Variable-speed pumps. A variable-speed pump varies the flow rate by maintaining a constant pressure differential as zone valves open and close. A sensor measures the difference in pressure between the supply and return lines, and either speeds up the pump or slows it down to maintain a preset pressure difference. If, for example, there is a pressure increase caused by a modulating valve closing, the pump will respond by slowing down. As a result, the flow rate delivered by the pump is decreased, and the reduced flow rate is better matched to what is required by the remaining emitters and the modulating valves that control them.

The proper design and selection of variable-speed pumps can help reduce the problems of noise, component wear, overheating of conditioned spaces, and valve hunting when flow requirements are low. Variable-speed pumps can match changing flow rate requirements more accurately than fixed-speed pumps, with the added benefit of reduced operating costs during low demand periods, such as spring and fall.

PARALLEL PIPING ARRANGEMENTS

Now that the basic operation of two-pipe systems has been discussed, it must be noted that parallel systems can be arranged in several different piping configurations. They include:

- direct-return systems
- reverse-return systems
- primary/secondary/tertiary loops
- home run systems.

Direct-return systems

The best way to describe the water flow through a direct-return system is “first in, first out”. The heat emitter closest to the boiler has the shortest piping run, and the emitter farthest away from the boiler has the longest piping run. Look at the system illustrated in Figure 4-9. As you can see, the

![Figure 4-9. Direct-return parallel system](image-url)
first emitter supplied with hot water by the boiler is also the first to return its cooler water back to the boiler—and the water that supplies the last emitter is the last to return. This configuration tends to cause higher flow rates in the emitters closer to the boiler, and lower flow rates in the emitters farther away. This is due to the resistance created by the additional lengths of piping and extra fittings needed for the more distant emitters.

Pressure differences across the branch circuits must be “evened out” (balanced) so that all of the emitters receive the proper flow, regardless of location. This can be partially accomplished by varying the size of both the supply line and the return line. Sizing the piping to accommodate the flow required for each successive emitter in the circuit means that the supply line starts off large and gets smaller as it gets farther away from the boiler. The opposite happens to the return line, which is smallest at the most distant emitter and increases in size as it approaches the boiler.

In addition to changing the pipe size to help control flow, balancing valves or circuit setters may be used to provide a preset pressure difference across each branch circuit (see Figure 4-10). The addition of balancing valves increases the cost of installation—however, flow rates cannot be precisely controlled without them, especially when modulating valves are used to regulate the heat output of each emitter.

**Reverse-return systems**

In a reverse-return system, the water flow is “first in, last out.” The heat emitter closest to the boiler is the first to receive supply water, but is the last to have its water returned to the boiler. The last emitter to receive supply water is the first to be connected to the return main. As you can see in Figure 4-11 on the next page, this means that the emitter with the shortest supply run has the longest return run, and vice versa.

The reverse-return configuration is the preferred way of piping a parallel distribution system, because the distance traveled by the water in each loop is about the same. Theoretically, this means that each heat emitter will be supplied with the same flow rate, since the resistances (pressure drops) through all of the branches are equal.

Obviously, a reverse-return system requires more piping than a direct-return system. However, the additional piping, if properly sized and designed, provides a “self-balancing” system. Strictly speaking, then, a reverse-return system eliminates the need for balancing valves. The use of balancing valves in conjunction with modulating valves, however, does improve the system’s ability to control heat output, and may also result in a more efficient system, providing better comfort and reducing operating costs. In general, balancing valves or circuit setters are recommended, regardless of whether the direct-return or reverse-return configuration is used.

**Primary/secondary/tertiary loops**

A primary/secondary system offers greater flexibility than the configurations discussed previously, allowing designers to expand the piping requirements and add more emitters as necessary.
A single primary loop transports hot water around the perimeter of the building. Individual secondary loops are connected to the main circuit with closely spaced tees. Sometimes tertiary loops are added as well. The concept is that every loop works independently of the other loops. Each loop has its own pump that supplies the exact flow rate required for that loop.

A major benefit of the primary/secondary design is that individual loops can supply water at different temperatures, making these configurations easily adaptable to a wide range of applications and enabling the use of colder return water temperatures. For example, the same boiler may supply water for a fan coil unit (high temperature), an in-floor radiant heating package (mid temperature), and a snow-melt system (low temperature). Be aware that in order to accommodate this type of installation, numerous other concerns must be addressed. One of these concerns is ensuring that the return temperature to a non-condensing boiler is not too low—if it is, condensing might occur in the heat exchanger and flue stack. Another consideration to keep in mind is that a glycol fluid must be used for the snow-melt system to safeguard it against freezing. The type of application described above actually would be better suited to the use of a condensing boiler, in which condensing is encouraged since boiler efficiency is increased as the return water temperatures drop.

One pump is used solely to circulate water through the primary loop (the boiler and the related supply and return piping). The pump is sized to provide the required flow according to the manufacturer to ensure proper boiler operation. Because there are no emitters connected directly into the primary loop piping, the flow through
the boiler remains constant. As a result, boiler operation is maximized. Not only are there fewer fluctuations (less ON/OFF cycling), but there is also a lower risk of low-flow or no-flow conditions, which can cause a boiler to overheat. If all of the necessary precautions are in place, the boiler should shut down or “trip” on a safety device. But in cases where low-flow and no-flow scenarios are not prevented, premature failure of the boiler can occur.

A pump or circulator installed in every secondary loop moves the exact flow of water required through any emitters connected directly into the secondary loop piping. The primary loop supplies the heated water from the boiler to the secondary loop, and the secondary loop returns an equal amount of water at a lower temperature back to the primary. Each secondary loop receives only the water it needs.

Primary/secondary/tertiary loops are connected with what are referred as “close-coupled” tees. The fittings are installed very close to each other—in many cases, less than 6 in. apart. The basic idea is to provide as little pressure drop as possible in the “common” piping (the short length of pipe between the two tees). Keeping the

![Figure 4-12. Primary/secondary/tertiary loops](image-url)
resistance in the common piping low makes it less likely for any water to flow from the primary loop into the secondary loop until there is a call for heat and the secondary circulator is turned on. Connections can be made with standard fittings, but manufactured tee assemblies are available to make installation easier and quicker.

An alternative to close-coupled tees is the use of a “decoupler” or “hydraulic separator.” This device connects two different loops in much the same manner as close-coupled tees do. The hydraulic separator is basically a heat exchanger—the two flows do not mix, but the higher-temperature water heats up the lower-temperature water. The separator produces a very low pressure drop, with the result that the flow in one circuit has no effect on the flow in the other circuit.

A tertiary (third) loop can be coupled to the secondary loop, as illustrated in Figure 4-12 on the previous page. The tertiary loop uses its own pump or circulator to provide only the flow necessary for those emitters connected directly into the tertiary loop piping. The secondary loop “hands off” the water required by the tertiary loop, and the tertiary loop “hands back” an equal amount of water to the secondary loop. If the temperature of the supply water is too low for comfort heating, a tertiary loop can be adapted for low-temperature applications, such as snow melting.

Note that Figure 4-12 shows a hydraulic separator between the secondary and tertiary loops. If this loop were to be used for snow melting, a heat exchanger could be installed to keep the two circuits totally isolated. This would be essential if the secondary loop used water and the snow melt (tertiary) loop used a glycol product to prevent freezing. The two loops would need to be completely sealed off from one another to avoid any cross-contamination.

**Home run systems**

A home run system makes use of two manifolds, or header assemblies. One manifold is located in the supply line where all of the emitter branch lines are connected and supplied with boiler water, and the other is located in the common return line (see Figure 4-13). Home run systems provide for the simple installation of any type, size, or configuration of heat emitters. Each space (zone) can be equipped with the emitter best suited to satisfy the exact heating load requirement for that particular location.

A home run system allows each circuit to be controlled as an independent zone. To provide the specific flow required for every emitter, flow control valves can be installed at those points where the branch supply lines tie in to the supply manifold. When necessary, balancing valves also can be installed at the manifold to allow for the different resistances of the various branch circuits. By making sure that the manifolds are in an easily accessible location, and by installing the flow control valves, modulating valves, or balancing valves at the manifolds, adjustments and maintenance procedures can be done in one place—in a basement or mechanical room or closet, for instance, instead of at each individual emitter scattered throughout the building.

The home run distribution system lends itself to applications in which flexible tubing is used to supply heat to a variety of emitters within a building. For example, this configuration can easily be set up to operate both a baseboard heating system (with long tubing requirements, high pressure drops, and high flow rates) and a towel rack (with much shorter tubing lengths and much lower pressure drops and flow rates). With the use of flow control valves and/or balancing valves, all types of emitters can be connected directly to the same manifold, each one essentially acting as an independent circuit.
designed to operate as needed based on tubing length, resistance, and flow rate requirements.

Home run systems are very adaptable when it comes to the addition of an extra circuit or two, which basically involves tapping into the existing manifolds, adding the necessary tubing and emitters, and then adding the controls needed to provide the required flow rate. Of course, this is true only if 1) the boiler can supply the extra heat load that is being added onto the supply manifold, and 2) the circulator can supply the necessary flow rate (gpm) to satisfy all of the circuits.

**THREE-PIPE AND FOUR-PIPE SYSTEMS**

Three-pipe and four-pipe distribution systems are used when both hot water for heating and chilled water for cooling are supplied to the same emitter from different heating and cooling sources. A *three-pipe system* gets its name from the fact that it has two supply lines—one for hot water and one for cold water—and a single, common return line (see Figure 4-14 on the next page). This means that an emitter (such as a fan coil unit) can be supplied with heated water from a boiler or chilled water from a chiller—or both water temperatures at the same time. The hot water and cold water can be mixed to “temper” one supply or the other, depending on the load and comfort level required. Some zones can be used for cooling while others can be used for heating, allowing for totally different setpoints for every zone.

![Figure 4-13. Home run system](Image)