# Hydronics 102 System Components

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*Authors' note: This introductory article builds on the information in "Hydronics 101," which appeared in the May 2015 issue. This article discusses additional hydronic components.*

Hydronic heating and cooling systems are popular in situations where designers and owners are conscious of space and system operating efficiency. Common components installed in hydronic systems to enable their operation include heat source or sink (boiler, chiller, water-source heat pump, heat exchanger), pump(s), flow control devices, and water treatment (air separation, antifreeze, chemical additives, and biocides).

This article focuses on providing an overview of expansion tanks and valves because these are common control devices in closed loop hydronic systems. These devices are identified in the systems diagram in *Figure 1.*

Why are control devices needed in hydronic systems? Obviously for control, but what are the different types of control?

- Control to maintain a desired temperature or pressure;
- Control for optimizing efficiency: balancing, variable flow, etc.;
- Control to protect the system and its components: maintain minimum flow rates, expansion, etc.; and
- Control for maintenance.

## Expansion Tanks

Expansion tanks have two roles in hydronic systems. One is to manage expansion as water temperature increases. More importantly for this article is control of the system pressure. Expansion tanks keep the system operating pressure within an acceptable range, with the high limit being the relief valve setting and the low limit being the pressure reducing valve (PRV) setting.

## Example

If filling a hot water hydronic system serving a two-story building with a boiler on the lowest level of the building, the expansion tank must be sized to limit the pressure increase to ensure the relief valve is not used except in an emergency situation.

Hydronic systems often have maximum design pressures of 125 psig (862 kPa), but some components such as boilers may have maximum allowable working pressure (MAWP) as low as 30 psig (207 kPa). The fill pressure is the pressure required to get water to the highest point in the system. If the fill point is located in the lowest level by the boiler, the vertical static pressure is calculated using the conversion value of 2.31 ft = 1 psig (0.7 ft = 7 kPa), assuming cool water is entering the system. If the two-story building has a 23 ft elevation distance between the fill connection and the top of the system, the resulting head is: 23 ft × (1 psig/2.31 ft) = 10 psig [7 m × 9.8 kPa/m = 69 kPa]. Commonly, pressure reducing valves (intended to reduce water pressure entering from the city main) come factory-preset to 12 psig (83 kPa), which will work for this application.

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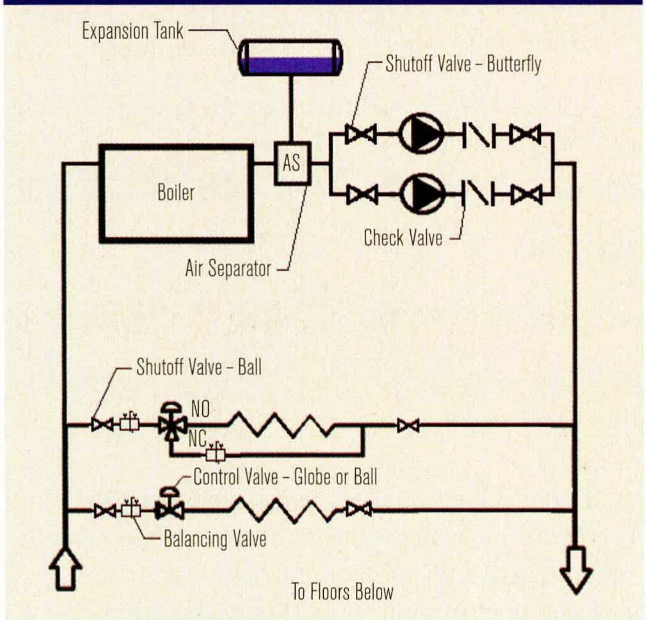
FIGURE 1 Hydronic heating system diagram.




This does not account for the pressure required at the highest points in the system to maintain enough positive pressure at the top of the system to be certain that negative pressure never occurs. If negative pressure occurs, air can enter at seals and devices such as automatic air vents. Traditionally, a safety factor of 5 psig (34 kPa) is included. Considering a boiler with a MAWP of 30 psig (207 kPa) and having a set pressure of 10 psig + 5 psig = 15 psig (69 kPa + 34 kPa = 103 kPa) requires an expansion tank large enough to limit the pressure increase to 15 psig (103 kPa).

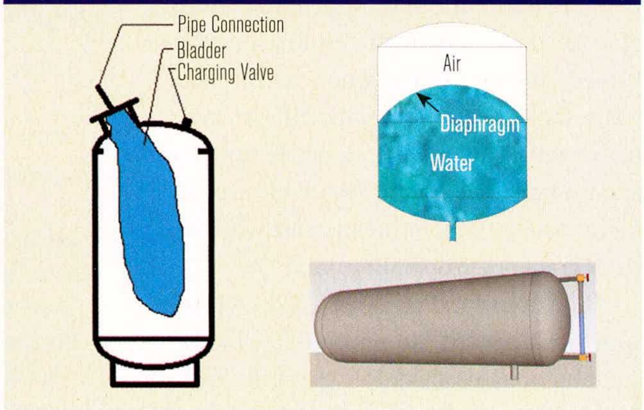
## Types of Expansion Tanks

A hydronic system should only contain a single expansion tank connection point, although large systems may require multiple tanks. When selecting the expansion tank there are three types to consider: open, bladder/diaphragm, and compression (shown in *Figure 2*).

**Open tanks.** Open tanks are just as the name implies, open to the atmosphere. They provide a space for expanding water to go. But they also expose the water to air and, therefore, introduce oxygen that promotes the corrosion process in hydronic systems. Though open tanks can still be found in older hydronic systems, they are normally only used today when a cooling tower basin is the highest point in the return system.

**Bladder/diaphragm tanks.** Bladder and diaphragm type tanks are similar in that they physically separate the air from the water with a membrane. This eliminates the opportunity for air to be reintroduced to the system. Bladder tanks are more commonly used today in situations requiring larger acceptance volume (the volume of water the tank must accept due to thermal expansion), because they require less space than diaphragm tanks.

FIGURE 2 Bladder (left), diaphragm (upper right), and compression (lower right) expansion tanks.




Bladder tanks have a membrane that resembles a balloon that contains water and expands and contracts as the system pressure changes. The space between the bladder and the metal tank is "charged" with compressed air to a pressure that must be specified by the designer. Often this is the same pressure as the fill PRV setting, but it may be different if the tank and PRV are at significantly different elevations. A diaphragm tank functions similarly to a bladder tank, but its membrane is limited in movement compared to a bladder. Therefore, the acceptance volume is less.

**Compression tanks.** The piping system is connected to the bottom of the compression tank. When the system is filled with water, the air in the tank compresses and acts as a spring to maintain pressure on the system. They are commonly fitted with a sight glass and two angle valves, so the system operator can visually verify the tank water level. Compression tanks have two disadvantages that make them less popular than bladder or diaphragm tanks: air is in direct contact with water, and they are often much larger to provide the same amount of expansion compensation.

## Tank Sizing

Expansion tank sizing is based on the following factors:

- Type of tank;
- System volume (requires calculation of all water in piping, equipment, etc.);
- Maximum temperature variation (generally in a hot

water system it is the maximum system temperature minus the minimum temperature at which the system might be filled [often assumed to be 40°F (4°C)]; whereas, in a chilled water system, it is typically the difference between the chilled water design temperature and the ambient air temperature, to account for the water temperature increase when the chillers are not in operation); and

- Maximum and minimum allowable pressure (this pressure range is impacted by the equipment in the system as well as the location of the tank in the system previously discussed).

TABLE 1 Expansion tank sizing scenarios for bladder and compression tanks.

| TANK EXAMPLES | | | | | | | | SCENARIOS |
|---|---|---|---|---|---|---|---|---|
| | BLADDER | COMP | BLADDER | COMP | BLADDER | COMP | BLADDER | COMP |
| Building Stories | 2 | 2 | 2 | 2 | 14 | 14 | 14 | 14 |
| Tank Floor | 1 | 1 | 2 | 2 | 1 | 1 | 14 | 14 |
| Fill Pressure (psig) | 12 | 12 | 5 | 5 | 75 | 75 | 5 | 5 |
| Max Pressure (psig) | 25 | 25 | 25 | 25 | 100 | 100 | 100 | 100 |
| | | | | | | | | RESULTS |
| Acceptance Gallons | 24 | 24 | 24 | 24 | 24 | 24 | 24 | 24 |
| Minimum Tank Gallons | 74 | 135 | 48 | 65 | 111 | 670 | 29 | 39 |
| Percent Acceptance | 32 | - | 50 | - | 22 | - | 83 | - |
| Tank Diameter (in.) | 24 | 24 | 24 | 20 | 24 | 36* | 20 | 14 |
| Tank Length (in.) | 56 | 72 | 41 | 62 | 78 | 93* | 34 | 63 |

* Requires two interconnected tanks this size

*Table 1* is a comparison of tank size needed for a compression (indicated by "Comp") and a bladder tank (indicated by "Bladder") for the example previously discussed. Diaphragm tanks are not included in the table in interest of conserving space. But, it can be assumed that the minimum diaphragm tank size is identical to that of the bladder until the acceptance volume of the diaphragm tank is exceeded.

At higher acceptance ratios, the diaphragm tank size likely falls between the bladder and compression tank. This is especially important when the ratio between fill pressure and maximum pressure becomes large, which results in a larger percent acceptance.

In addition to the sizing for the previous example, this table also identifies the size of tank that would be required if the building were increased from two to 14 stories. This demonstrates the impact building height and tank location have on the unit size and the importance of considering this piece of equipment when defining required mechanical room space. This example assumes 1,000 gallons (3785 L) of water in the system, 40°F (4°C) fill temperature, and 170°F (77°C) maximum average temperature. (Note that the expansion per degree of temperature difference is larger when glycol is added to the water system.)

## Valves

Valves take on a number of different roles in the control of hydronic systems. Valves serve everything from the basic function of turning on or off water flow, to much more complex functions of diverting, mixing, or modulating flow.

### Types of Valves

Different types of valves are specified based on their intended function and size. The most common valves and their functions are introduced in the next few paragraphs.

**Shutoff Valves.** As the name implies, shutoff valves allow flow or discontinue flow. These valves are often found on either side of equipment, e.g., coils and pumps, to allow removal of those devices without requiring draining of the entire system. In this situation the valve is typically manually operated. Shutoff valves can also be actuated by a control system that communicates a need for water flow based on another control input.

An example would be a shutoff valve on a hot water coil serving a terminal unit that opens or closes based on a signal from the space thermostat. Some styles of valves used as shutoff valves can also be used to modulate flow. This is desirable in situations like the previous terminal unit example because, rather than allowing only 100% of heating capacity or no heating, the hot water flow can be adjusted to meet demand.

**Gate Valves.** Gate valves are commonly used today as shutoff valves in steam pipes and underground water pipes. Formerly, they were common in indoor hydronic systems, but they have largely been replaced by ball and butterfly valves. Partially, this is because of cost, but also gate valves have a reputation for eventually sticking fully open or fully closed.

**Ball Valves.** Improvements in elastomer technology have made ball and butterfly valves very reliable. Ball valves are probably the most common valve type in most hydronic systems. They are inexpensive in sizes up to approximately 3 in. (76 mm). In large sizes, the amount of metal used in the ball makes ball valves more expensive. Ball valves are available as manual shutoff valves as shown in *Figure 3*, or with motorized operators for control valves.

Specifying full port valves is appropriate when system total head is a concern. This is because free area within the valve assembly is maintained when in the full open position, minimizing head loss. Either soldered or screwed connections are acceptable. But if soldered connections are used, the valve must be rated for soldering at the temperature that is needed for the solder specified without the ball removed. Often, handle or lever stem extensions are required, so the handle is outside of the insulation.

**Butterfly Valves.** Butterfly valves are the most common valve type for 2½ in. (64 mm) and larger sizes. This is because large butterfly valves are less expensive than other large valves, and because butterfly valves are reliable. Manual butterfly valves use a 10-position locking lever for operation (*Figure 3,* lower left). Above approximately 6 in. (152 mm), however, a gear operator is used to reduce the manual force (strength) that is needed to open and close the valve (*Figure 3* lower center).

Butterfly valves are generally applied in large piping applications. Their installation is different than for ball valves because large piping commonly uses flanged connections. One option is wafer-style valves (*Figure 3,* lower left) with no threaded bolt holes. This option is the least expensive but limits the system maintenance flexibility. Another option is fully lugged butterfly valves (*Figure 3,* lower right) that have the same number of lugs as pipe flanges. When rated for the system maximum pressure, and with bolts extending to the midline of the valve, disassembling of piping on one side of the valve without draining the entire system is possible without additional flanges. Semi-lugged valves (*Figure 3,* lower center) have lugs, but not as many as the pipe flanges. They normally will require draining of the system for disassembly unless the maximum system pressure is low. Semi-lugged valves are less expensive than fully lugged valves.

**Globe Valves.** Globe valves are generally more expensive than ball or butterfly valves, and they have higher pressure drop for the same connection size because of the tortuous path water takes through the globe valves. Although less common today due to the introduction of ball and butterfly valves, the most common uses are as small control valves in water systems and for steam control valves.

**Three-Way Valves.** Three-way valves can either be mixing valves as shown in *Figure 4* or diverting valves that have one inlet and two outlets. Mixing valves are more common because the operators required are smaller and

FIGURE 3 Ball, globe, and butterfly valves.

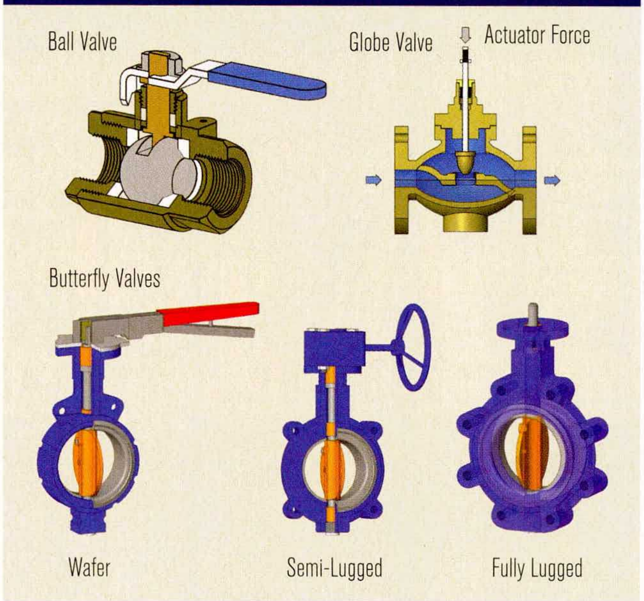
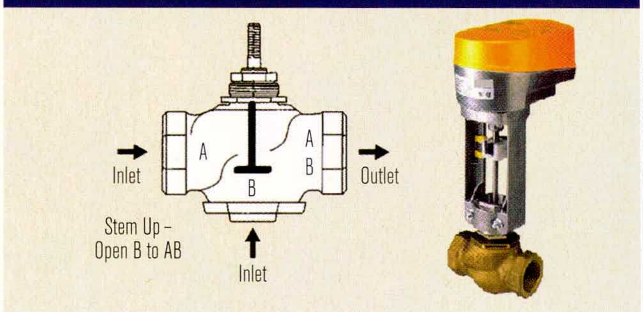



FIGURE 4 Three-way valves.

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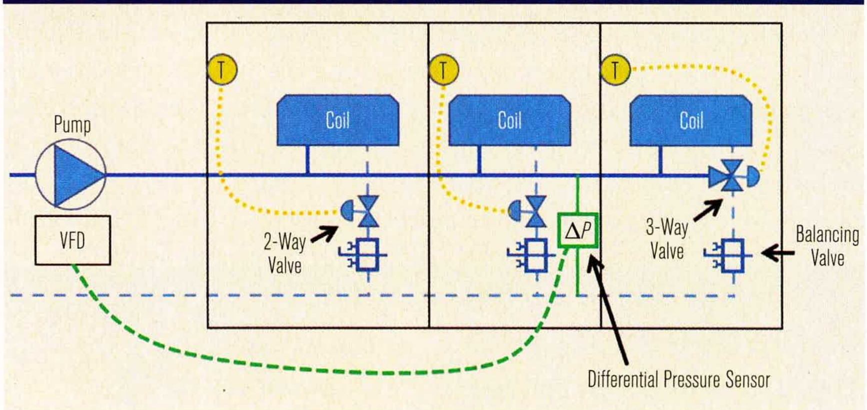
because it is usually possible to pipe systems so a mixing valve can be used instead of a diverting valve. Older hydronic systems typically used three-way control valves to allow a constant flow of water in the main pipes, while modulating the amount of water that was routed through devices based on demand. This design wasted significant pumping energy because the systems operated at maximum flow and head continuously.

Today, with the incorporation of variable frequency controllers on pumps to save pump energy, two-way control valves are used primarily. However, a few three-way valves may be used to accommodate the minimum flow requirements for specific equipment such as pumps (*Figure 5*).

Check valves allow flow in one direction and prevent flow from reversing. Check valves are installed in hydronic systems to protect equipment that can be damaged by reverse flow, and to prevent reverse flow upon system shutdown (typically seen at pump discharge and steam traps). The three types of check valves commonly used in hydronic systems are swing, double disc, and silent.

Swing check valves use gravity to close a swinging disc. They can be installed in horizontal pipes or vertical pipes with upward flow. They cannot be installed in pipes that flow downward. They are most commonly specified in applications up to 2 in. (51 mm) pipe size. One disadvantage of swing check valves is that they close slowly and can "hammer" if flow reverses.

FIGURE 5 Two- and three-way valves.




Double disc check valves have a center post, two pivoting discs, and a spring coiled around the center post. Double disc check valves are commonly used in 2½ in. (64 mm) pipes and larger. They have the lowest pressure drop of the common check valve types, and close fast enough to prevent water hammer in nearly all applications.

Silent check valves are also known as center-guided check valves and are commonly used in applications in 2½ in. (64 mm) pipes and larger. They have a central shaft that is parallel with the fluid flow. That shaft has a coiled spring that pushes the disc in the opposite direction of the fluid flow. When a pump applies adequate pressure, the disc lifts and permits flow. Silent check valves are used where large amounts of back-pressure exist, because they are almost completely resistant to water hammer. Most silent check valves will close even before fluid flow reverses. The main disadvantage of silent check valves is their high pressure drop.

**Balancing Valves.** Balancing valves are used to impose artificial head in all pipe routes besides the critical one to prevent short circuiting (excessive flow through lower pressure drop paths that results in insufficient flow through the highest pressure drop path). These valves are usually located on the return side (outlet) of the device as shown in *Figure 5* because this subjects their elastomers to lesser extremes of temperature and pressure, extending their lives. The most common type of balancing valve consists of a variable orifice and two pressure taps to measure the pressure differential across the valve. The flow rate is determined by measuring the pressure drop and noting the opening position of the variable orifice. Then a chart is used to find the flow rate.

Another type of balancing valve uses a flow sensor to measure the flow rate, plus some type of throttling valve, impeller trimming, or a variable speed drive to limit the maximum flow rate. This approach is generally more expensive, but has lower pressure drop and reduces pumping energy.

Automatic flow-limiting valves (aka automatic balancing valves) are preferred by some designers. They consist of a spring and variable orifice to limit the flow rate to the maximum intended for that flow path. They are commonly applied on heat pumps. One apprehension with this type of control device is that there is often no way to measure flow other than to assume that the automatic flow limiting valve is operating properly. There is also no way to adjust the maximum flow rate without replacing the automatic balancing valve. The advantage is that no manual balancing is required if they operate properly and are not fouled by debris in the piping.

## Summary

Hydronic systems are a staple of our industry. The components discussed in this article are not all applied in every hydronic system, but are incorporated as needed for the specific application.

## References


1. Taylor, S., J. Stein. 2012. "Balancing variable flow hydronic systems." ASHRAE Journal (8).

2. *2012 ASHRAE Handbook—HVAC Systems and Equipment*, Chapters 32, 36, 43, and 44. ■