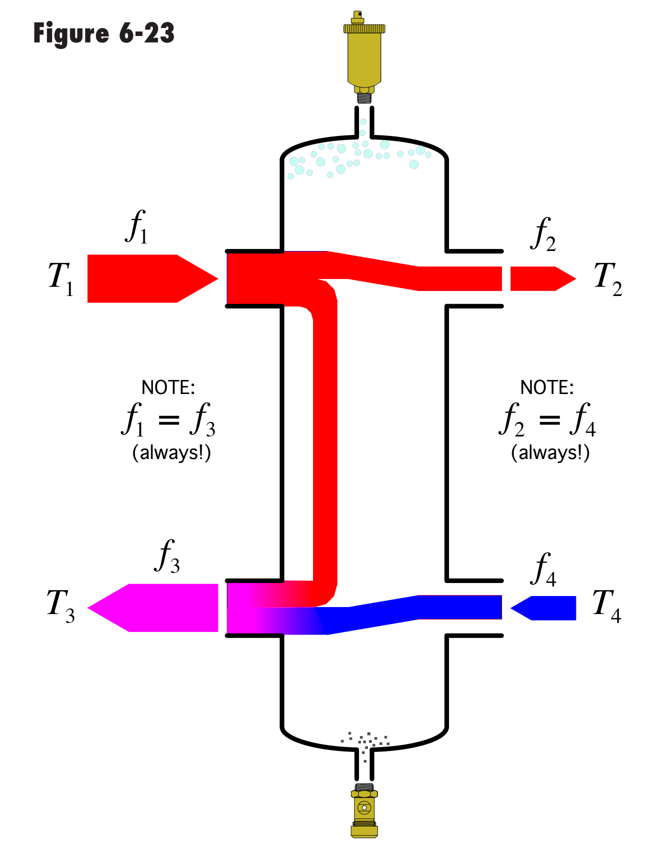
If the boiler firing rate is to be modulated based on the supply temperature to the distribution system, *the temperature sensor providing supply temperature information to the modulating controller should be located within a sensor well in the upper portion of the hydraulic separator, or downstream of the distribution system outlet port (port 2) of the hydraulic separator*, as shown in Figure 6-22. If the sensor is strapped to the outer surface of the pipe, it should be firmly secured, then wrapped with insulation to minimize error due to surrounding air temperature.

Figure 6-22



Case #3: Distribution system flow is less than boiler flow: Again, since the flow rates on opposite sides of the hydraulic separator are not equal, mixing will occur inside the separator. In this case, a portion of the hot water entering from the boiler circuit moves downward through the separator and mixes with cool water entering from the distribution system, as shown in Figure 6-23.

Figure 6-23



This condition occurs when the boiler heat output rate is (temporarily) higher than the current system load. Under this condition, heat is being injected into the system faster than the load is removing heat. This produces a relatively fast increase in boiler return temperature. If a modulating boiler is being used, this will lead to a relatively fast decrease in firing rate, which usually will result in a reduction in boiler-side flow rate.

Under this scenario, the temperature returning to the boiler (T_3) can be calculated using Formula 6-3:

Formula 6-3

$$T_3 = \left(\frac{(f_1 - f_2)T_1 + (f_4)T_4}{f_1} \right)$$

Where:
T_3 = temperature of fluid returned to the boiler(s) (ºF)
f_1 = flow rate entering from boiler(s) (gpm)
f_2, f_4 = flow rate of the distribution system (gpm)
T_1 = temperature of fluid entering from boiler(s) (ºF)
T_4 = temperature of fluid returning from distribution system (ºF)

Assume the boiler supply temperature is 170ºF, and that boiler flow rate into port 1 of the hydraulic separator is 15 gallons per minute. Water returns from the distribution system and enters port 4 of the hydraulic separator at 100ºF and 10 gallons per minute flow rate. What is the water temperature returned to the boiler?

Substituting these operating conditions into Formula 6-2 yields:

$$T_3 = \left(\frac{(f_1 - f_2)T_1 + (f_4)T_4}{f_1} \right) = \left(\frac{(15-10)170 + (10)100}{15} \right) = 123.3^{o} F$$

Notice that the boiler inlet temperature is about 23°F higher than the return temperature of the distribution system. This is caused by mixing within the hydraulic separator.

If the system uses a conventional (non-condensing) boiler, one might consider the boost in boiler return temperature beneficial because it moves the boiler operating condition away from potential flue gas condensation. However, this temperature boost effect can quickly diminish if flow through the distribution system increases (i.e., more load circuits turn on), or if the return temperature of the distribution system drops. Use of a hydraulic separator alone does not prevent flue gas condensation under all circumstances.

EXPANSION TANK PLACEMENT RELATIVE TO THE HYDRAULIC SEPARATOR:

Because there is very little head loss across a hydraulic separator, vertically or horizontally, the system's expansion tank can be teed into the piping near any of the separator's 4 main ports. The lower ports are preferred because they expose the expansion tank to lower temperature fluids compared to the upper ports. Figure 6-24 shows both of these options.

The system's expansion tank should *not* be connected to the bottom of the hydraulic separator. This would allow dirt to migrate from the bottom of the separator into the expansion tank, where it will accumulate on top of the tank's diaphragm.

Figure 6-24

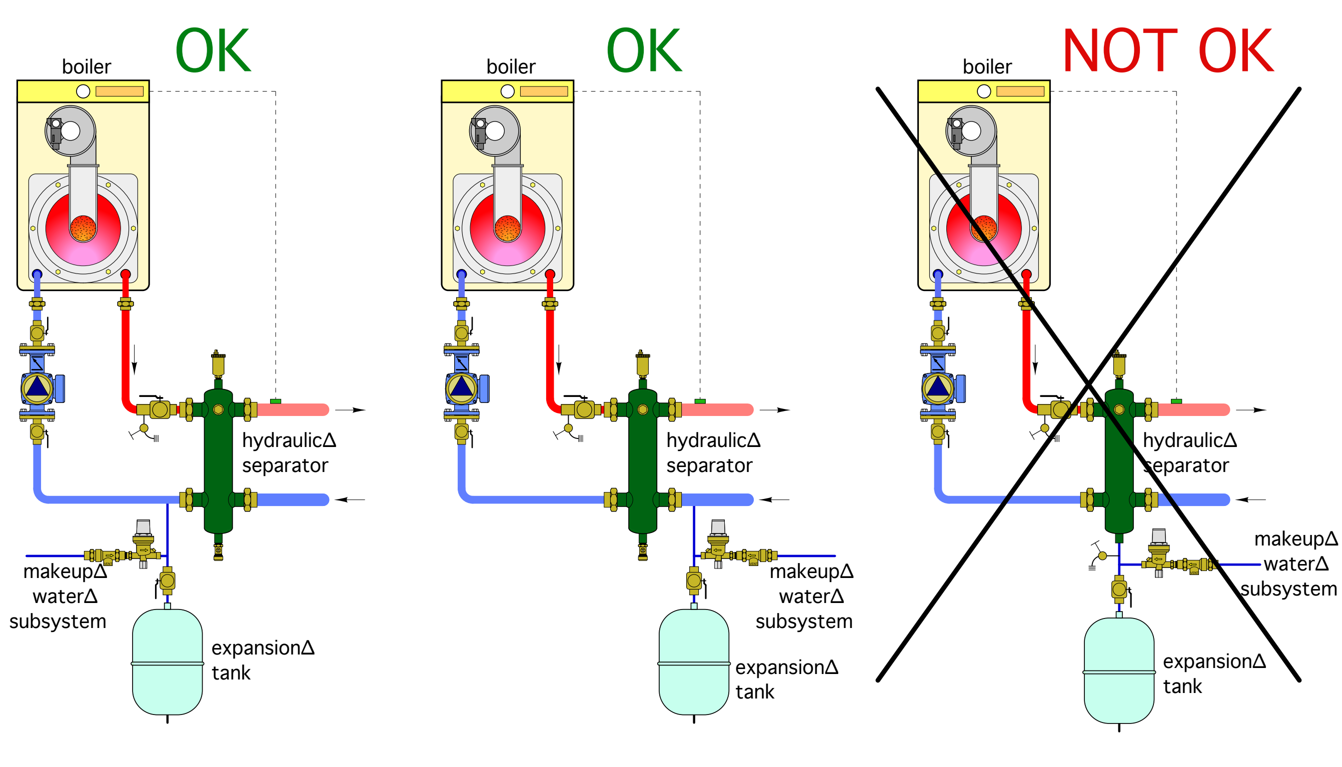
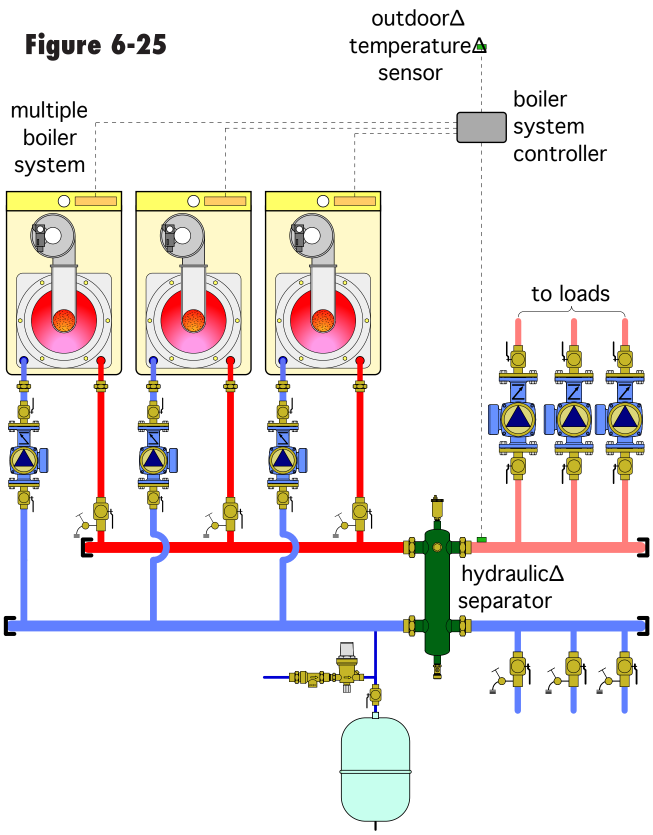


Figure 6-25



HYDRAULIC SEPARATION WITH MULTIPLE BOILERS OR CHILLERS:

Hydraulic separators are ideal for use with multiple boiler systems. Figure 6-25 shows an example.

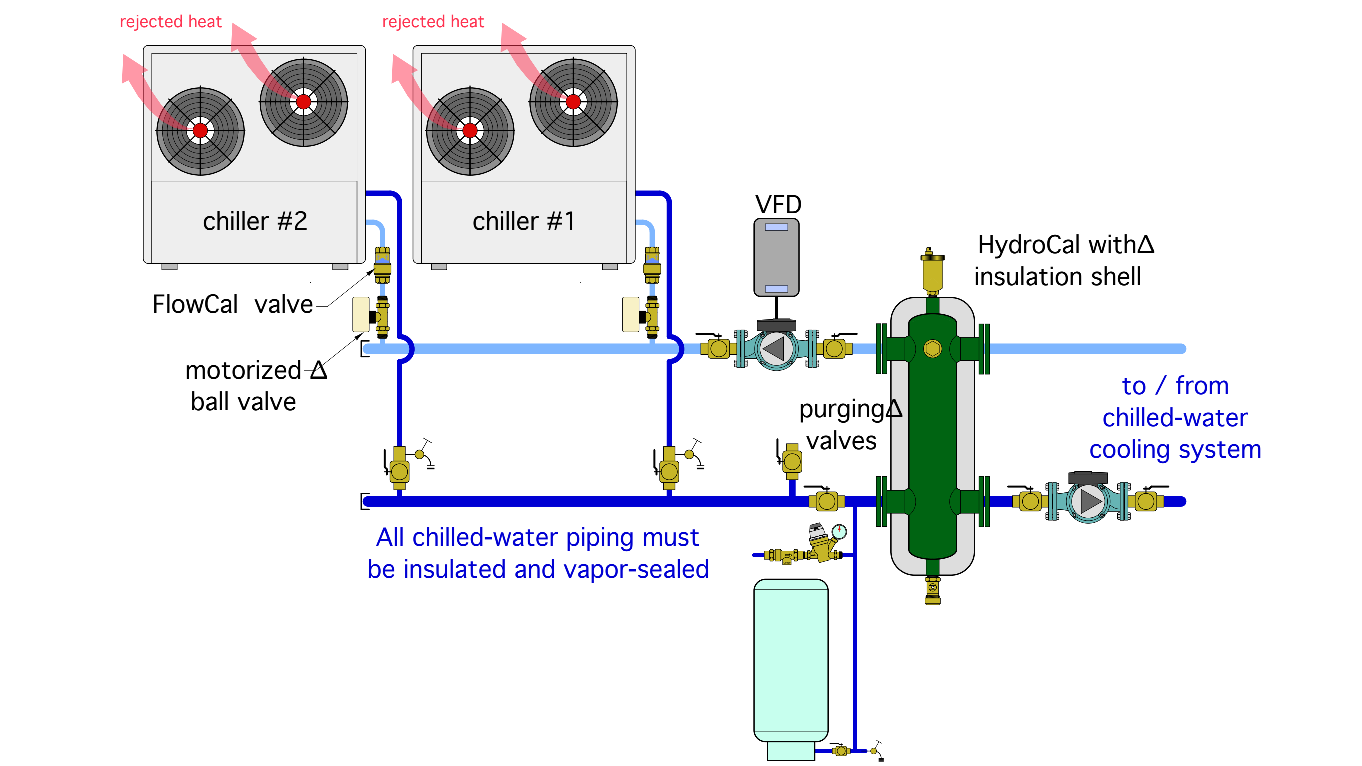
The headers supplying the boilers should be sized for minimal head loss. A suggested sizing criteria is a flow velocity of 2 to 4 feet per second when all boiler circulators are operating.

The hydraulic separator allows the boiler side flow rate to be significantly different from the distribution side flow

Figure 6-26

Courtesy of Coffey Plumbing & Heating

Figure 6-27



rate. It also allows for efficient air and dirt separation within the system. Figure 6-26 shows an example of this type of system.

Each boiler has its own circulator and check valve. This makes it possible to stop flow through boilers that are not operating, and thus stop unnecessary heat loss. It also allows for partial heat delivery to the hydraulic separator if one of the boilers, or one of the boiler circulators, is not responding.

This piping arrangement is also suitable for multiple chillers in chilled-water cooling systems, as shown in Figure 6-27.

Notice that the chilled water from the chillers flows into the *lower* side connection of the hydraulic separator. The somewhat warmer "chilled" water returning from the distribution system flows into the *upper* side connection. This arrangement creates more favorable conditions for air separation at the top of the hydraulic separator and minimizes the potential for dirt being carried into the chillers.

This piping arrangement uses a motorized ball valve on each chiller that opens only when that chiller is active. The variable frequency drive (VFD) operates the chiller circulator as necessary to maintain a nearly constant differential pressure across the headers serving the chillers. This reduces the input power to the chiller circulator under partial load conditions.

Caleffi FlowCal balancing valves are used to maintain the present flow rate through each chiller when it is active.

7: PRODUCTS WITH INTEGRATED HYDRAULIC SEPARATION

The principle of hydraulic separation combined with uniform supply water temperature to distribution circuits is desirable in both large and small hydronic systems.

Caleffi Hydro Separators are ideal for medium to large systems. Currently available models range from 1-inch to 12-inch pipe size connections.

For smaller systems, Caleffi offers products that integrate the principle of hydraulic separation with the functionality of distribution headers. One example is the Caleffi HydroLink, shown in Figure 7-1.

Figure 7-1

The HydroLink provides a chamber to hydraulically separate the boiler circuit from the distribution circuits. It also provides a self-contained manifold station that supplies up to four independently controlled load circuits with the same supply temperature. These features and their equivalent piping are shown in Figure 7-2.

A critical detail within the HydroLink is the hydraulic separation chamber on the left side of the unit. This chamber is separated from the manifold chambers by a baffle plate with two closely spaced openings. Given their size and placement, these openings act similarly to a pair of closely spaced tees, eliminating any significant pressure differential between the upper and lower manifold chambers. This prevents flow in the boiler circuit from inducing flow in any of the distribution circuits connected to the manifold chamber.

The HydroLink is available in several models with differing numbers and placement of the manifold connections. Figure 7-4 shows some of the combinations.

Figure 7-2

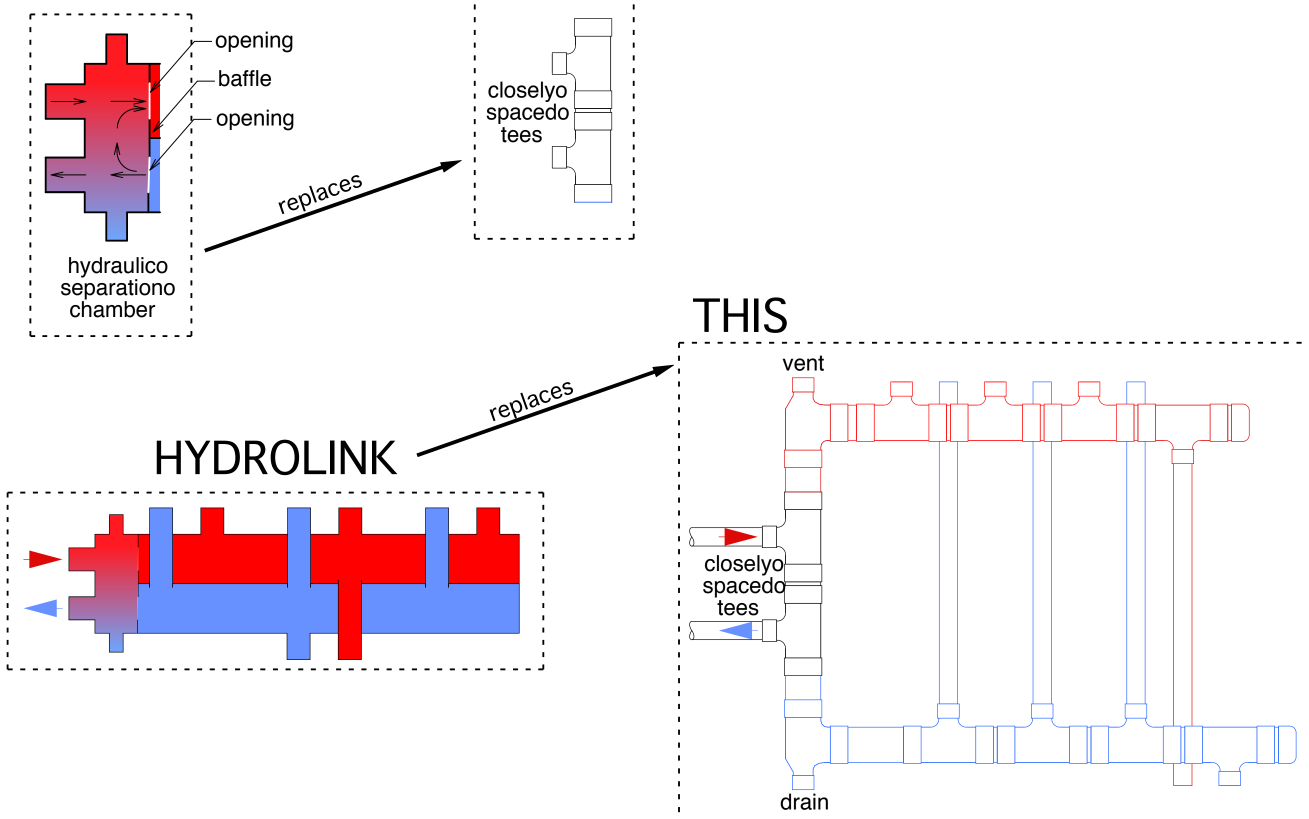


Figure 7-3

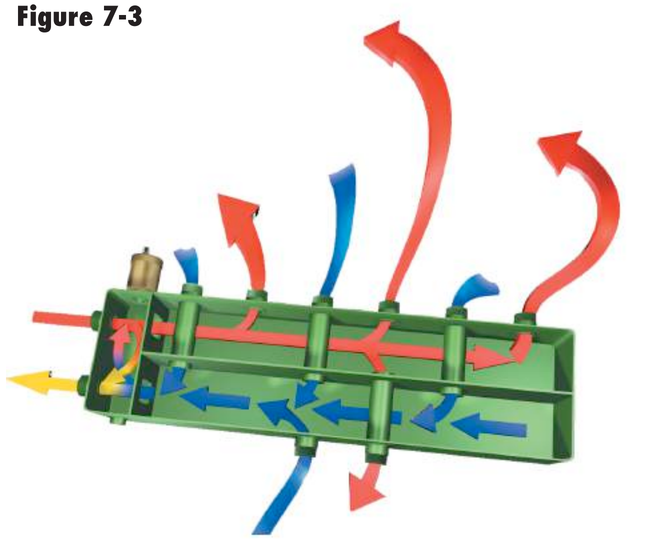
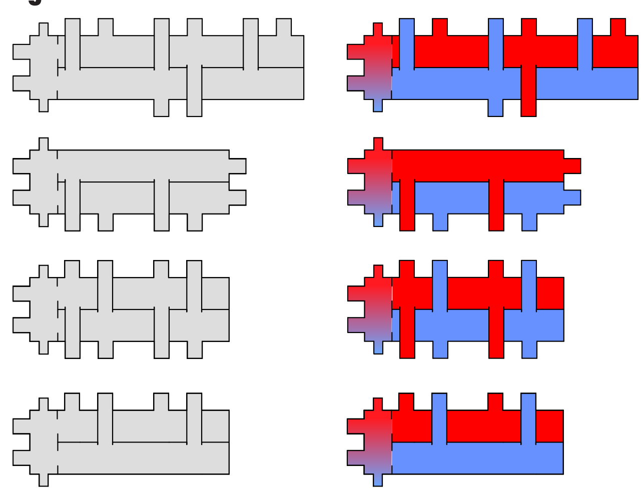


Figure 7-4



A typical configuration for the HydroLink has the heat source connected to the "primary" chamber piping on the left side of the unit, along with several load circuits connected to the other "secondary" connections that connect into the manifold chamber. Two additional tapped connections are provided in the top and bottom of the primary chamber for mounting an air vent and drain valve/makeup water assembly, as shown in Figure 7-5.

The HydroLink product is supplied with a form-fitting insulation shell to minimize heat loss.

Figure 7-5

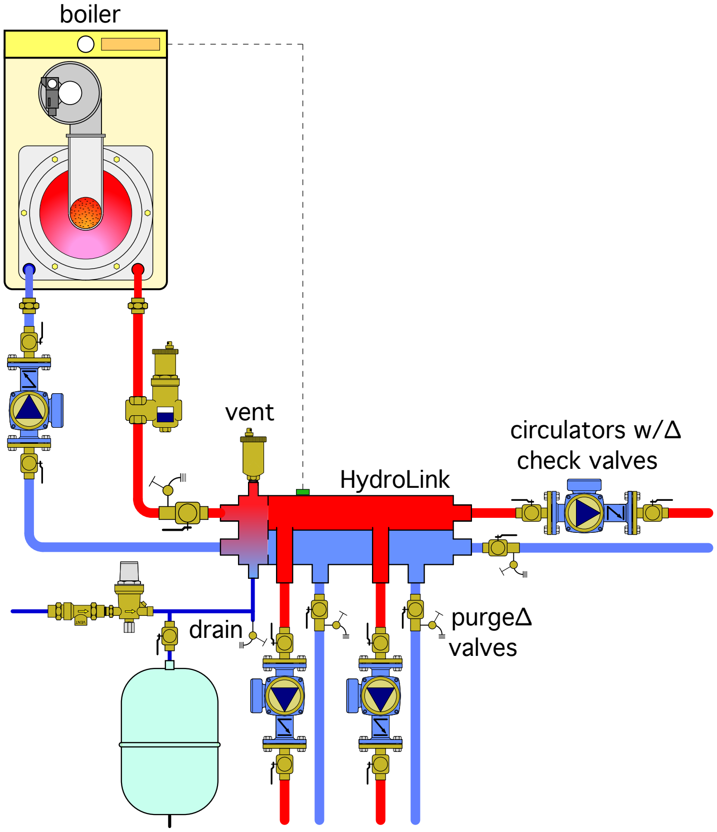


Figure 7-6

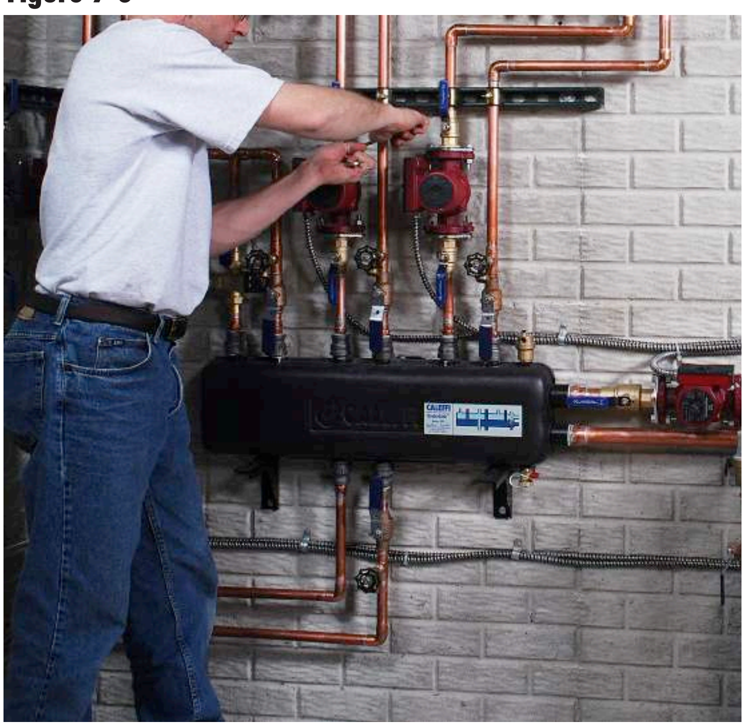
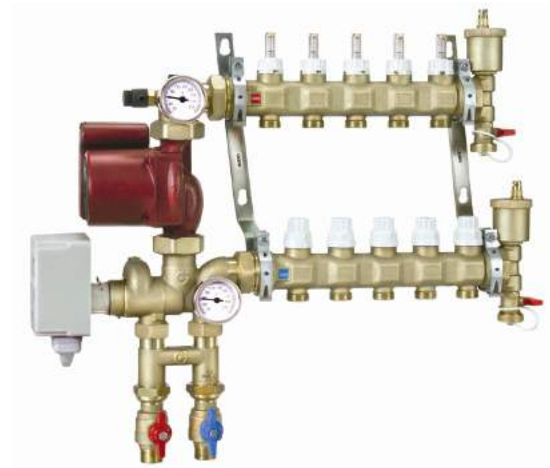
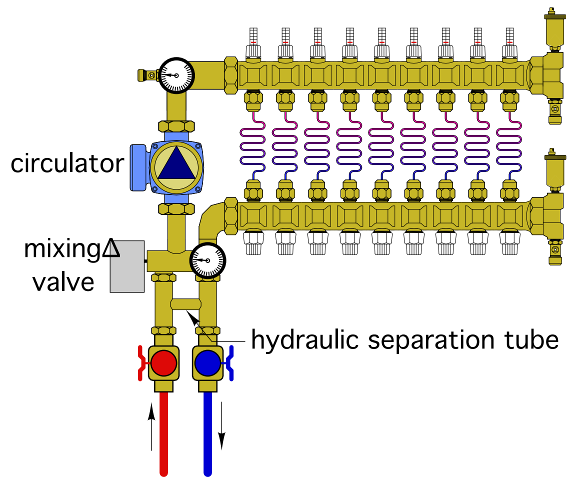


Figure 7-7

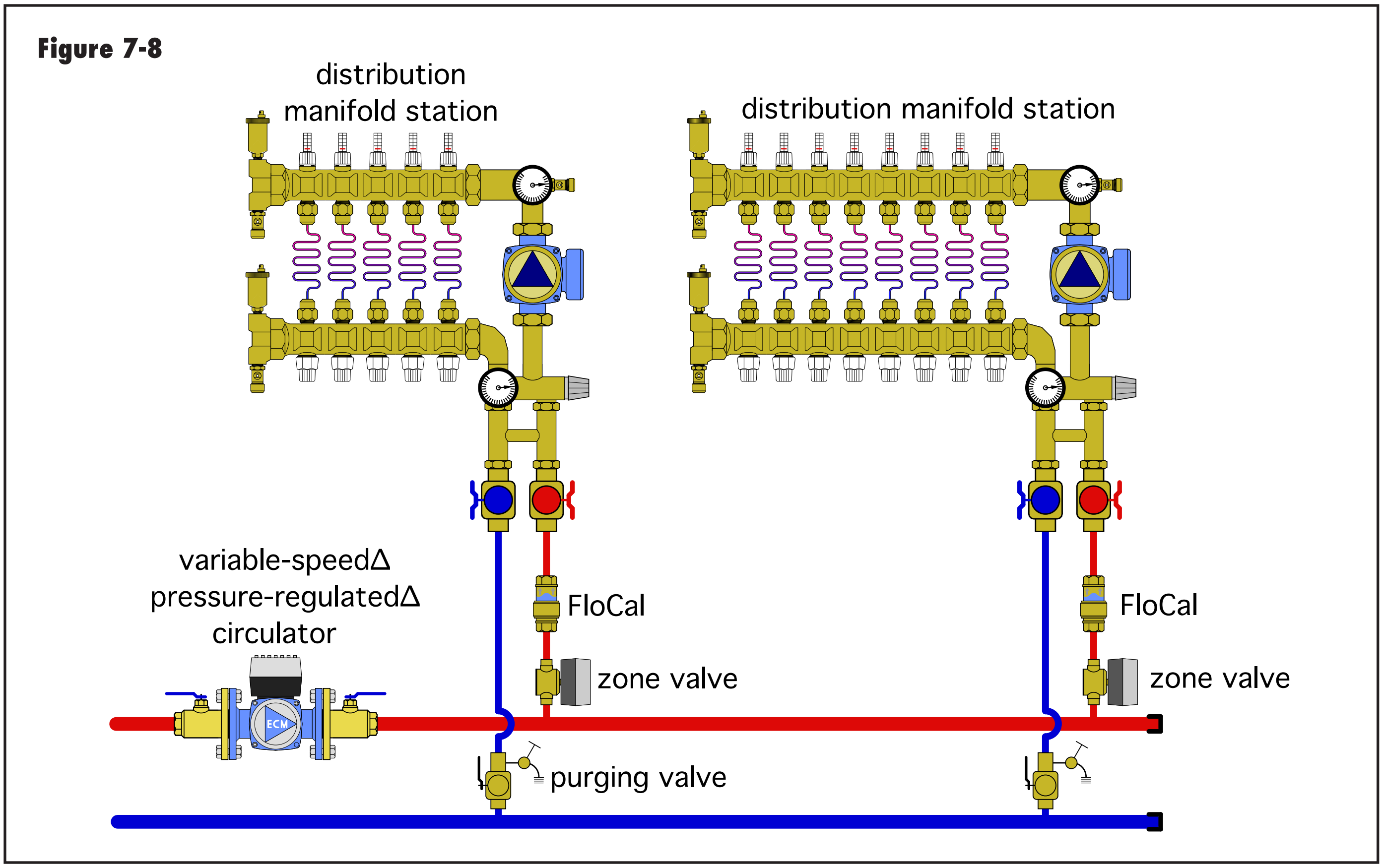




Caleffi also offers distribution manifold stations with integrated hydraulic separation details, an example of which is shown in Figure 7-7.

The small tube that connects the supply and return piping just above the isolation ball valves provides hydraulic separation between the circulator supplying flow from the heat source to the distribution manifold station and the circulator integrated into the distribution manifold station. This allows two or more distribution manifold stations to be piped as shown in Figure 7-8.

Each manifold station is supplied from a common header system. A zone valve opens whenever its associated distribution manifold station requires heat. The Caleffi FlowCal pressure-independent valves maintain the desired flow rate to each manifold



station. The "crossover" tubes just above the isolation ball valves on each manifold station allow hydraulic separation between the built-in manifold station circulator and the variable-speed pressure-regulated circulator that supplies flow in the headers. This arrangement also allows the option of continuous flow through the distribution circuits connected to the manifold stations. The mixing valve within each distribution manifold station allows the possibility of high-temperature supply water from the header system. This, in combination with the relatively low return water temperature that is typical of many radiant panel systems, allows a low flow rate between the headers and manifold station, which minimizes pipe size and circulator power requirements.

8: EXAMPLE SYSTEMS

This section shows several examples of how air, dirt and hydraulic separation can be applied in modern hydronic heating and cooling systems.

EXAMPLE SYSTEM #1:

The system shown in Figure 8-1 uses a modulating/condensing boiler to supply two zones of low-temperature radiant panel heating, as well as an indirect domestic water heater.

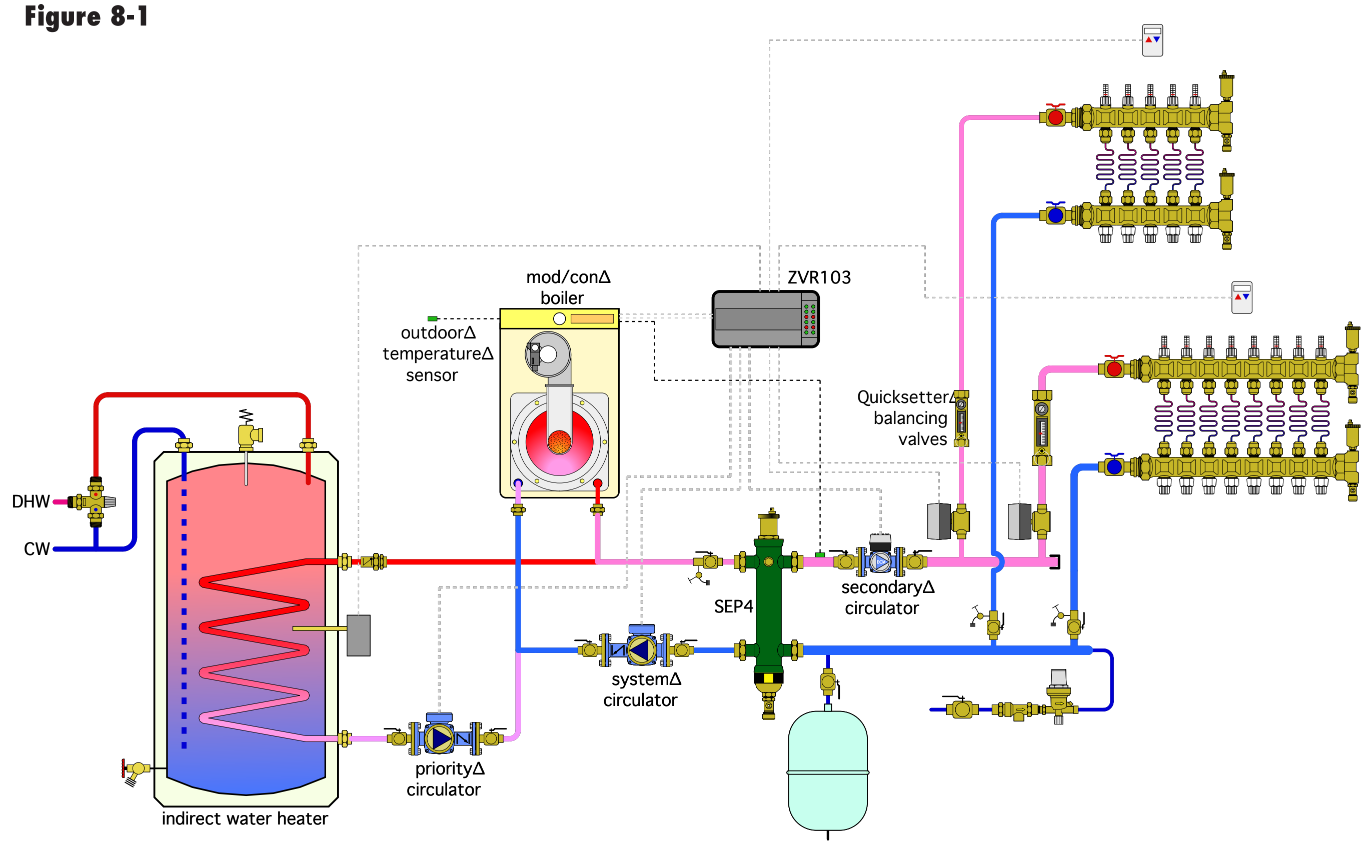
The limited zoning in this system provides a good match between the modulating output of the boiler and the space-heating loads. Thus, the system is able to operate without a buffer tank.

Upon a demand for heating from either zone thermostat, the Caleffi ZVR103 relay center powers on the associated zone valve and turns on the variable-speed pressure-regulated secondary circulator, as well as the system circulator. The boiler operates based on outdoor reset control and monitors the temperature of the water exiting the SEP4 separator and flowing onward to the space-heating zones. This allows the boiler to respond to any variations in the water temperature supplied to the distribution system. The secondary circulator operates in a constant differential pressure mode and automatically changes speed as required depending on the number of active space-heating zones. Each zone circuit is equipped with a Caleffi FlowCal balancing valve to assure properly proportioned flow.

Upon a call for domestic water heating, the ZVR103 operates the boiler in setpoint mode to create a higher supply water temperature, which allows for full boiler output to be transferred to the heat exchanger coil inside the indirect water heater. The ZVR103 also turns off the system circulator, temporarily stopping any heat transfer to the space-heating zones.

The SEP4 provides hydraulic separation between the fixed-speed system circulator and the variable-speed secondary circulator. It also provides high-efficiency air and dirt separation, including magnetically enhanced dirt separation. The latter is desirable because of the high-efficiency circulator used in the system.

Figure 8-1



EXAMPLE SYSTEM #2:

The system shown in Figure 8-2 uses a single modulating/condensing boiler to supply space heating and domestic hot water.

Space heating is supplied by several panel radiators, each of which is equipped with a thermostatic radiator valve allowing it to operate independently of the other panels. Because of the extensive zoning, a small buffer tank is used to prevent boiler short cycling. This buffer tank, when piped as shown, also provides *hydraulic separation* between the boiler circulator and the variable-speed pressure-regulated distribution circulator.

A vertical Discal air separator is mounted just below the boiler's outlet port, where the water is hottest and near it lowest pressure. This encourages microbubble formation, capture and elimination from the system.

A float-type air separator is mounted at the top of the buffer tank to prevent air entrapment.

Manual air vents are located in the upper left corner of each panel radiator to expedite air removal at system commissioning.

A DirtMag separator with an integral magnetic collar is mounted on the piping leading into the boiler and boiler circulator. Its use helps ensure that the high-efficiency variable-speed circulator, as well as the small heat exchanger passages inside the boiler, remain clear of ferrous metal particles and other debris.

Domestic hot water is heated by an indirect water heater that is controlled as a priority load by the boiler's internal control circuitry.

EXAMPLE SYSTEM #3:

Hydraulic separators can be well-applied in modern geothermal heat pump systems. One example is shown in Figure 8-3.

The HydroCal separator shown in Figure 8-3 provides hydraulic separation between the earth loop circulator and the variable-speed pressure-regulated circulator that provides flow to the heat pumps. This allows for a different flow rate in the earth loop compared to those to the heat pump array. The flow rate to the heat pump array is controlled by the variable-speed pressure-regulated circulator, which responds to the opening and

Figure 8-2

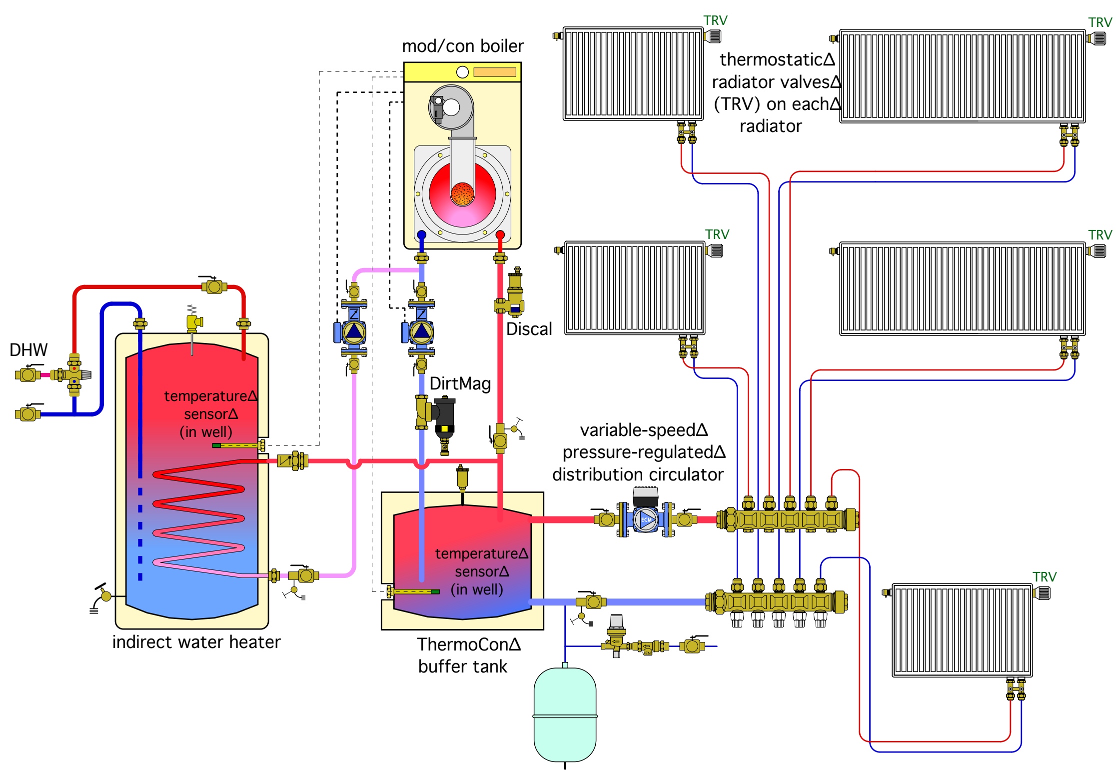
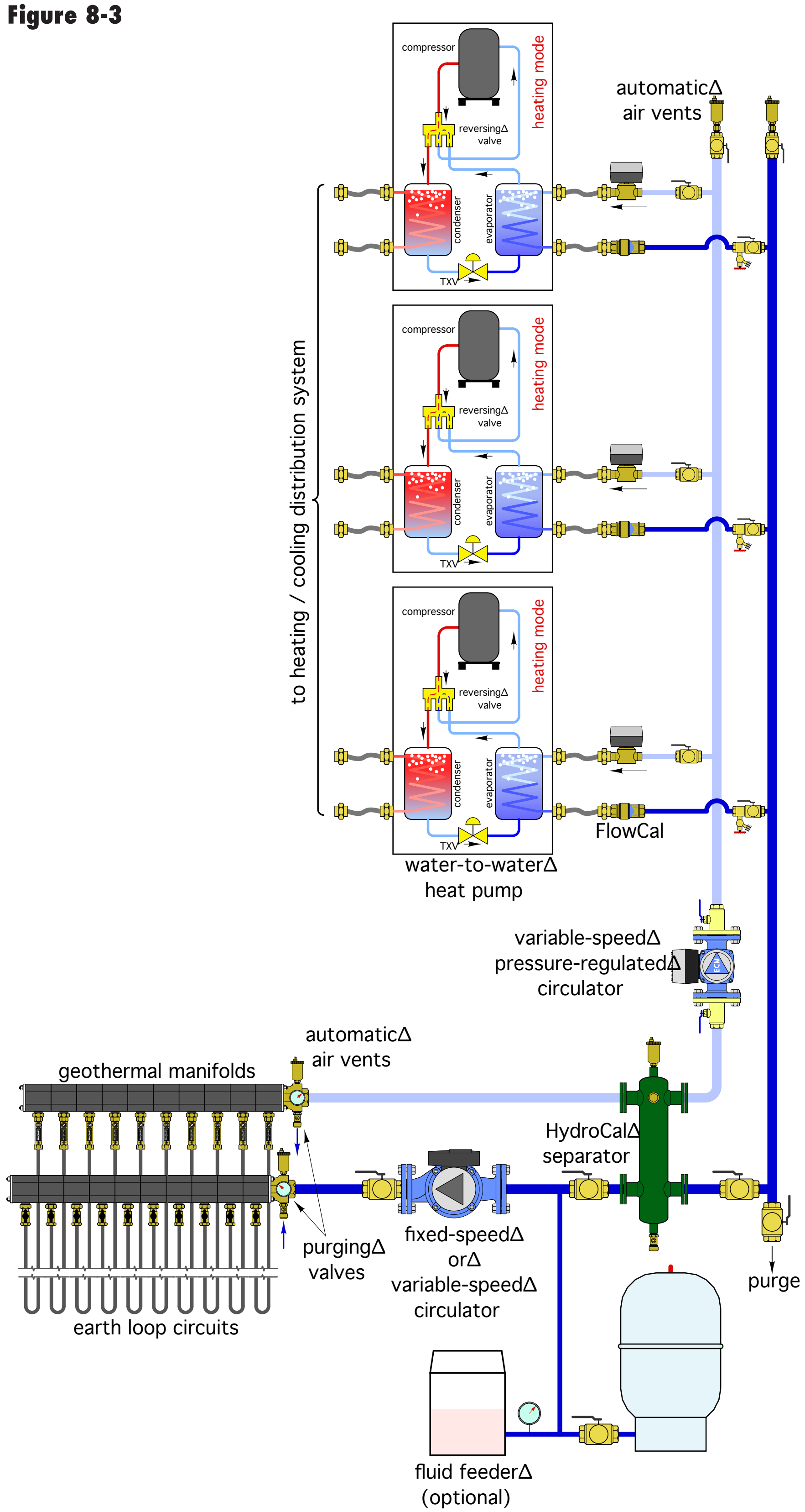


Figure 8-3



closing of zone valves or motorized ball valves on each heat pump. The earth loop circulator could also vary its speed in response to some control criteria, such as the temperature drop or rise across the earth loop connections to the hydraulic separator. This allows the power required by the earth loop circulator to be reduced as the number of operating heat pumps decreases.

The HydroCal separator also provides high-performance air and dirt removal from the earth loop and heat pump array portions of the system. The latter function is especially useful given the likelihood of dirt and debris entering the earth loop piping during construction.

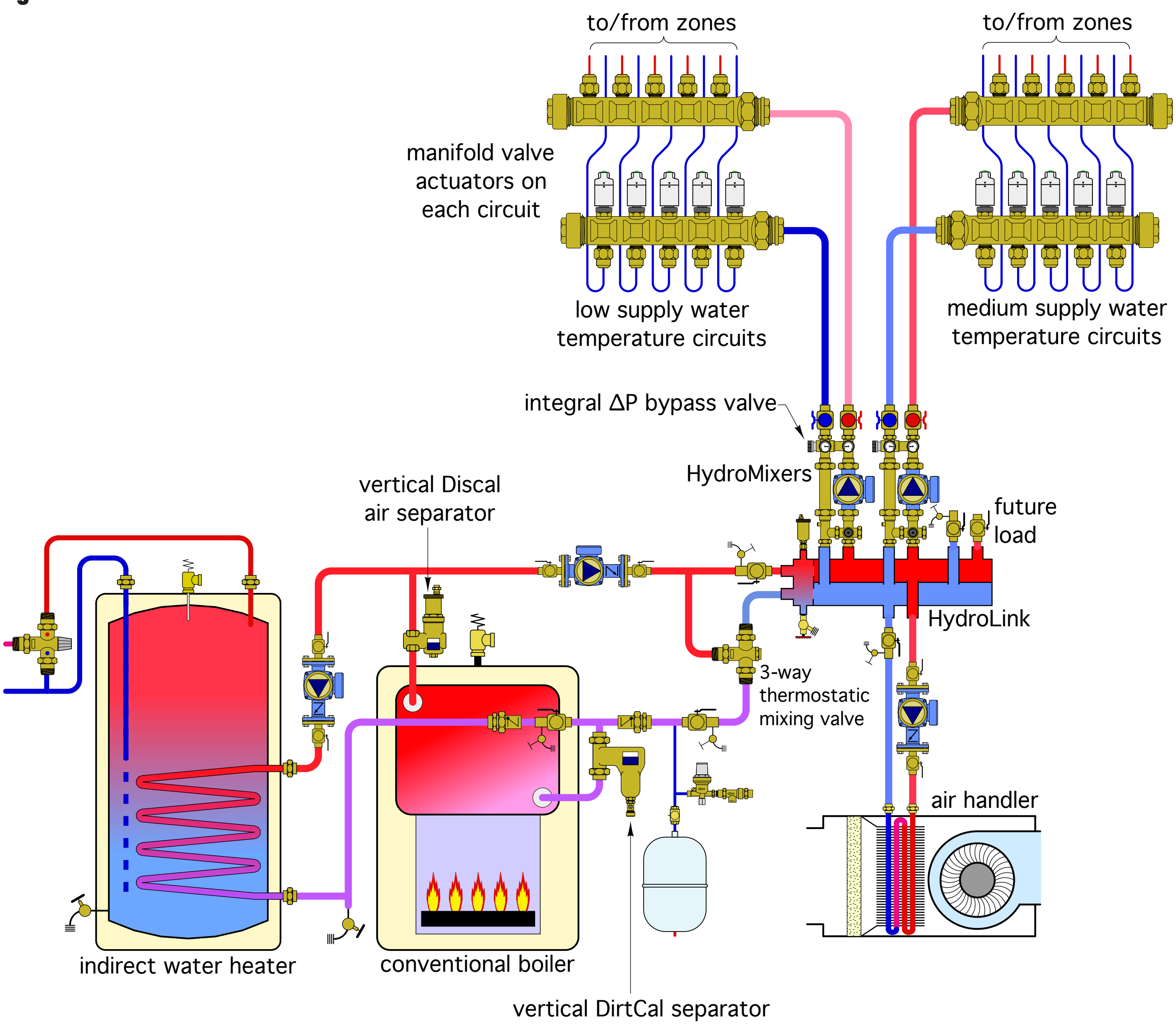
EXAMPLE SYSTEM #4:

The system shown in Figure 8-4 uses a Caleffi HydroLink as the "hub" of a multi-temperature/multi-load system.

The conventional boiler supplies heat to the hydraulic separation chamber in the HydroLink. This hydraulically separates the boiler circulator from the other circulators. The water temperature supplied to the boiler is regulated by a Caleffi 3-way ThermoMix boiler protection valve. This ensures the boiler does not operate with low inlet water temperatures that could cause sustained flue gas condensation.

Two of the loads attached to the HydroLink are supplied through Caleffi HydroMixers. These modules include a mixing valve, circulator and differential pressure bypass valve. The mixing valve reduces the water temperature to that required by the low-temperature radiant panel circuits. The differential pressure bypass valve modulates to maintain a reasonably steady differential pressure across

Figure 8-4



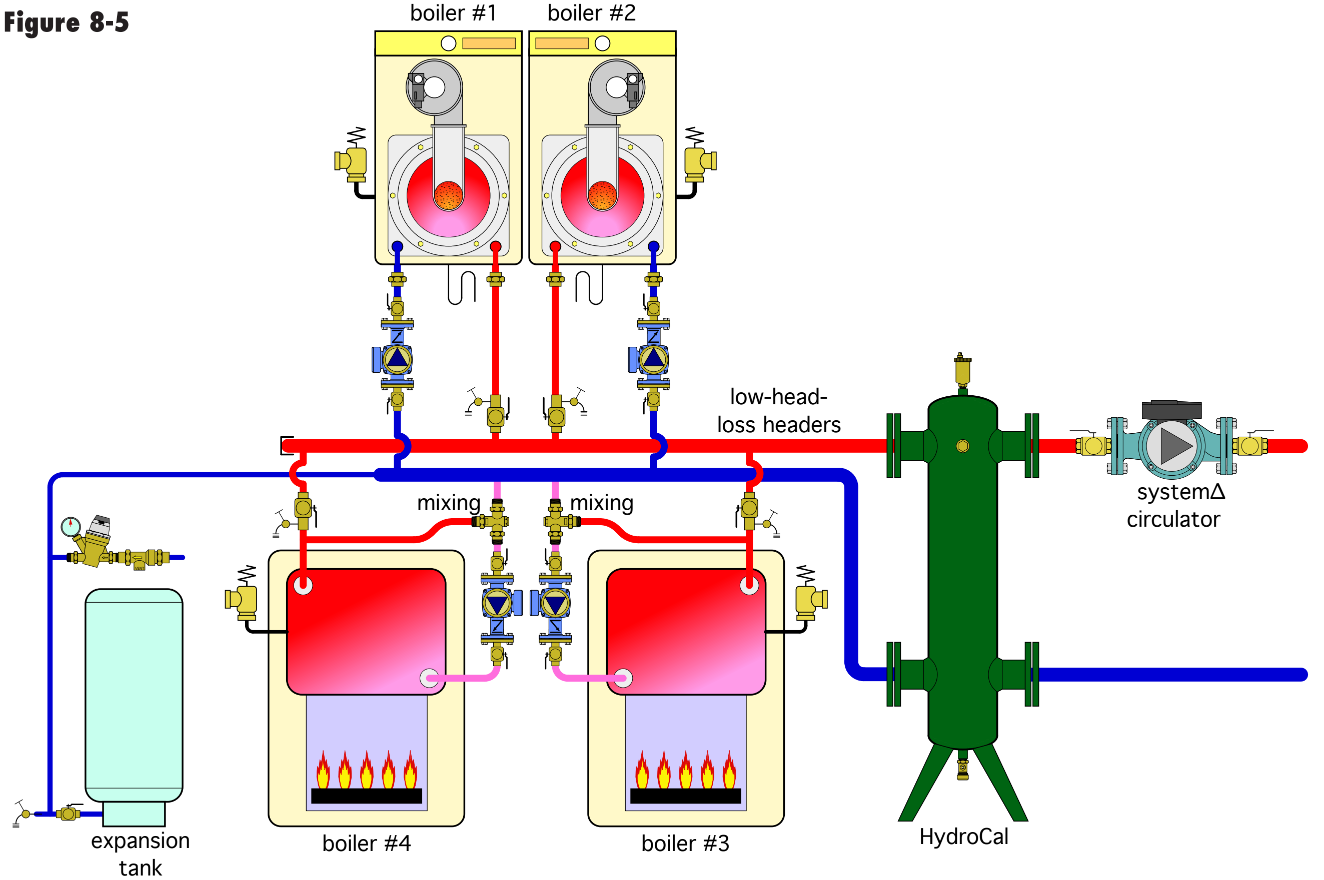
the manifold station as the manifold valve actuators open and close in response to zone thermostats. The supply water temperature from each HydroMixer can be independently adjusted. The mixing can be done with either a thermostatic valve or motorized 3-way valve.

The HydroLink also supplies hot water directly to the coil of an air handler, which operates as a separate zone.

The indirect water heater is operated as a priority load. It is not connected through the HydroLink. This reduces the amount of piping and water that must be heated during a call for domestic water heating. It also allows the domestic water heating mode to operate with a single circulator.

To minimize thermal migration, spring-loaded check valves are provided in the piping returning to the boiler from both the indirect water heater and from the HydroLink.

A vertical Discal air separator provides high performance air separation whenever heated water is flowing from the boiler. Likewise, a vertical Dirtcal separator provides dirt separation for all flow about to pass into the boiler.



EXAMPLE SYSTEM #5:

The heating loads in large buildings are often supplied from a multiple boiler system. The water temperature required for space heating is determined by the type and size of heat emitters used in the distribution system. When convectors or air handlers are selected as the heat emitters, the water temperature required under design load conditions is relatively high, often in the range of 170º to 190ºF. However, under partial load conditions, the supply water temperature can be reduced using outdoor reset control.

When the water temperature returning from the distribution system is approximately 130ºF or lower, some condensation forms on the combustion side of the boiler heat exchangers. This is beneficial if a modulating/condensing boiler is supplying heat, but must be avoided if a conventional boiler is supplying heat. Thus, when the system is operating at part load with low to medium supply water temperature, it is beneficial to supply the required heat using a modulating/condensing boiler.

However, as outdoor temperature drops, the required supply water temperature increases along with the increasing load. If modulating/condensing boilers are operating, they will eventually stop condensing and provide almost the same thermal efficiency as conventional boilers.

This situation can be well served by a "hybrid" multiple boiler system that includes both modulating/condensing boilers and conventional boilers. An example of such a system is shown in Figure 8-5.

Under low to medium load conditions, mod/con boilers #1 and #2 provide heat to the system. During this time, the system water temperatures are low enough to allow these boilers to operate with sustained flue gas condensation, and thus high thermal efficiency. As the load and required supply water temperature increases, boiler #3 and eventually boiler #4 are brought online. Boilers #1 and #2 continue to operate, but not in a condensing mode. As such, they contribute heat to the load at approximately the same thermal efficiency as the conventional boilers. This approach reduces overall boiler plant cost because it uses less expensive conventional boilers with efficiency comparable to that of a mod/con boiler operating in non-condensing mode.

Figure 8-5 shows how a larger Caleffi HydroCal separator can be used in combination with low-head-loss headers to combine these boilers. The HydroCal unit provides hydraulic separation between the boiler circulators and the system circulator. It also provides high-efficiency air and dirt separation for the system. The low-head-loss headers in combination with the HydroCal separator provide hydraulic separation between the individual boiler circulators.

Note that boilers #3 and #4 include a high-flow-capacity 3-way thermostatic mixing valve. This ensures that the inlet water temperature to these boilers remains above the dewpoint of their exhaust gases, and thus the boilers will operate without sustained flue gas condensation.

The firing order of boilers #1 and #2 can be rotated to allow each boiler to accumulate approximately the same number of run hours over the course of a heating season. This can also be done for boilers #3 and #4.

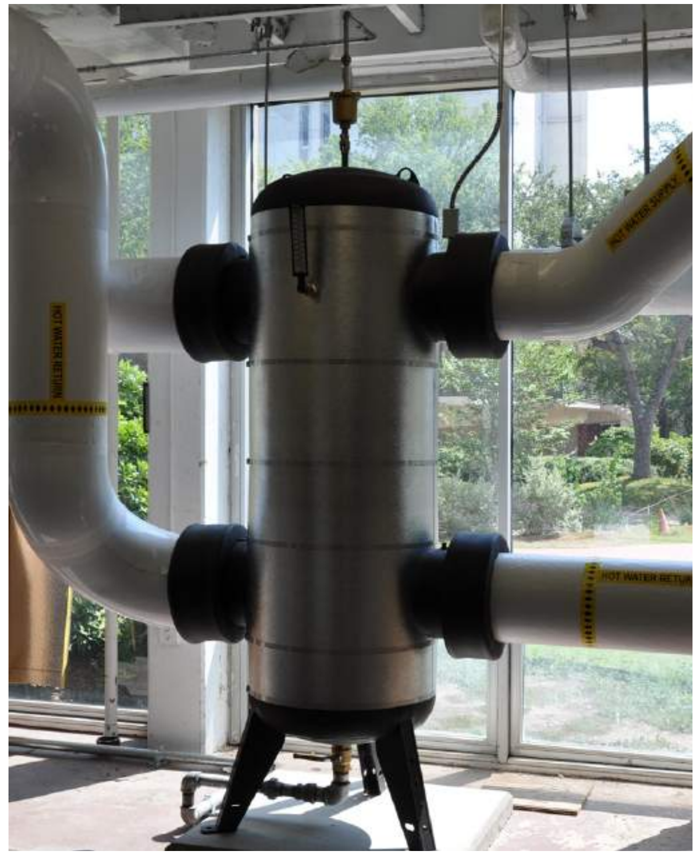
Figure 8-6 shows an example of a hybrid multiple boiler system using two modulating/condensing boilers as the "lead stages," and three conventional boilers as stages 3, 4 and 5. The insulating piping above the boiler leads to the hydraulic separator seen wrapped with insulation at the far left of the photo.

Figure 8-6

Courtesy of GOES Heating Systems

Figure 8-7 shows another example of a large (8" pipe size) Caleffi hydraulic separator that has been fully insulated. Large hydraulic separators have several square feet of surface area. Without insulation, this surface area would create a high rate of heat loss and needlessly overheat the mechanical room.

Figure 8-7



Courtesy of GOES Heating Systems

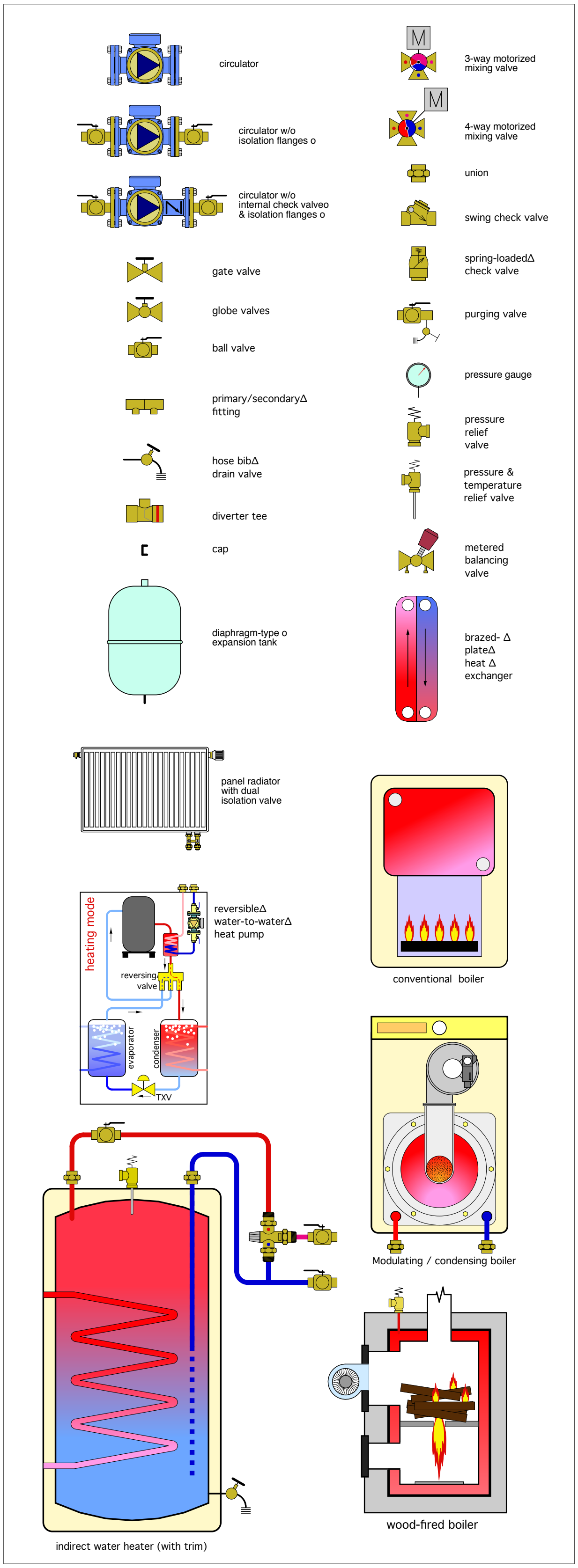
If the hydraulic separator is used for a chilled-water cooling system, or as part of a geothermal earth loop system, the insulation should include a vapor barrier to prevent condensation on the surface of the separator.

SUMMARY:

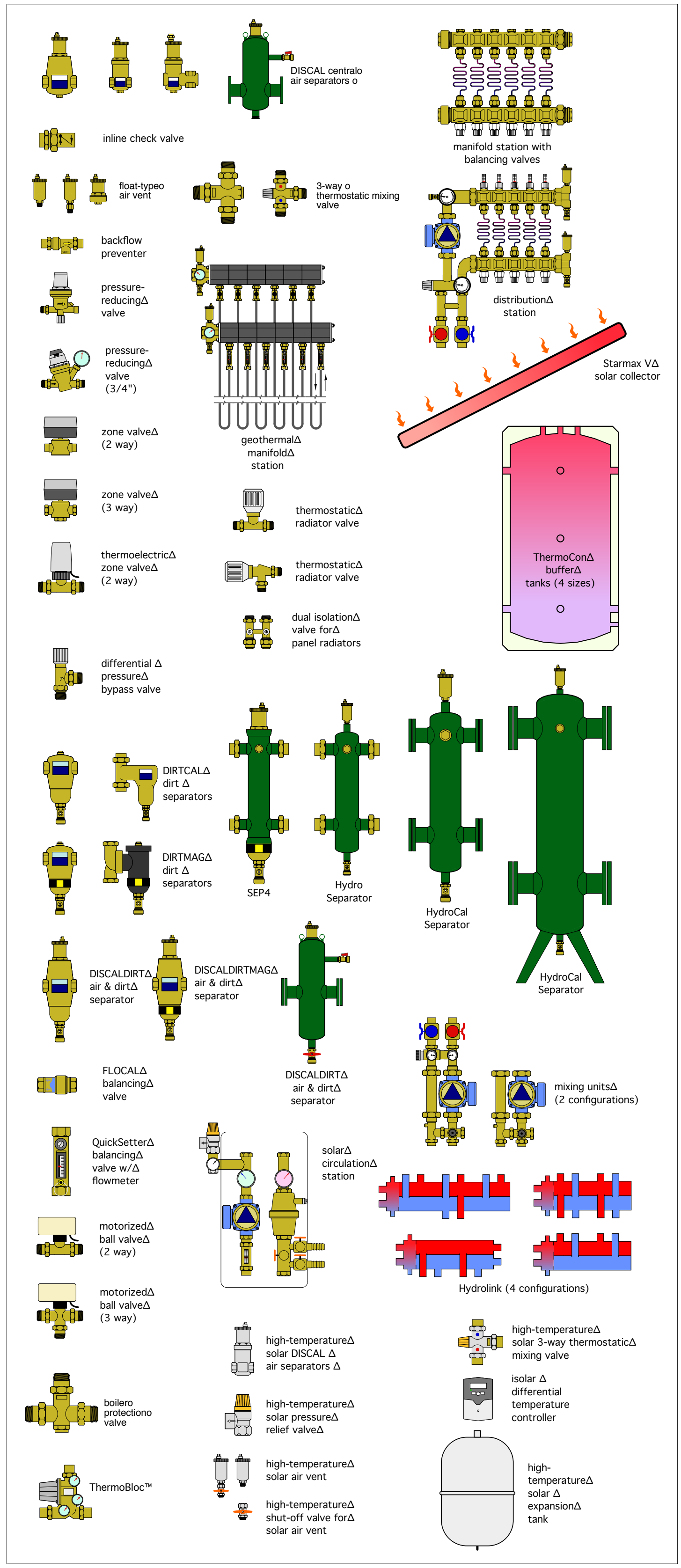
For optimal performance, modern hydronic systems require several types of separating devices. These include air separation, dirt separation, and in many cases, hydraulic separation. The latter eliminates undesirable interaction of simultaneously operating circulators. This issue of *idronics* has discussed the best available technology for providing these functions. When properly implemented, these functions allow the system to operate without the detrimental effects of entrapped air, accumulating debris and inconsistent flow.

APPENDIX A: PIPING SYMBOL LEGEND

GENERIC COMPONENTS



CALEFFI COMPONENTS

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Removes 95% of ferrous impurities

Ferrous oxide forms in hydronic systems when iron or steel corrodes. This abrasive, extremely fine sediment is difficult to remove; it can deposit onto heat exchanger surfaces and accumulate in pump cavities causing reduced efficiency and premature wear. Caleffi magnetic dirt separators accomplish 2½ times the ferrous oxide removal performance of standard dirt separators.

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