Block B: Heating & Cooling Systems

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BC Plumbing Apprenticeship, Level 2

SKILLED TRADES BC

BC PIPING ARTICULATION AND CURRICULUM SUBCOMMITTEE; ROD LIDSTONE; AUDREY CURRAN; AND PAUL SIMPSON

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Block B: Heating & Cooling Introduction

In the field, there are many similarities or overlaps with the work of plumbers and gas fitters. Many plumbing and heating contractors employ both plumbers and gas fitters as well as tradespeople with dual certifications.

Upon completion of a Plumbing Apprenticeship, a plumber can receive cross-program credit for a portion of the Gas fitter apprenticeship. As such, training in fuel gas has been incorporated into all levels of the Plumbing Apprenticeship.

Block B of the **Plumbing Apprenticeship Program Level 2 Series** focuses on the fundamentals of heating and cooling systems, providing apprentices with a thorough understanding of various system types and their components. This section is designed to equip apprentices with the knowledge needed to install, maintain, and troubleshoot complex heating and cooling systems, with an emphasis on hydronic technology.

Plumbing Apprenticeship Program Level 2 Series

The *Plumbing Apprenticeship Program Level 2 Series* offers comprehensive training materials designed to build on foundational skills and knowledge. The series is divided into four main blocks, each focusing on critical areas of plumbing systems and installations.

Block A: Fuel Gas Systems (https://a-fuelgas-bcplumbingapprl2.pressbooks.tru.ca/)

A-1: Gas Fired Appliances
A-2: Gas Codes Regulations and Standards
A-3: Gas Appliance and Building Air Requirements
A-4: Technical Instruments and Testers

Block B: Heating and Cooling Systems (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/)

B-1: Types of Heating and Cooling Systems
B-2: Hydronic Heating and Cooling Generating Equipment
B-3: Hydronic Heat Transfer Units
B-4: Hydronic Heating Piping and Components

Block C: Install Fixtures and Appliances (https://c-plumbfixappliance-bcplumbingapprl2.pressbooks.tru.ca/)

C-1: Plumbing Fixtures and Trim
C-2: Plumbing Appliances

Block D: Drainage Systems (https://d-drainagesystems-bcplumbingapprl2.pressbooks.tru.ca/)

D-1: Sanitary Drain, Waste and Vent Systems
D-2: Planning and Installation of DWV Systems
D-3: Storm Drainage Systems
D-4: Test and Drainage Systems
D-5: Drainage System Maintenance and Repairs

Plumbing Apprenticeship Program Overview and Upcoming Resources

- **Plumbing Apprenticeship Program Level 1 Series** is coming soon to TRU Open Press in 2025–2026!
- **Plumbing Apprenticeship Program Level 3 Series (https://collection.bccampus.ca/search/?q=%22pl3%22)** can be found in the BCCampus Open Collection (https://collection.bccampus.ca/).
- **Plumbing Apprenticeship Program Level 4 Series** (https://bccampus.ca/projects/archives/zed-cred-z-degrees/ztc-open-educational-resources-for-trades/) can be found in the BCCampus Open Collection. (https://collection.bccampus.ca/) (Block F: Commission and Service will be available soon.)

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Symbol Legend

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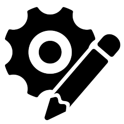
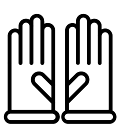
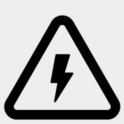
	Required or Optional Resources
	Potentially Flammable Situation
	Complete a Self-Test
	Possibly Explosive Situation
	Use Protective Equipment
	Potential Electric Shock

Acknowledgments

The development of the *Piping Trades Learning Guides* was a collaborative effort driven by a commitment to excellence in trades education. These guides were created to support apprentices and journeypersons in mastering the skills and knowledge essential to the piping trades. This achievement would not have been possible without the dedication and expertise of *Skilled Trades BC* and the *Piping Trades Articulation Committee*, whose leadership and guidance have been instrumental in shaping high-quality training resources. We extend our sincere gratitude for their contributions and ongoing stewardship in advancing the piping trades.

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References

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SkilledTradesBC. (2022, December 1). Introducing Skilled Trades BC. YouTube. https://www.youtube.com/watch?v=OQgwdP0rNog

Trades Training BC. (2021). A-1: Introduction to gas-fired appliances. In: *Plumber Apprenticeship Program: Level* 2. Industry Training Authority, BC.

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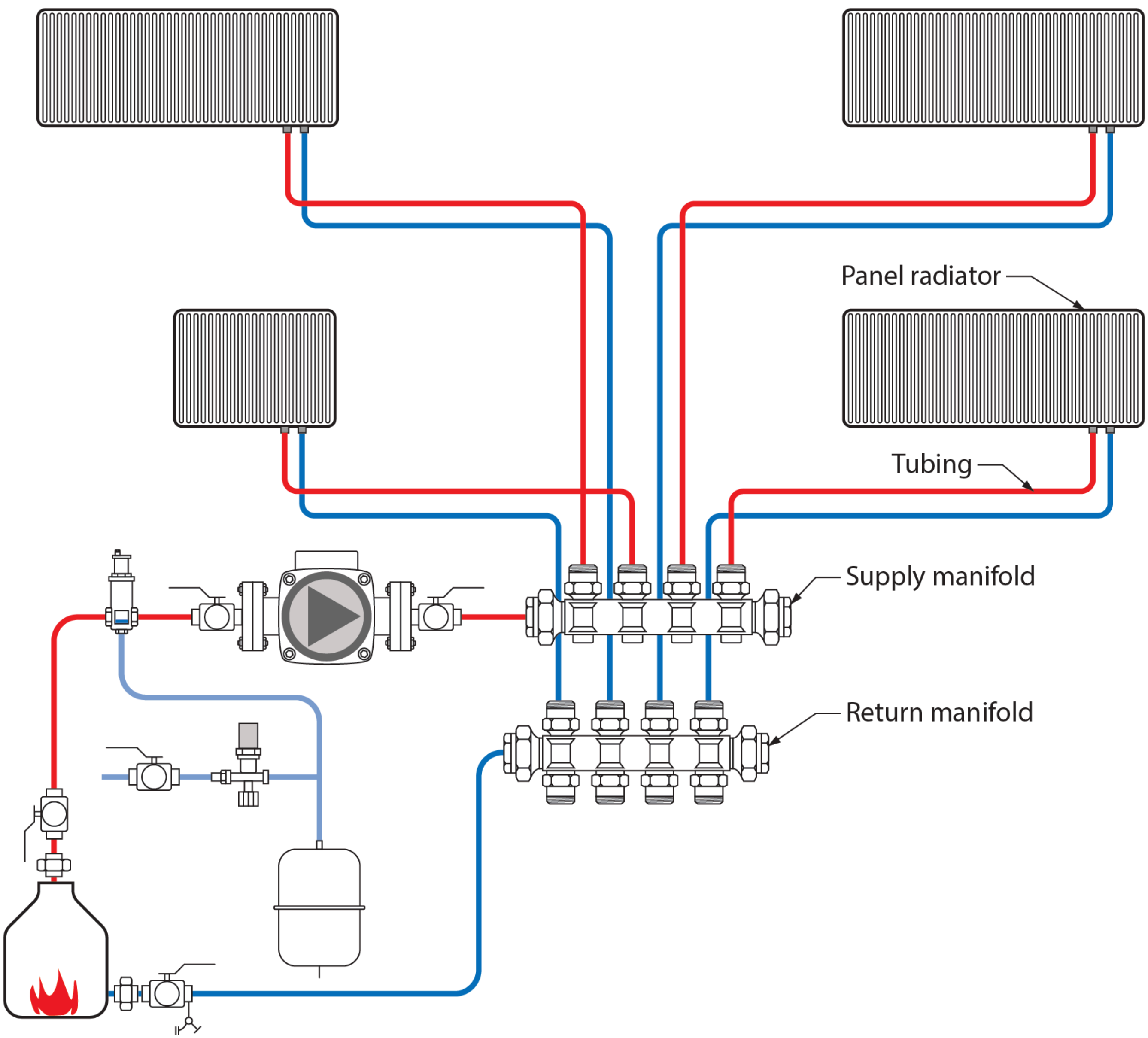
B-1 TYPES OF HEATING AND COOLING SYSTEMS

Plumber Apprenticeship Program – Level 2



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B-1 Types of Heating and Cooling Systems Introduction

The purpose of a building's heating or cooling system is not necessarily to raise or lower the temperature of the building but rather to offset or balance the amount of a heat lost or gained in order to maintain a constant temperature within the building. A building's heating system is said to be in thermal equilibrium when the heat input is in balance with the heat lost. In an ideal system, the occupants would not be conscious of either warm or cold sensations. This thermal equilibrium situation would be the goal of the heating ventilation and air-conditioning (HVAC) system designer/installer.

Learning Objectives

After completing the chapters in this section, you should be able to:

- Describe the concepts of heat and heat transfer.
- Describe low-pressure steam heating systems.
- Describe residential forced-air systems.
- Describe hydronic heating and cooling systems.

Terminology

The following terms will be used throughout this section. A complete list of terms for this section can be found in the **Glossary**.

- **air vents:** Steam cannot circulate, nor can radiators emit heat until air has been vented from the system. Thermostatic air vents are installed on each radiator and at the end of each steam main. Thermostatic steam traps also act as air vents. (Section B-1.1)
- **dry return:** The portion of the return main located above the boiler water level. (Section B-1.2)
- **equalizer line:** The vertical piping at the end of the header going back to the boiler return connection. Its job is to return any water that slips out of the boiler with the steam and to balance the pressure between the supply and the return sides of the boiler. Without a properly sized equalizer, water can back out of the boiler. (Section B-1.2)
- **gauge glass:** Used to identify the water level in the boiler. Expect to see some minor movement in the water line when the boiler is operating. When the boiler is off, the "normal" water line is the centre of the gauge glass. When the system is running, the "normal" water line is near the bottom of the gauge glass. (Section B-1.2)
- **Hartford loop:** A piping arrangement designed to prevent complete drainage of the boiler if a leak

develops in the wet return. The wet return is connected to an equalizing line between the supply and return opening of the boiler. This connection is made about 2 in. below the normal water level of the boiler. This connection between the loop and the equalizer must be made with a close nipple to prevent water hammer. (Section B-1.2)

- **header:** Boilers, depending upon their size, have one or more outlet tappings. The vertical steam piping from the tapped outlet joins a horizontal pipe called a "header." The steam supply mains are connected to this header. If the boiler has more than one outlet, it's important to remember to pipe the headers with swing joints. This will help alleviate any stress on the boiler when the header heats up and expands. (Section B-1.2)
- **heat emitters (units):** Steam heating systems use convectors, cast-iron radiators, wall fin tubes, and similar heat-emitting units. (Section B-1.4)
- **low-water cutoff:** Shuts off the burner should the water level fall to an unsafe level. The boiler manufacturer determines this level, but it's usually within one-half inch of the bottom of the gauge glass.
- **radiator valve:** Controls the steam supply to the system radiators. Each radiator is equipped with an angle pattern radiator supply valve. (Section B-1.2)
- **relief valve:** Protects the boiler against a runaway fire. On space-heating steam boilers, the relief valve is set to pop open and relieve pressure at 15 psi. This is the limit for any low-pressure boiler. (Section B-1.2)
- **risers:** The vertical pipe carrying steam to the radiator from the supply main. (Section B-1.2)
- **steam boiler:** A steam boiler is a device that heats water until it turns into steam. This steam is then used to provide heat or power. It works by burning fuel like coal, oil, or gas, or by using electricity to generate heat. The steam produced can be used for various purposes, such as heating buildings, running engines, or powering machines. (Section B-1.2)
- **steam supply main:** Carries steam from the header to the radiators connected along its length. (Section B-1.2)
- **steam traps:** Prevent steam from getting into the condensate returns because they close in the presence of steam, creating a separation from the return piping of the system. The steam trap has three jobs — to let air pass through the radiators, to close when steam reaches it, and to open when condensate accumulates. (Section B-1.2)
- **wet return:** The portion of the return main located below the boiler water level. It is always completely filled with water and does not carry air or steam in the same way that the dry return does. (Section B-1.2)

B-1.1 Heat and Heat Transfer

Heat is a form of energy. In North America, heating is commonly discussed using imperial units. Heat can be measured by its quantity and intensity. Before any heating system can be designed, it is necessary to understand what heat is, how it is transferred, and how that heat movement can be measured.

Quantifying Heat Energy

Heat quantity is described in British thermal units (BTU). One BTU is defined as the amount of energy it takes to raise one pound of water by one degree Fahrenheit. This is the approximate amount of energy released by burning one wooden match.

The metric unit of energy is the joule (J) or kilojoules (kJ). 1 BTU equals 1.054 kJ. The metric equivalent of the BTU is the kilowatt (kW). Note that the kilowatt incorporates one hour of time within its definition. Sometimes kilowatts are described as kilowatt hours.

Power is the rate at which energy is generated, converted, or used. The power ratings of heating and cooling equipment are expressed in BTU's per hour (BTU/h) or kilowatts (kW). One kilowatt is equivalent to 3,412 BTU/h.

Temperature is the measure of heat intensity and is expressed in degrees Fahrenheit (°F) or degrees Celsius (°C). Fahrenheit and Celsius are often associated with imperial and metric scales, but that is not the case. Rather, they are parts of scales that have their baseline at the point where all heat is absent. This point is known as absolute zero.

The scale that shares degrees with the Fahrenheit scale is the Rankine scale. It has 460 of its degrees below 0°F — so 32°F would be expressed as 492°R (Rankine):

$$32^\circ\mathrm{F} + 460 = 492^\circ\mathrm{R}$$

The other scale that corresponds to degrees Celsius is the Kelvin scale. There are 273 degrees Kelvin between 0°C and absolute zero — so 100°C would be expressed as 373°K (Kelvin):

$$100^\circ\mathrm{C} + 273 = 373^\circ\mathrm{K}$$

Figure 1 compares the various temperature scales.

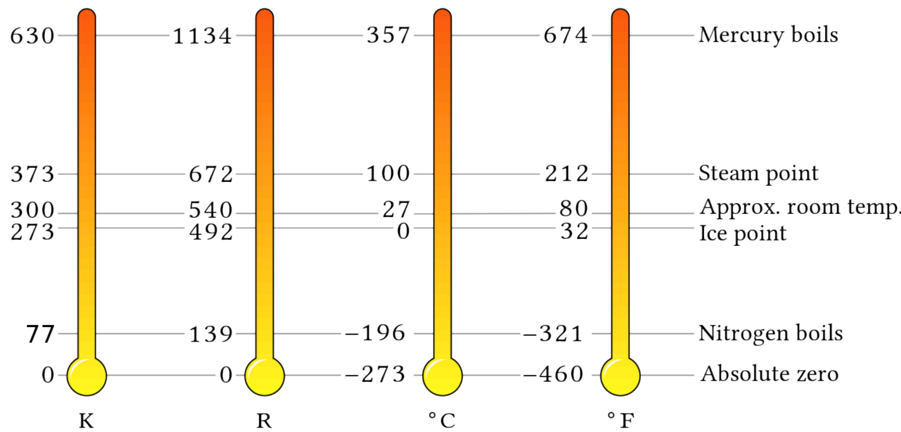

Figure 1 *Comparison of the Various Temperature Scales (Steven Baltakatei Sandoval/Wikimedia Commons)* CC BY-SA 4.0 *(https://creativecommons.org/licenses/by-sa/4.0/deed.en)* (***Long description*** *(#Fig1_longdesc)*)

All matter is composed of atoms. All atoms vibrate, and this vibration is caused by the presence of heat. Even matter that is at temperatures below 0°C will vibrate because they contain heat. At absolute zero, all vibration stops, and no heat is present. The higher the intensity of atomic vibrations within a material, the greater the temperature of the material and the greater its heat content. Any material above absolute zero contains some measurable amount of heat energy. So, you could say that adding 10 BTU (a unit of heat) to a pound of water will increase the water's temperature by 10°F (which measures the intensity of heat). Heat's intensity is measurable with a thermometer, while the heat content of a material is the result of applying its temperature to a formula. A material's heat intensity is a result of its heat content.

Heat Transfer

Heat always moves from an area of increased atomic activity (higher temperature) to an area of decreased atomic activity (lower temperature). Heat is transferred from one material to another by three main processes:

- **Conduction**
- **Convection**
- **Thermal radiation**

In a hot water heating system, heat transfer units or emitters use the processes of conduction, convection, and radiation to transfer heat to rooms or zones. The rate of heat transfer, known as heat flow, depends on the temperature difference between materials. Heat energy will continue to transfer from warm material to cool material until both are the same temperature.

Conduction

Conduction is the transfer of heat by contact. Molecules vibrate in response to their level of heat energy. When two molecules bump into each other, the vibration of one affects the other, and heat energy is transferred. When materials that have different temperatures are in contact, heat from the warm material is conducted to the cool material (Figure 2).

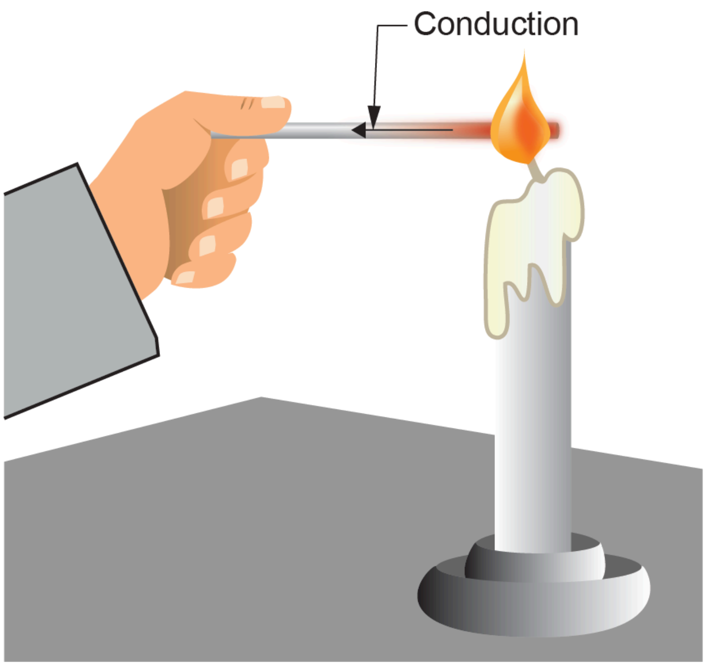

Figure 2 *Heat transfer. (Skilled Trades BC, 2021) Used with permission.*

Effects of Conduction

Hot water loses heat through the walls of containing vessels and piping. Water in piping has molecular contact with the piping walls. This contact causes heat to conduct through the piping walls to outside air.

The speed at which heat energy transfers through conduction depends on the difference in temperature between the two materials. If the temperature difference is doubled, the heat flow rate also doubles.

The amount of heat transferred is also affected by the amount of surface area in contact. If the surface area in contact is doubled, the amount of heat transferred also doubles.

All materials allow some movement of heat. Some materials, such as metals, allow heat to conduct very rapidly. Other materials, like air, allow heat to conduct slowly. Heat conductivity (or thermal conductivity) is the speed at which a material is able to transfer heat. A material with low heat conductivity is called an insulator. The lower the heat conductivity, the greater the insulation value. Table 1 lists the heat conductivity of several common substances with a thickness of 1 in., a surface area of 1 sqft, and a temperature difference across the material of 1°F.

Table 1: Heat Conductivity of Common Substances

Substance	Conductivity
Copper	2660 BTU/h
Steel	320 BTU/h
Concrete	12 BTU/h
Water	4.1 BTU/h
Plastic	1.2 BTU/h
Air	0.15 BTU/h

Copper conducts heat more quickly than steel, and steel conducts heat more quickly than plastic. Plastic conducts so little heat that it is classed as an insulator. Plastic's low conductivity and high corrosion resistance make it an ideal material for moving water within a heating or cooling system.

Convection

Convection is the transfer of heat in a fluid (a gas or a liquid) caused by a difference in densities. It is sometimes called gravity circulation. When heat is applied to a fluid, the temperature of the fluid increases, causing it to expand and become less dense than the surrounding fluid. It is then pushed upward as cooler, denser fluid flows downward to take its place. This upward push by cooler, denser fluid is known as buoyancy. Early hydronic heating systems depended on gravity circulation to move heat from the heat source (boiler) through piping to the heat transfer units (cast-iron radiators) in the heated areas.

Air in contact with the radiators was heated by conduction, which in turn created movement of heated air in the room through convection (Figure 3). This process of heating the air is still used by modern convectors, although the circulation of water is accomplished through the use of pumps.

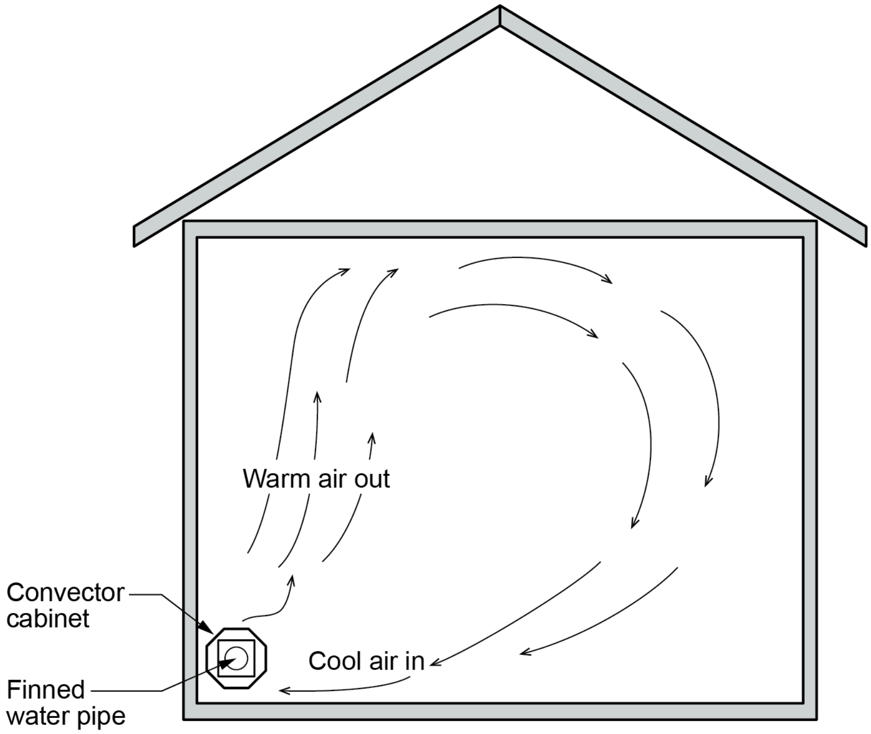

Figure 3 *Convection currents in a room or zone. (Skilled Trades BC, 2021) Used with permission.*

Radiation

Radiation is the transfer of heat by electromagnetic heat rays emitted directly from a heat source to a receiving material. Heat rays travel through space in the same way that light rays travel. It is important to note that radiant heat does not raise the temperature of the air between the source and the material. Heat rays are rarely impeded or absorbed by intervening air due to air's lack of mass or density. When the heat rays reach a material other than air, that material absorbs them and becomes warmer.

A good example of a radiant heat source is the sun (Figure 4). Imagine you are outside on a very cold yet sunny day. If you stand facing the sun, you will feel warmth on your face, but not on your back. On the other hand, if you turn away from the sun, your back warms up, but your face will feel cold. The sun's rays are heating you directly, rather than heating the air between it and you.

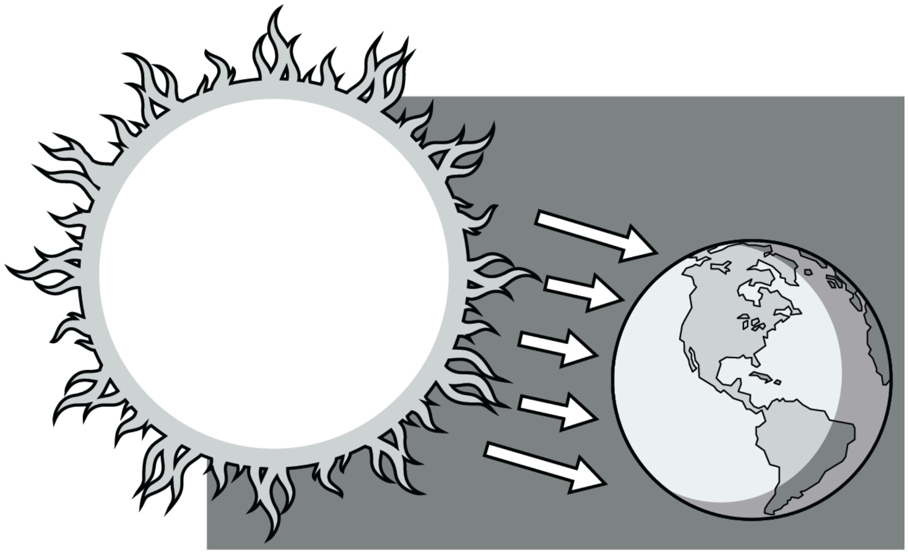

Figure 4 *The Sun's radiation reaches the Earth through space. (Skilled Trades BC, 2021) Used with permission.*

Radiant Heat

The amount of heat transmitted by a radiator is proportional to its surface area and temperature. The best radiators of heat are rough and black, such as cast-iron stoves. Light-coloured, smooth, and shiny materials, such as toasters and kettles, tend to reflect heat. As the temperature of the radiating material increases, the amount of radiation increases.

Self-Test B-1.1: Heat and Heat Transfer

Complete Self-Test B-1.1 and check your answers.

If you are using a printed copy, please find Self-Test B-1.1 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=37#h5p-1 (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=37#h5p-1)

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- **Figure 1** Comparison of the various temperature scales (https://commons.wikimedia.org/wiki/File:Temperature_scales_comparison_(K,R,C,F).svg) is by Stephen Baltakatei Sandoval (2023) via Wikimedia and is used under a CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0/deed.en) licence.

Long Description: Figure 1 Comparison of the Various Temperature Scales

The following table shows a comparison of the various temperature scales: Rankine, Fahrenheit, Celsius, Kelvin.

Comparison of the Various Temperature Scales

Rankine (°R)	Fahrenheit (°F)	Description	Celsius (°C)	Kelvin (°K)
1134	674	**Mercury boils**	357	630
672	212	**Water boils; steam point**	100	373
492	32	**Water freezes**	0	273
460	0	**—**	-18	256
139	-321	**Nitrogen boils**	-196	77
0	-460	**Absolute zero**	-273	0

Back to Figure 1 (#Fig1)

B-1.2 Low-Pressure Steam Heating Systems

A steam heating system takes advantage of the high latent heat given off when steam condenses to water. Although residential steam heating systems were very common in the late 19th and early 20th centuries, they are rarely installed in new single-family residential construction. Compared to other heating methods, it is more difficult to control the output of a steam system.

However, steam can be sent to places (e.g., between buildings on a college or university campus), which allows an efficient central boiler and low-cost fuel to be used. Tall buildings take advantage of steam's low density to avoid the excessive pressure required to circulate hot water from a basement-mounted boiler. In industrial systems, process steam used for power generation or other purposes can also be tapped for space heating. Steam for heating systems may also be obtained from heat-recovery boilers using otherwise wasted heat from industrial processes.

In a steam heating system, each room is equipped with a radiator, which is connected by piping to a **steam boiler**. Steam entering the radiator condenses and gives up its latent heat, and the radiator, in turn, heats the room or zone. The condensate water (or condensate) returns to the boiler either by gravity or with the assistance of a pump. Some systems only use a single pipe for combined steam and condensate return. Since trapped air prevents proper circulation, such systems have vent valves to allow air to be purged. Pipes must be carefully sloped to prevent trapped condensate blockage. In domestic and small commercial buildings, the steam is generated at relatively low pressure, less than 15 psig (200 kPa).

Latent heat, not steam pressure, does the actual heating work in a residential steam heating system. Remember that steam gives up 970 BTU of usable heat for every pound that condenses back to water. The job of steam pressure is strictly to overcome the friction that steam meets as it works its way around the system. A steam heating system requires only enough pressure back at the boiler to overcome the system piping's friction; that pressure is very low because the pipe is sized to offer very little resistance to steam flow. Therefore, house steam heating systems should not operate at pressures higher than two psig.

Steam heating piping systems are classified by how they handle the steam and condensate. One-pipe systems use common piping for both the steam and condensate, whereas two-pipe systems use separate piping for each.

System Components

The following is a list of some more common components found in low-pressure steam heating systems, some of which are shown in Figure 1.

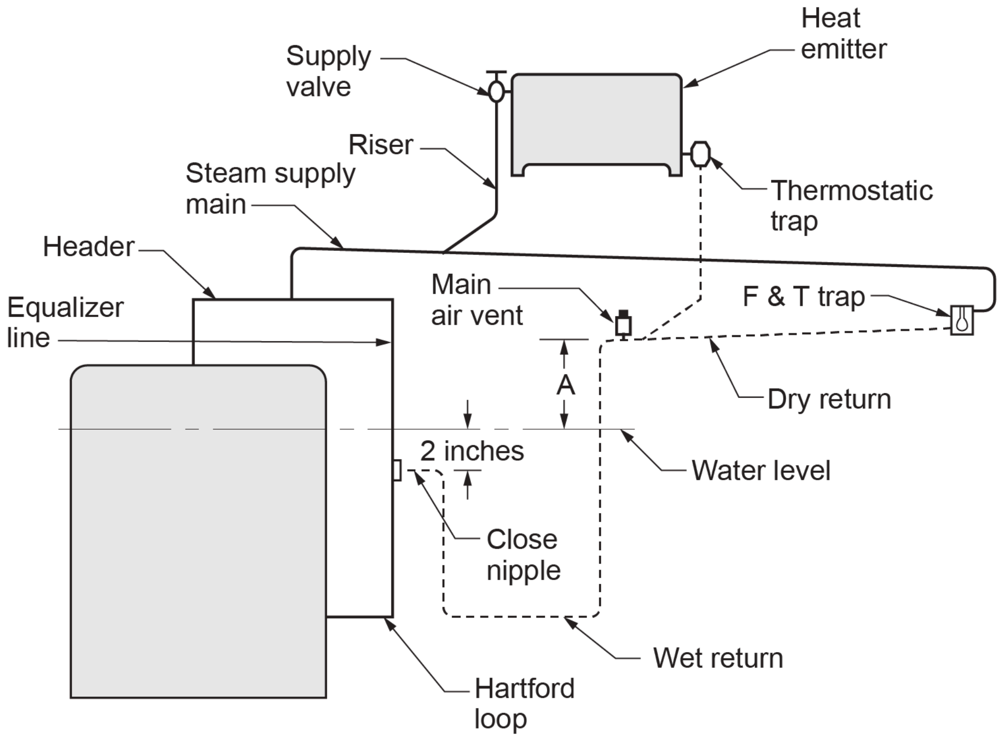

Figure 1 *Steam heating components. (Skilled Trades BC, 2021) Used with permission.*

Steam boiler: Steam boilers differ from hot water boilers in that they are only partially filled with water. A sight glass is provided for visual observation of the boiler water level. A relief valve protects the boiler from damage should excessive pressures occur. The burner is operated from a steam pressure switch, called a pressuretrol, which determines the operating pressure range of the boiler. During a call for heat, the boiler will cycle up to the cut-out setting of the pressuretrol. At that point, the pressuretrol will shut off the burner. Commercial boilers also require a manual-reset high-limit pressuretrol to shut off the burner should the pressure rise too high.

Header: Boilers, depending upon their size, have one or more **outlet tappings**. The vertical steam piping from the tapped outlet joins a horizontal pipe called a header. The steam supply mains are connected to this header. If the boiler has more than one outlet, it is important to remember to pipe the headers with swing joints. This will help alleviate any stress on the boiler when the header heats up and expands.

Equalizer line: The equalizer line is the vertical piping at the end of the header going back to the boiler return connection. Its job is to return any water that slips out of the boiler with the steam and to balance the pressure between the supply and the return sides of the boiler. Without a properly sized equalizer, water can back out of the boiler.

Steam supply main: The steam supply main carries steam from the header to the radiators connected along its length.

Risers: The vertical pipe carrying steam to the radiator from the supply main is called a riser.

Heat emitters (units): Steam heating systems use convectors, cast-iron radiators, wall fin tube, and similar heat-emitting units.

Dry return: The dry return is the portion of the return main located above the boiler water level.

Wet return: The wet return is the portion of the return main located below the boiler water level. It is always completely filled with water and does not carry air or steam in the same way that the dry return does.

Hartford loop: The Hartford loop is a piping arrangement designed to prevent complete drainage of the boiler should a leak develop in the wet return. The wet return is connected to an equalizing line between the supply and return opening of the boiler. This connection is made about 2 in. below the normal water level of the boiler. This connection between the loop and the equalizer must be made with a close nipple to prevent water hammer.

Gauge glass: The gauge glass is used to identify the water level in the boiler. Expect to see some minor movement in the water line when the boiler is operating. When the boiler is off, the "normal" water line is the centre of the gauge glass. When the system is running, the "normal" water line is near the bottom of the gauge glass.

Air vents: Steam cannot circulate, nor can radiators emit heat until air has been vented from the system. Thermostatic air vents are installed on each radiator and at the end of each steam main. Thermostatic steam traps also act as air vents.

Radiator valves: Radiator valves control the steam supply to the system radiators. Each radiator is equipped with an angle pattern radiator supply valve.

Steam traps: Steam traps prevent steam from getting into the condensate returns because they close in the presence of steam creating a separation from the return piping of the system. The steam trap has three jobs — to let air pass through the radiators, to close when steam reaches it, and to open when condensate accumulates.

Relief valve: The relief valve protects the boiler against a runaway fire. On space-heating steam boilers, the relief valve is set to pop open and relieve pressure at 15 psi. This is the limit for any low-pressure boiler.

Low-water cut-off: The job of the low-water cut-off is to shut off the burner should the water level fall to an unsafe level. The boiler manufacturer determines this level, but it is usually within one-half inch of the bottom of the gauge glass.

One-Pipe Steam Systems

One-pipe systems take their names from the single pipe that connects each radiator to the steam main. Both steam and condensate travel in this pipe but in opposite directions.

Counterflow System

In **counterflow** systems (Figure 2), the steam and condensate travel in opposite directions in the steam main piping. When there is counterflow, the pitch must be at least 1 in. in 10 ft. The steam main must be one size larger than one used for other types of one-pipe systems.

Dimension A (Figure 2) must be of sufficient height to provide enough gravity head pressure to return condensate to the boiler. The head provided by the height of this column consists of the steam system pressure drop and the static head needed to overcome the pressure drop in the condensate return lines. It is standard practice for a system based on $\frac{1}{2}$ psi pressure drop to make the minimum distance for Dimension A not less than 28 in.

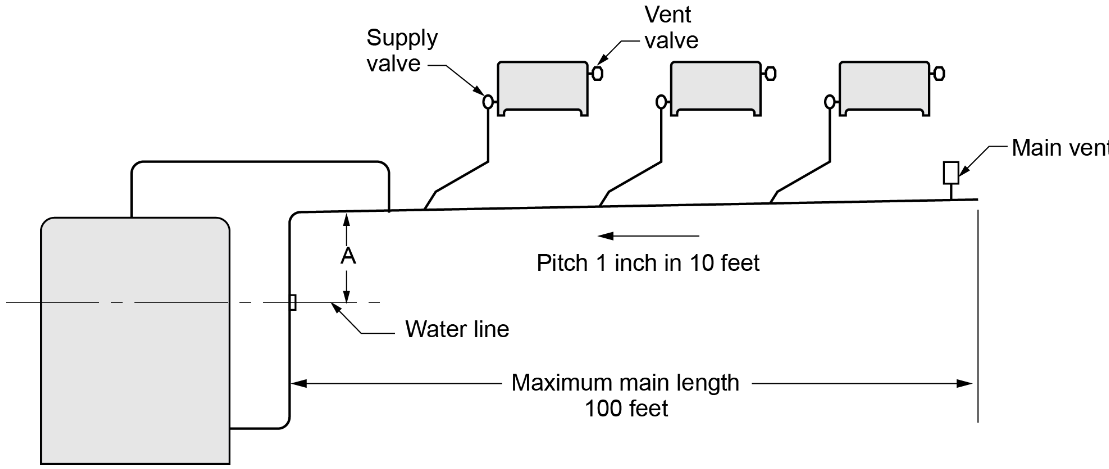

Figure 2 *Counterflow system. (Skilled Trades BC, 2021) Used with permission.*

Parallel Flow System

In **parallel** flow systems, the steam and condensate move in the same direction in the horizontal steam and return mains. The pitch on the mains should be at least 1 in. in 20 ft. Figure 3 shows a parallel flow system with a **wet return** from the end of the steam main, and Figure 4 shows a **dry return**.

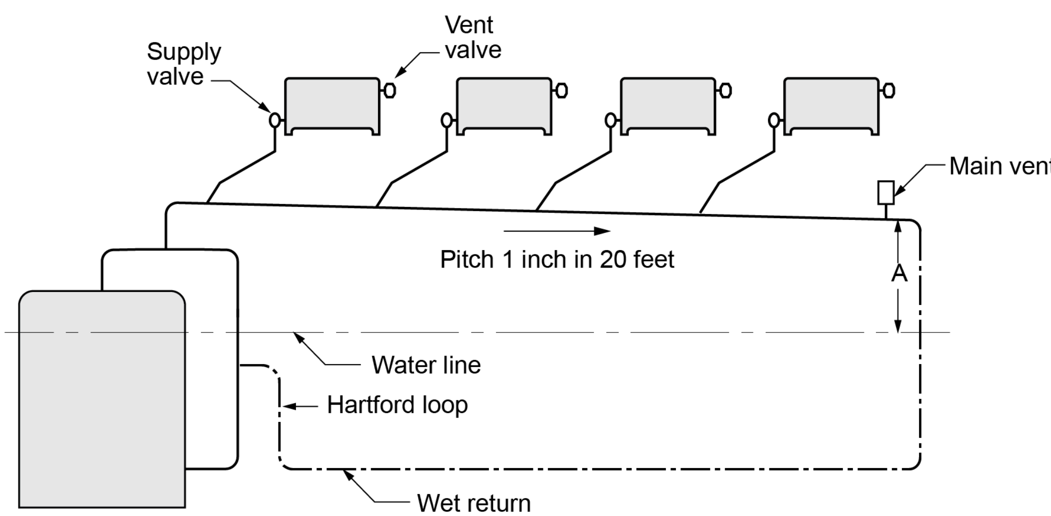

Figure 3 *One-pipe parallel flow system, with wet return. (Skilled Trades BC, 2021) Used with permission.*

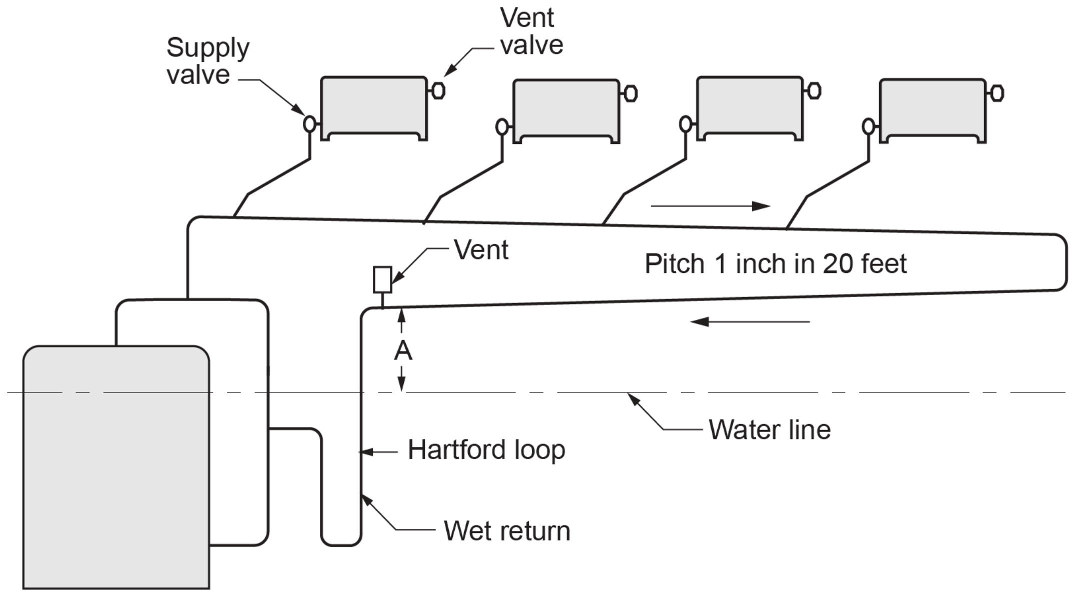

Figure 4 *One-pipe parallel flow system, with dry return. (Skilled Trades BC, 2021) Used with permission.*

Two-Pipe Steam Systems

Two-pipe systems (Figure 5) differ from one-pipe systems in that the former carries steam and condensate to and from the radiators using separate lines. The steam lines supply steam to the radiators, which discharge their air and condensate to the return lines. Traps are used at each radiator and at the end of each supply main to prevent the entry of steam into the return lines.

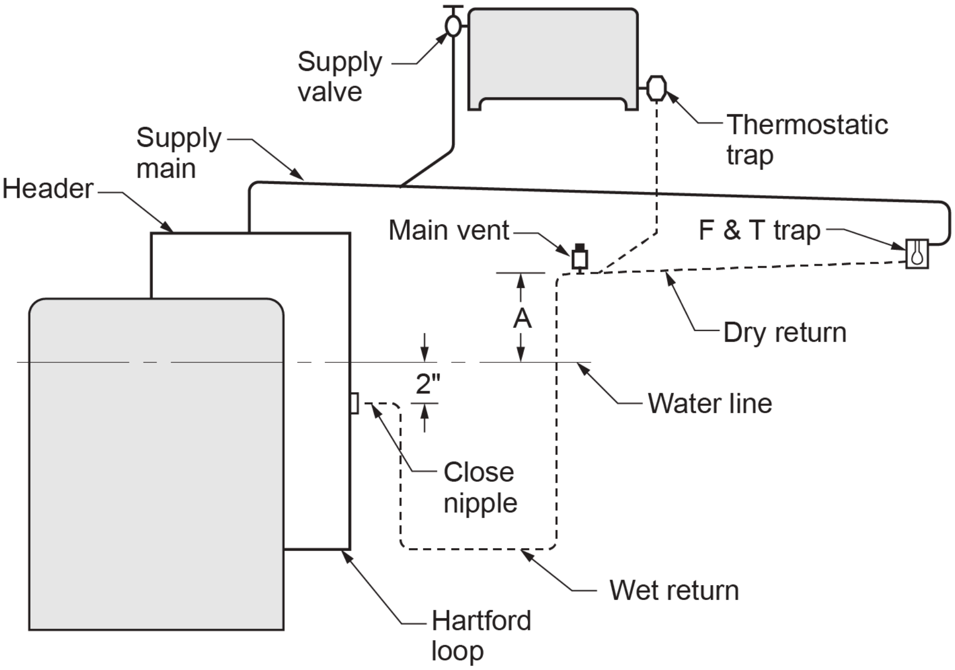

Figure 5 *Two-pipe gravity return system. (Skilled Trades BC, 2021) Used with permission.*

Steam traps also have a curious effect on the system's returns. Because they close off the steam, traps prevent steam pressure from getting into the returns. In a one-pipe system, the water returns to the boiler because of the static weight of the water in Dimension A and the "leftover" steam pressure at the end of the main.

Two-pipe systems do not have any leftover steam pressure to help move the condensate back into the the boiler. This is because of the traps. This means that with two-pipe steam systems, Dimension A must be at least 30 in. for every pound of pressure in the boiler. In other words, if a boiler fires at 2 psig, it will need 60 in. of height between the centre of the **gauge glass** and the bottom of the lowest steam main.

This is why condensate pumps are often used in two-pipe steam systems.

Pumped Condensate Return Systems

Installations with their dry return at an insufficient elevation over the boiler water line to provide gravity condensate return must be equipped with condensate return pumps (Figure 6). A condensate pump is the low point in the system. Everything must flow downhill to it. A condensate pump has a receiver tank for collecting returning condensate; the tank is vented to the atmosphere.

Inside the receiver is an electrical float switch. This switch turns the pump on when the water level inside the receiver rises and off when it falls. On the discharge side of the pump is a check valve (to keep the boiler water in the boiler) and a throttling valve. The throttling valve is used to slow the pump down because most pumps discharge at too high a rate and pressure for most residential heating applications. The throttling valve will stop the check valve from chattering by adding resistance to the pump's pressure.

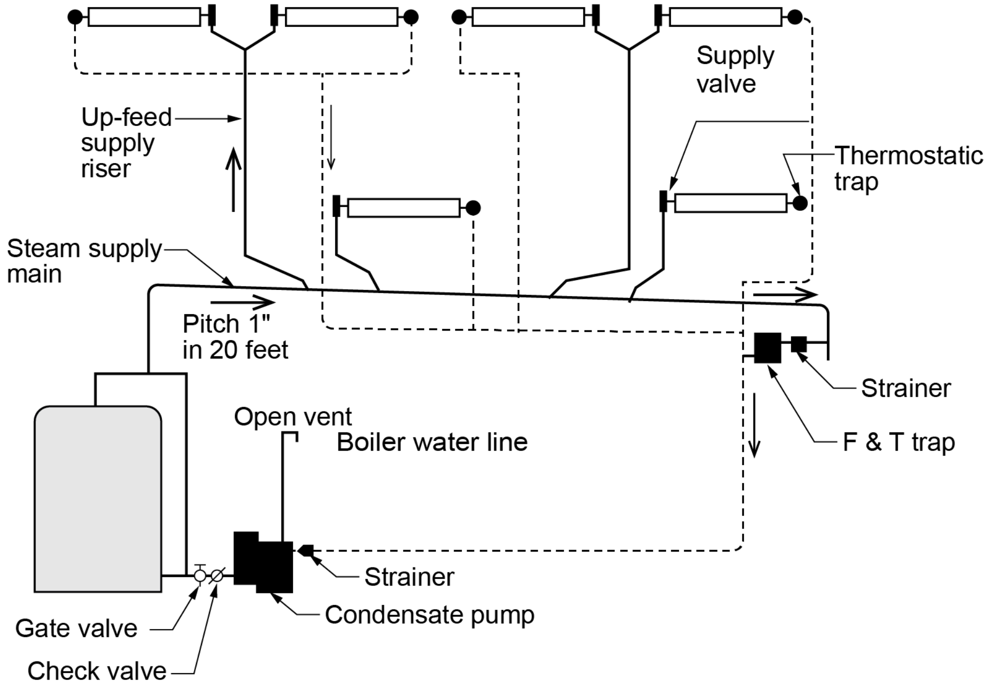

Figure 6 *Steam heating system with condensate pump. (Skilled Trades BC, 2021) Used with permission.*

One problem with condensate pumps is that they are only designed to fill and dump. They have no way of detecting if the boilers they serve need water or not, which can be a problem for low-water-content boilers. Because of this, boiler-feed pumps are sometimes used in place of condensate pumps.

A boiler-feed pump is different from a condensate pump because the float switch that controls the pump is located on the boiler itself rather than in the pump's receiver. With a boiler-feed pump, the pump can come on only if the boiler needs water.

The receiver in the boiler-feed pump is also much larger than the condensate pump's receiver. This oversized receiver gives the condensate a place to wait until the boiler needs it.

Self-Test B-1.2: Low-Pressure Steam Heating Systems

Complete Self-Test B-1.2 and check your answers.

If you are using a printed copy, please find Self-Test B-1.2 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

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B-1.3 Residential Forced Air Heating and Cooling Systems

In Canada, forced-air heating is the most common type of heating system used for residential and commercial buildings.

Pros and Cons of Forced Air Heating

One advantage forced-air systems have over other heating systems is the movement of the return air through a filter that constantly removes dust and other airborne particles from the air stream as the system works.

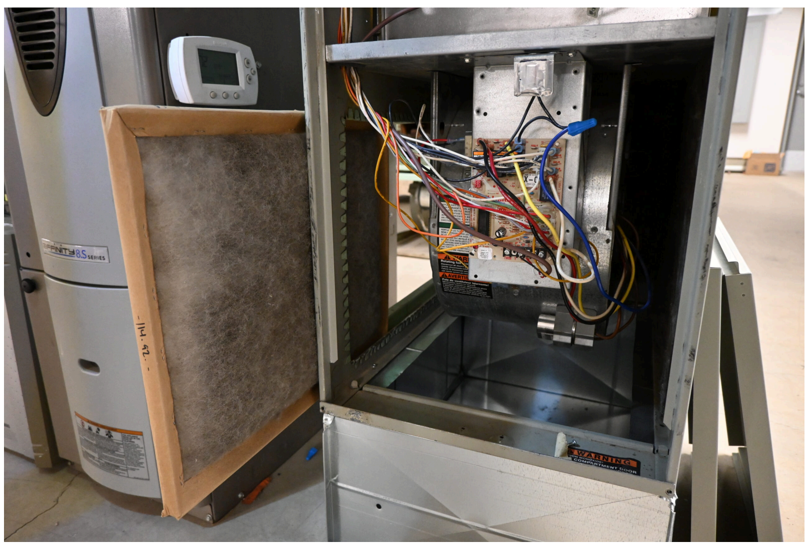

Figure 1 *Forced air furnace media filter installation.* (TRU Open Press) CC BY-NC-SA (*https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en*)

Air filtration is a feature that neither electric baseboard nor hot water (hydronic) heating systems contain. Filtering the air lessens the amount of dust and debris that settles on furniture or is breathed in by occupants and keeps debris from plugging heating and cooling coils.

Another reason for the popularity of forced air heating systems is the ability to add an evaporator coil (Figure 2) into the ductwork so that the system can be used to cool the house in the summer months. This is another feature that neither electric baseboard nor hydronic systems can offer.

Forced-air systems are often chosen over hydronic heating systems because of the cost of installation. The cost of a ducted forced-air heating system is generally lower than a hydronic heating system.

Figure 2 *Evaporator (A) coil. (Skilled Trades BC, 2021) Used with permission.*

The downside of forced-air heating is the difficulty in maintaining a comfort level in all areas of the home. Typically, a single thermostat is located central to the structure, so it is not affected by cold transfer from outside walls and windows. The thermostat controls the on/off operation of the system. Airflow regulators, known as dampers, are installed in the individual supply duct runouts and/or the grilles and registers (Figure 3) to throttle airflow to a specific area. To maintain a consistent comfort level everywhere, the system must be balanced by adjusting each damper and measuring airflow at the outlets. Every adjustment has a direct effect on the airflow at other outlets, and any miscalculated movement of a damper's setting will throw the entire system out of balance.

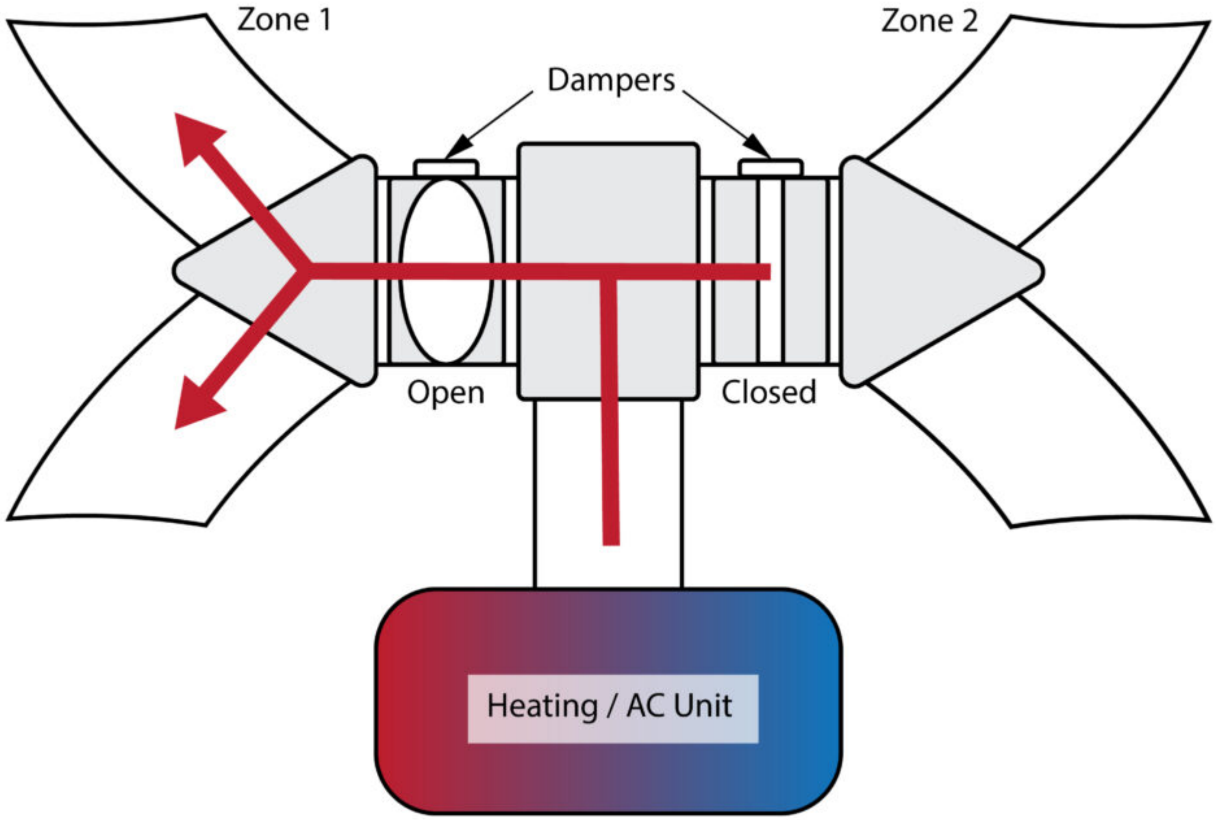

Figure 3 *Supply duct dampers. (TRU Open Press; [modified] Angi, 2024)* CC BY-NC-SA (*https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en*)

The air flow in individual rooms can be restricted by dampers in the floor grilles.

Figure 4 *Floor grille with damper. (Skilled Trades BC, 2021)*
Used with permission.

Furnace Types

Regardless of type, all furnaces consist of an air filter, a blower, a heat exchanger/element/coil, various operating and limit controls, and two main air plenums (supply and return) for ductwork connections.

Efficiency Types

As of January 1, 2010, Canadian federal efficiency guidelines have determined that all new installations of residential furnaces must have a minimum annual fuel utilization efficiency (AFUE) of 90%. This means that new gas furnace installations must be of the condensing type. When more heat energy is taken out of the products of combustion to meet this new requirement, the water vapour within those products condenses back into water, which forms carbonic acid when mixed with the carbon dioxide in the flue gases. Depending on the drainage system and its overall dilution capabilities, this fluid may need to be drained directly (Figure 5) into an acid neutralizer.

Older (1980s–1990s) furnaces were considered mid-efficient, due to the design of the heat exchanger. These furnaces were capable of 80–83% efficiency. Very old furnaces (pre–1980) were known as standard efficiency, rarely breaking 78% efficiency.

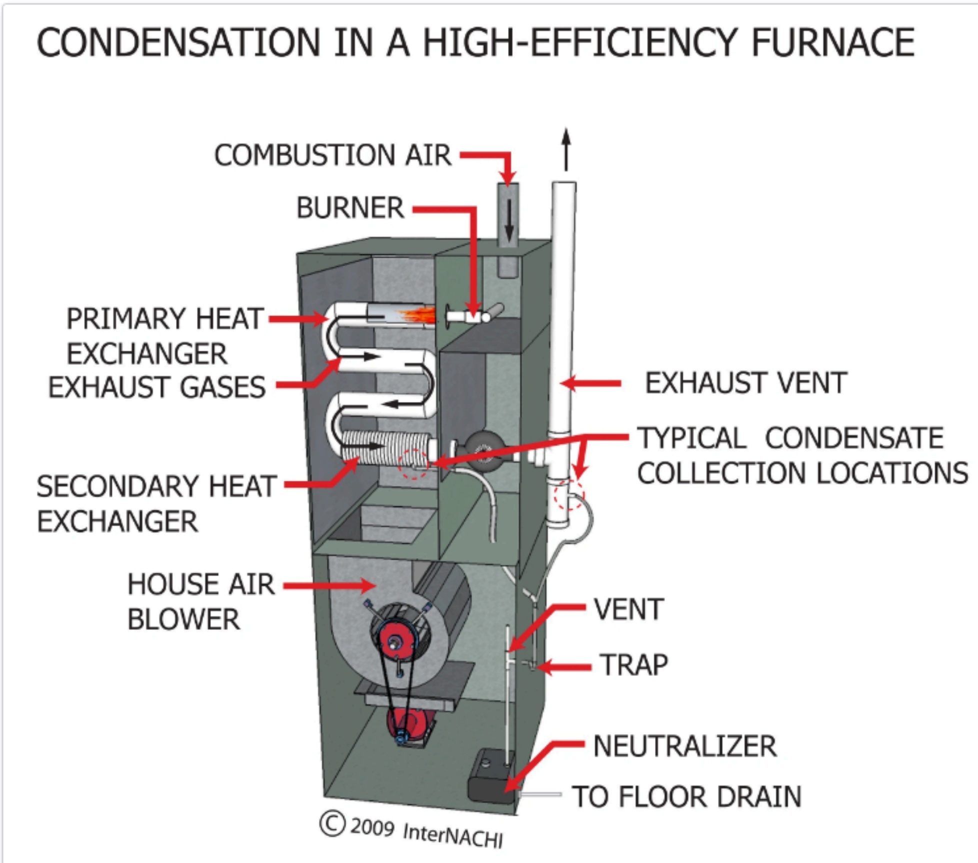

Figure 5 *High efficiency gas furnace with condensate drain going to an acid neutralizer. ©InterNACHI® Used with Permission.*

Gas-fired furnaces are also split into categories based on their vent pressures and efficiencies (flue losses). Mid-efficiency furnaces are known as Category I and vented using metal Type B venting materials, whereas high-efficiency furnaces are Category IV and commonly use pressure sealed plastic Type BH venting materials.

Air Flow Configurations

Because of their in-shot burner orientation, most mid- and high-efficiency furnaces can be installed as upflow (most common for multi-level homes) (Figure 6), downflow (for rancher-style construction with a crawl space) (Figure 7), or horizontal flow (for mounting in a crawl space or attic) (Figure 8). These are known as convertible or multi-position furnaces (Figure 9). A convertible gas furnace may require special vent and drainage modifications to accommodate the various configurations.

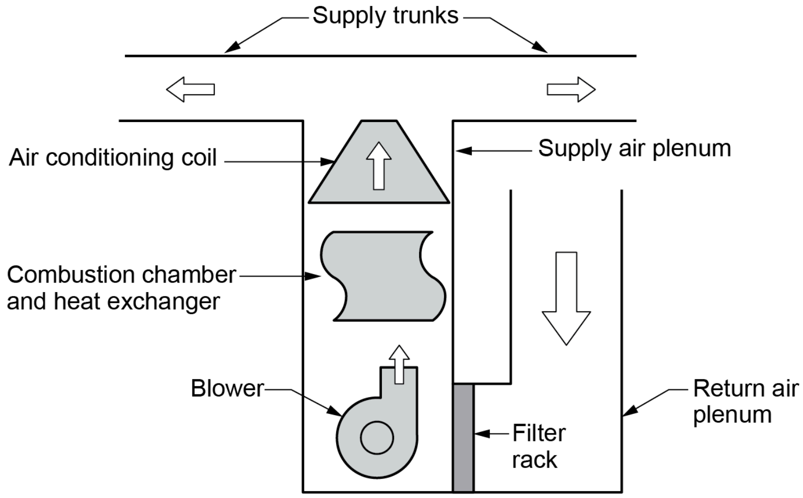

Figure 6 *Upflow furnace. (Skilled Trades BC, 2021) Used with permission.*

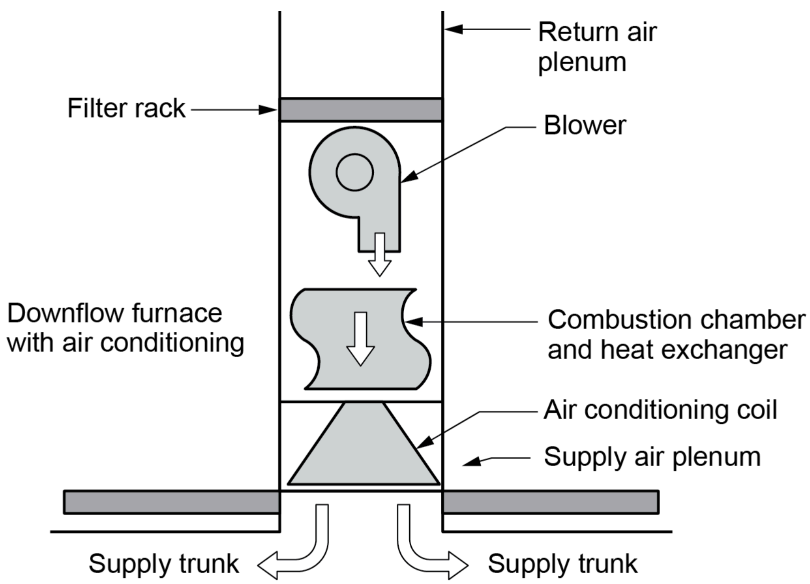

Figure 7 *Downflow furnace. (Skilled Trades BC, 2021) Used with permission.*

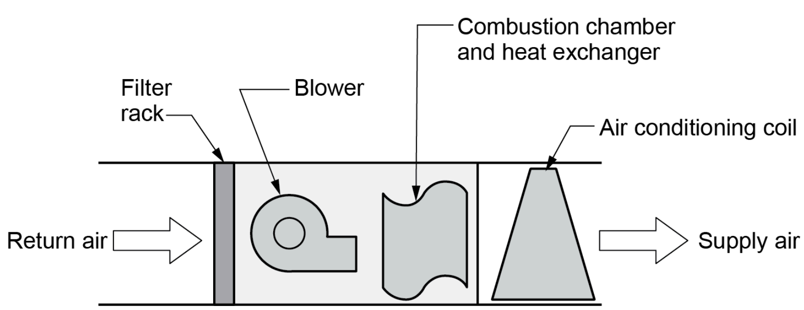

Figure 8 *Horizontal flow furnace. (Skilled Trades BC, 2021) Used with permission.*

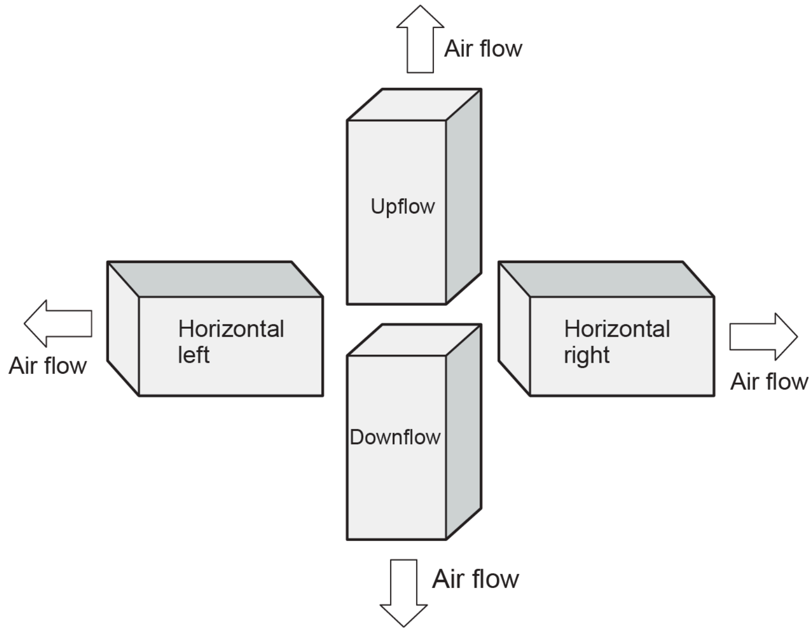

Figure 9 *Convertible furnace positions. (Skilled Trades BC, 2021) Used with permission.*

Air Filters

All forced-air furnaces require air filtration to operate safely and efficiently. Some furnaces are intended for use with specific types of filters, but in many cases, the filter is an add-on component, so the appropriate filter must be chosen.

Airborne particles can include dust created by activities both inside and outside the house, hair and skin flakes from pets and humans, tobacco smoke, spores, bacteria, and viruses. Some filters will easily remove the larger particles, such as visible dust, but smaller particles that can enter the lungs, such as bacteria and viruses, are the most problematic. For these particles, the chosen filter must have the ability to remove such small particles.

The minimum efficiency reporting value (MERV) is a numerical value given to filters to identify their filtering ability. This industry standard operates on a numerical value between one and 16 microns, with higher numbers indicating greater filtering capacity.

High-efficiency particulate arrestance (HEPA) filters, which remove a very high percentage of airborne contaminants, are often specified for various commercial, industrial, and institutional applications.

The tighter the filter media's fabrication, the harder it will be for airflow to pass through it. The blower fan's power and volume capabilities will need to be assessed for compatibility with each filter type.

Filter Types

The three basic types of air filters are media, electrostatic, and electronic.

Media filters (Figure 10) are the least complicated and, therefore, the least costly and most-used type. Made from paper, fibreglass, or cloth, they are positioned in the return air stream, where air is pulled through them toward the blower. They have a hammock, slab, or pleated design; can be reusable or disposable; and are available as low-, medium-, and high-efficiency types.

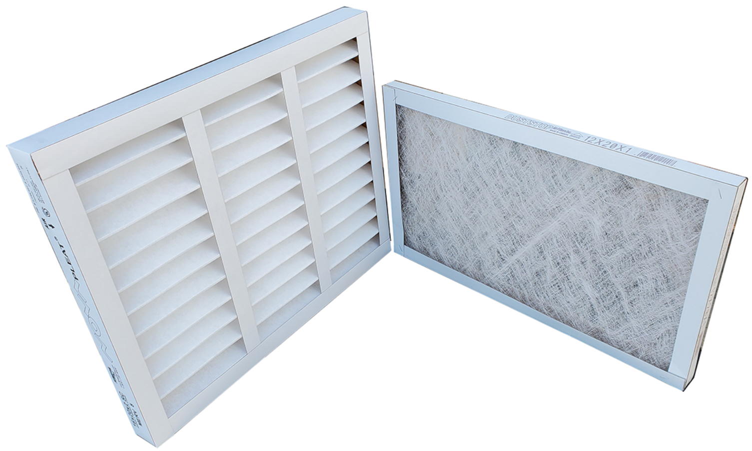

Figure 10 *Media-type filters. (Skilled Trades BC, 2021) Used with permission.*

Electrostatic filters (Figure 11) are media-type filters made from a material that generates a static charge when air flows through it. This static charge attracts and holds more particles to the medium than regular media filters.

Figure 11 *Electrostatic filters. (Skilled Trades BC, 2021) Used with permission.*

Electronic air cleaners (EAC) use an electronic charge to remove and collect particulate from the circulated air (Figure 12). They use an external power source rather than the airflow itself to generate the charge that attracts the particles. A charged plate collects the particles and requires manual cleaning.

Figure 12 *Electronic air cleaners. (Skilled Trades BC, 2021) Used with permission.*

Blowers

The blower is a squirrel-cage-type fan positioned between the filter and the heat exchanger. Air is pulled through the filter and pushed across the heat exchanger into the main supply plenum. Older models were driven by a belt connected by pulleys or sheaves to an alternating current (AC) single-speed electric motor (Figure 13). The speed of the blower could be increased or decreased by altering the position of the belt within an adjustable pulley mounted on the motor's shaft. Blowers can still be found today in appliances, such as rooftop heating and cooling units, which can be built larger to accommodate the extra room needed for the fan and motor.

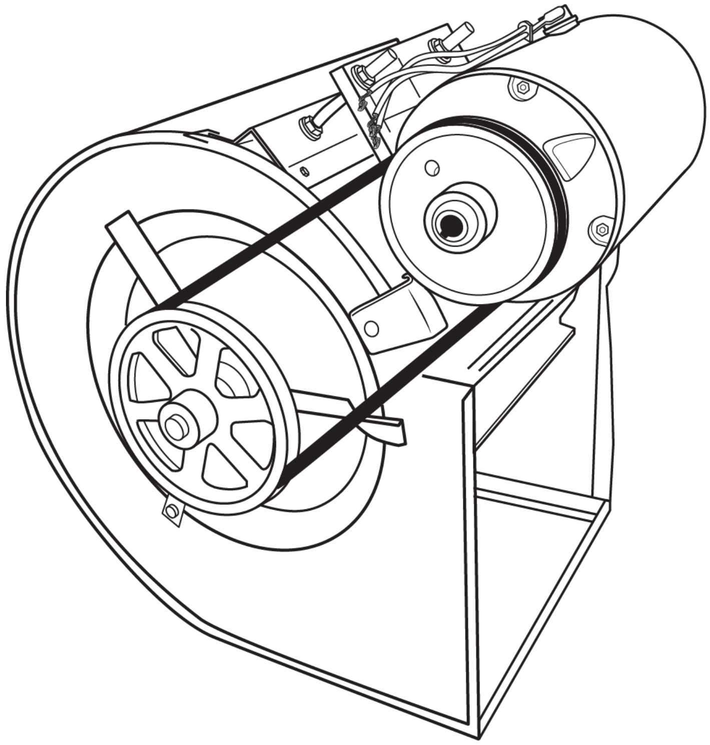

Figure 13 *Belt-driven blower. (Skilled Trades BC, 2021) Used with permission.*

Modern blowers (Figure 14) do not use pulleys and belts. The motor is mounted within the fan housing and connected directly to the fan's drive shaft direct drive. The speed of the fan is adjusted by connecting one of the wires from the motor's speed taps to the power supply.

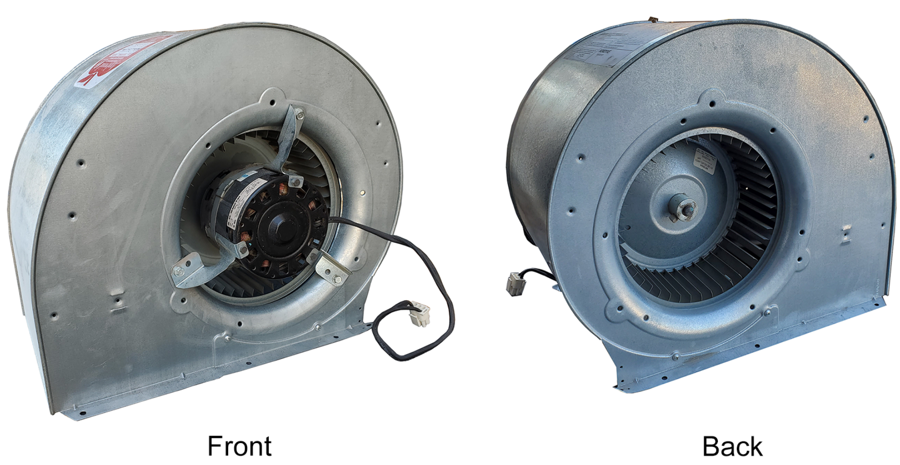

Figure 14 *Direct-drive blower (front and back). (Skilled Trades BC, 2021) Used with permission.*

Some high-efficiency blower models use direct current (DC) direct-drive motors capable of automatically adjusting their speed in relation to the filter's airflow. As the filter starts to collect dust, air flow through it is restricted, and the blower ramps up its speed to maintain the required air flow.

Heat Exchangers

Forced-air furnace energy sources are gas (natural or propane), fuel oil, electricity, heat pump, or hydronic (hot water) coil.

Gas or Fuel Oil Furnace

- Heat is produced by combustion of fuel gas through a burner or oil-type burner located in a combustion chamber.
- A heat exchanger keeps the products of combustion separated from the supply air stream.
- Ignition is provided by an electric spark, standing pilot, or hot surface igniter.
- There is a delay between the burner ignition and blower operation so that cold air is not blown into heating spaces before the heat exchanger has reached temperature.
- High-efficiency gas furnaces have a secondary heat exchanger to absorb as much heat as possible from the products of combustion and, thus, release flue gas condensate that must be drained to a safe location (Figure 15).
- Safety devices ensure that combustion gases and unburned fuel do not accumulate in the event of an ignition or venting failure.

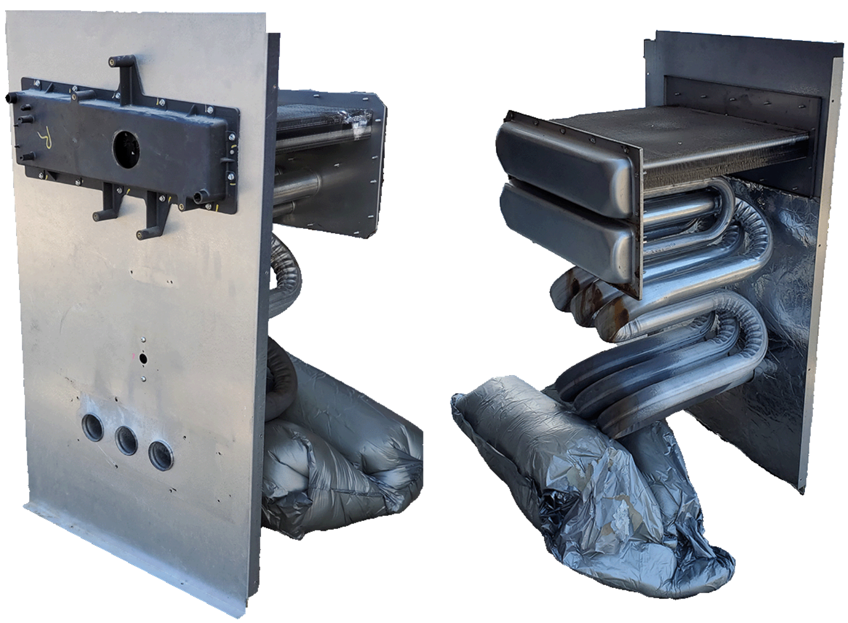

***Figure 15** High-efficiency heat exchanger (front and back). (Adapted from Skilled Trades BC, 2021) Used with permission.*

Electric Furnace

- Heating elements installed in the air stream are used to heat the supply air.
- When the thermostat calls for heat, the blower and electric element(s) come on at the same time.

- When the thermostat is “satisfied,” the blower and element(s) shut off.
- It has no heat exchanger, minimal moving parts, and requires very little maintenance.
- It is usually more expensive to operate than a natural gas furnace.

Heat Pump

- A heat pump extracts heat from the environment, using either the ground or outside air as the source, via the refrigeration cycle.
- It requires less energy than electric heat and is normally more efficient than fossil-fuel-fired furnaces (gas/oil).
- Air-source types may not be suitable for cold climates unless used with a backup (secondary) source of heat. Newer models may still provide heat when installed in temperatures below 0°C (32°F).
- A refrigerant coil is installed in place of the burner/heat exchanger. The system can also be used for cooling in a central air-conditioning system.

Figure 16 *Air source outdoor unit (left) and indoor A-coil (right). (Adapted from Skilled Trades BC, 2021) Used with permission.*

Hydronic Coil

- A hydronic coil combines a hydronic (hot water) heat source with forced-air delivery.
- Heat is produced by the combustion of fuel (natural gas, propane, wood) or electric heating elements in a hot water boiler.
- A heat exchanger, in the form of a hydronic coil, is placed in the air stream of the air handler. Copper is often used in the construction of supply and return manifolds and tube coils.
- Heated water is pumped through the heat exchanger then back to the boiler to be reheated. The air stream picks up the heat from the hot water coil and distributes it through the duct system.
- With a wood-fired boiler, a buffer tank is used between the hydronic coil and the boiler to store the energy. This

enables the wood boiler to fire continuously while loaded with wood and the hot water to circulate intermittently as space heating is required.

Duct Systems

Ducting is normally made of galvanized sheet metal or aluminum. It can be formed into square or rectangular ducts with machines or purchased in two L-shaped pieces and snapped together on site. Round ducts are also available in the same configuration and material and can be purchased in snap-together pieces or continuously formed lengths known as "spiral."

Warm air is moved by the blower through the supply air plenum into the trunk duct and distributed into the branches connected to the supply grilles or registers.

The plenum is the duct that connects directly to the furnace. There is a supply plenum and a return plenum on each forced-air furnace. The air filter is always mounted either inside the blower compartment or onto the return air plenum, where it attaches to the furnace.

If the plenum directs air into a trunk that runs in one direction only, away from the furnace, it is a one-way trunk and branch system (Figure 17). Such a system might result from the furnace being located near one side of a structure. A furnace located near the middle of the structure has two or more trunks running in each direction and is therefore called a two-way trunk and branch system (Figure 18).

Branches are ducts connected to the trunk main and terminating at the boot, which holds the heat grille or register in the floor, wall, or ceiling.

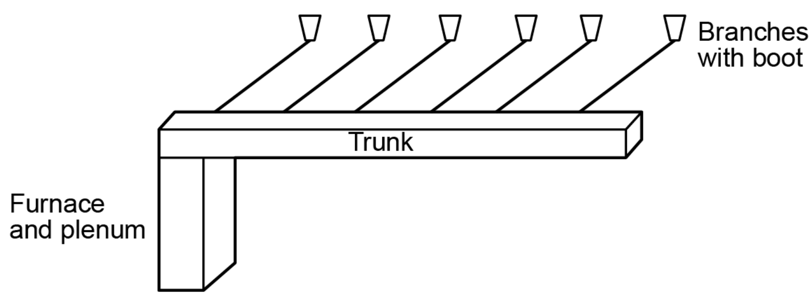

Figure 17 *Trunk and branch (one-way system). (Skilled Trades BC, 2021) Used with permission.*

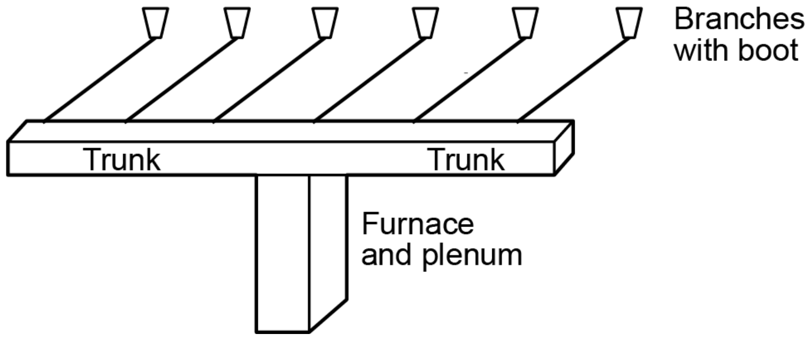

Figure 18 *Trunk and branch (two-way system). (Skilled Trades BC, 2021) Used with permission.*

In addition to the trunk and branch layout, branches can be installed in a spider, radial, or perimeter loop configuration (Figure 19).

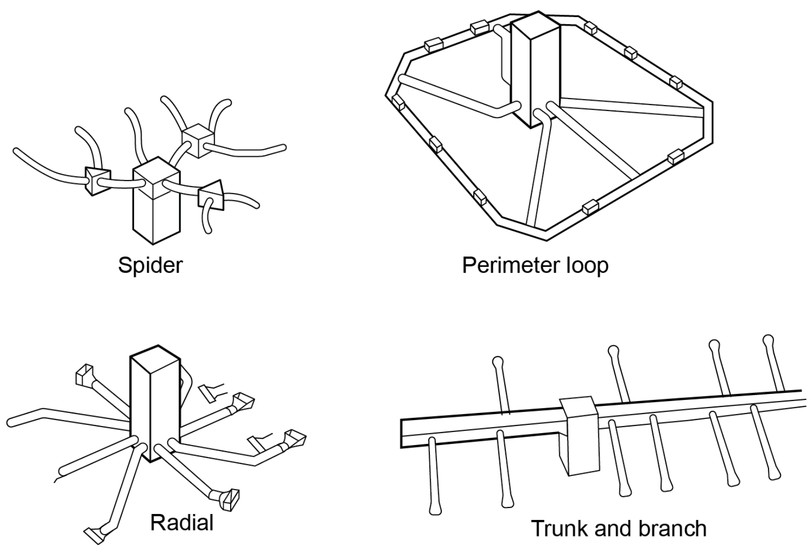

Figure 19 *Duct system configurations. (Skilled Trades BC, 2021) Used with permission.*

A branch that connects to a terminal fitting on an exterior wall will allow outside air to be drawn into the return air system whenever the blower operates. This is installed so that fresh air for the ventilation of the building and health of its occupants can be heated and distributed throughout the building.

Airflow Controls

Most duct systems in residential applications have manually adjusted dampers to control the airflow to the heat registers. The initial commissioning balancing process sets and locks these dampers into place. When the heating system operates, warm air is delivered evenly to all areas of the structure. If a demand for heat exists in selected areas only, a more sophisticated system of control is required, known as "zoning." This involves installing motorized dampers on either the trunk or branches that open or close in response to an electric circuit being energized. For instance, in a two-storey home with a suite in the basement, one dedicated trunk could supply heat to the basement branches only while the other supplies the upstairs branches. A large motorized damper on each trunk would allow someone to control the heat supply to either the upstairs or the basement independently or simultaneously. Motorized dampers are not normally found in residential buildings.

Figure 20 *Motorized zone damper (TRU Open Press) CC BY-NC-SA (https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en)*

Forced-Air Add-On Devices

Outdoor air in the winter can become very dry. Moisture levels are reduced with a drop in temperature. A humidifier maintains indoor relative humidity to around 40%. Moist air helps maintain comfort. Excessively dry air can make occupants feel colder than normal.

Benefits of Humidifiers

- Assists in minimizing the presence of static electricity.
- Helps keep nasal membranes from drying out (dry nasal membranes reduce occupants' susceptibility to fight colds and other airborne viruses).
- Prevents certain building materials from drying out, such as hardwood floors.

There are many types of humidifiers available, with each type introducing water vapour into the supply air stream in various ways. A control called a humidistat measures indoor humidity and activates an atomizing or steam type humidifier installed onto or inside the supply air plenum.

Controls

The main comfort control for a forced-air system is the thermostat. It is mounted on an interior wall, usually central to the floor area on the main living floor. It is installed around 1.5 m (5 ft) above the finished floor level in an area where it will not be exposed to stray heating or cooling effects. Older-style thermostats contain an internal bimetal coil that, when exposed to a change in temperature, rotate and make or break a set of electrical contacts to activate or deactivate a heating system. Newer-style thermostats use thermistors to sense the temperature in the structure. Most thermostats, as well as the other controls on a heating system, operate on a 24-volt AC-control voltage.

Thermostats can be heat-only, heat/cool, analogue, digital, digital/programmable, or Wi-Fi–enabled ("smart"). Programmable thermostats are increasingly popular with forced-air heating due to the air's low thermal mass. This means the temperature settings on a thermostat serving a building heated with forced air can be set to a lower temperature in the evening or anytime the building is unoccupied, then raised quickly during occupied hours. "Smart" thermostats communicate through the customer's Wi-Fi system and can be adjusted remotely for even more control options.

Figure 21 *"Smart," digital-programmable, and non-programmable analogue thermostats. (Adapted from Skilled Trades BC, 2021) Used with permission.*

Other controls found on gas-fired furnaces include:

- High temperature limit switches that open an electrical circuit and shut off the gas valve when it senses excessive temperature inside the heat exchanger.

Figure 22 *High-limit thermal switch. (Adapted from Skilled Trades BC, 2021) Used with permission.*

- Flame rollout switches that open an electrical circuit to shut off the gas supply if the flame rolls off the burners and into the appliance's controls compartment.
- Air pressure switches (Figure 23) that are set to sense designed pressures within the combustion chamber, vent piping, or combustion air intake piping and that open or close electrical contacts when it senses pressures above or below the required designed pressure.

Figure 23 *Pressure switch. (Skilled Trades BC, 2021) Used with permission.*

- Blocked vent safety switches located on the draft hood of older appliances that sense the heat from a blocked venting system above the draft hood and open electrical contacts to shut off the burner.

- Gas pressure regulators that control the pressure of gas supplied to the burner and in the piping that feeds heating equipment.
- A furnace control module that controls the operation of the gas delivery system. Newer modules, called integrated furnace controls, also control the blower.

Self-Test B-1.3: Residential Forced Air Heating and Cooling Systems

Complete Self-Test B-1.3 and check your answers.

If you are using a printed copy, please find Self-Test B-1.3 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=41#h5p-3 (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=41#h5p-3)

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- **Figure 1** Force air furnace media filter installation is by TRU Open Press.
- **Figure 3** Supply duct dampers is by TRU Open Press, modified from original image by Angi (2024) for educational purposes.
- **Figure 5** High efficiency gas furnace with condensate drain going to an acid neutralizer (https://www.nachi.org/gallery/heating/condensation-in-a-high-efficiency-furnace-2) is ©InterNACHI® and is used with Permission.

B-1.4 Hydronic Heating and Cooling Systems

Hydronics is the concept of using water as a vehicle to move thermal energy between two points. Installers must understand that both hydronic heating and cooling involve the transfer of heat. Heating and cooling systems for buildings either add or remove heat from a space to keep its occupants comfortable. In some cases, heating or cooling is used for process purposes, as with refrigerators, freezers, and kilns.

The study of hydronics here will focus on providing an environment within buildings that allows people to be comfortable during their daily activities. This section will concentrate primarily on using hydronics for heating because this practice is widespread and occurs in both residential and commercial environments, whereas hydronic cooling is not as common in homes and residential buildings.

Hydronic Systems

In hydronic heating systems, water can be thought of as the transportation medium for heat. Thermal energy is absorbed by the water at the heat source (most commonly a boiler), carried by the water through the piping, and released into a space by a **heat emitter**. Hydronic cooling systems use the same principle, except the water carried by the piping absorbs unwanted heat from a space, such as a room or zone, and takes it back to the equipment that removes the heat (most commonly a cooling tower and chiller). It then sends this chilled water back to the space again. In many of today's sophisticated building energy systems, the heat absorbed by the chilled water can be used to transfer heat to other parts of the building or to preheat domestic water. This creates greater efficiency within the heating and cooling systems.

Water has many characteristics that make it ideal for heating and cooling. It is nontoxic, non-flammable, and readily available and has one of the highest heat-storage capabilities of any material.

The earliest hydronic heating systems, known as gravity systems, operated on the principle of buoyancy (Figure 1). Water becomes less dense when heated, and this density differential between water in the boiler supply and return mains causes convection currents that carry the hot water out and up through piping to the heat transfer units (HTU). At the HTUs, the water releases its heat and regains density, falling back down through the return piping to the boiler. Because of the absence of electricity and pumps, these systems needed larger diameter piping to create enough circulation to carry heat to the far reaches of a building. With the advent of compact electricity pumps came forced circulation systems to move the water between the heat source and emitters (Figure 1). This resulted in many improvements, such as better control and smaller-diameter piping.

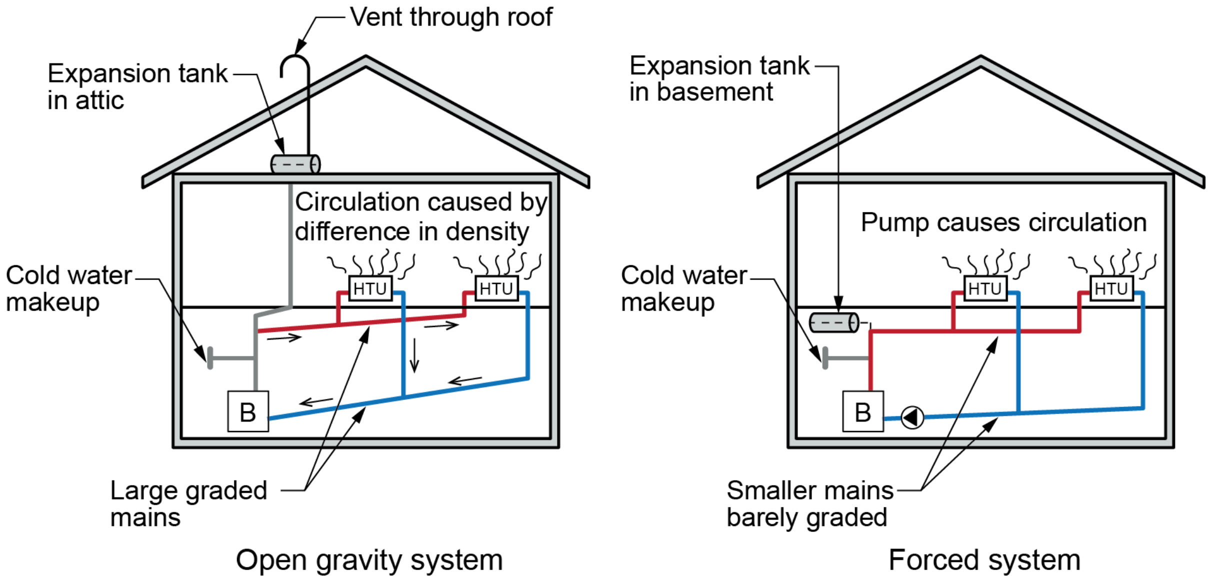

Figure 1 *Water circulation systems. (Skilled Trades BC, 2021) Used with permission.*

Comfort is the Goal

Comfort can best be described as the absence of discomfort, for example, when a person feels neither too hot nor too cold. It is rare that someone will comment on how comfortable a room feels, but they certainly know when they feel uncomfortable. Maintaining comfort is not a matter of supplying heat to the body but of controlling the manner and rate at which the body loses heat.

Heat is a byproduct of our bodies' functions, and a normal adult engaged in light activity generates heat at a rate of approximately 400 British thermal units per hour (BTU/h) or 422 kiloJoules per hour (kJ/hr). Comfort is achieved when the interior environment allows heat to leave the body at the same rate as it is produced. As the activity level increases so does the need for the immediate environment to transfer the extra heat away at the same rate that it is being generated. Failing to do so fast enough will cause the person to feel overheated and uncomfortable. When interior conditions allow heat to leave a person's body at the same rate that it is generated, that person feels comfortable.

In a typical indoor environment, approximately 48% of a person's body heat is released by thermal radiation to colder surfaces (e.g., standing by a window), 30% is released by convection to surrounding air (e.g., sitting in a drafty room), and 22% is released by evaporation from the skin (sweating). A small amount may also be released by conduction from skin or clothing surfaces in contact with cooler objects (e.g., bare feet on a cold floor and also through respiration (breathing out warm air)). Because the human body is affected mostly by radiant heat loss, people feel the effects of proximity to cold surfaces such as windows and supermarket refrigerators and freezers more easily. The greater the temperature differential (ΔT) between body temperature and ambient or surface temperature, the faster the rate of departing body temperature. Sometimes people notice that they feel cold while standing beside cold surfaces when the ambient temperature is actually at the comfortable level of 22°C. This is the reason that radiant heating systems are widely accepted as being the most comfortable of all (Figure 2).

The advantage of heating through radiation is that surfaces in rooms tend to become warmer. This reduces the effect of radiant heat loss from the body and increases comfort. Later sections will cover radiant systems in greater detail.

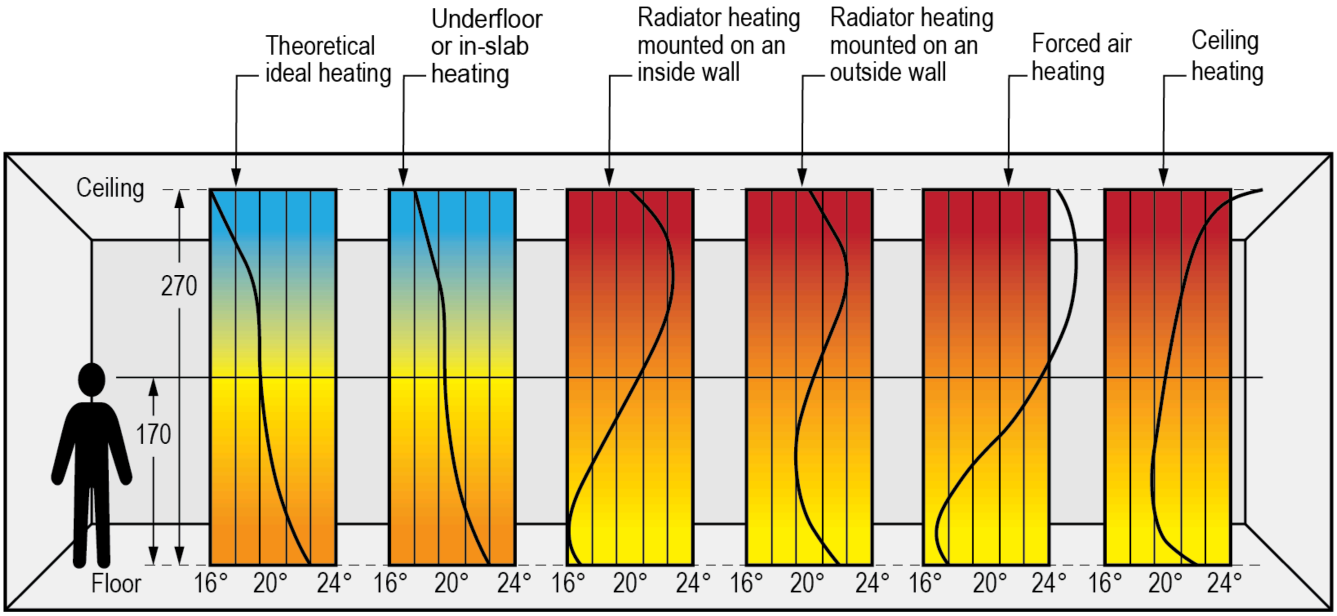

Figure 2 *This graph shows ideal heat and temperature; blue is cold, red is hot. (Skilled Trades BC, 2021) Used with permission.*

Advantages and Disadvantages of Hydronic Heating and Forced-Air Heating

Water has long been known to be a good heat transportation medium, particularly in Europe, where houses and buildings have been heated by water for decades, even centuries.

The practice of using air for heating is a North American development. Houses here do not tend to stay with one family for generations, as is common in Europe. Many studies have indicated that North Americans stay in one house for an average of seven years and, consequently, the extra cost of a hot water heating system over that of a forced warm air system may not be recovered by the time a person sells their house. Short-term economics are at play here, and comfort is collateral damage.

There are many advantages, and some disadvantages, of heating with hot water rather than with forced air.

Main Advantages

- **Energy savings:** many studies have consistently shown that hot-water heating systems use less energy than forced-air heating systems in similar structures.
- **Control:** a hydronic system can have as many areas of control (zones) as the occupants desire. A forced-air system typically has one thermostat location and can only hope to achieve comfort in all areas of a building according to that thermostat's set point.
- **Design flexibility:** hydronic heating offers almost unlimited possibilities to accommodate, such as space heating, domestic water heating, snow melting, and pool heating.
- **Clean and quiet operation:** a hydronic system operating properly is silent, whereas airflow through ducts and outlets generates noise.
- **Fewer germs and contaminants:** hydronic systems do not circulate as much dust and pollen through the air as forced-air systems. Also, people who are ill can be isolated in bedrooms and their germs are not as readily spread

throughout the rest of the building.

- **Less air stratification:** stratification is the tendency of warm air to rise and accumulate at the ceiling, as shown in Figure 2, while cold air falls and gathers at the floor. The heat losses through the walls near the ceiling are much higher with these "bands" of stratification.
- **Non-invasive installation:** a $\frac{3}{4}$ in. copper tube can carry the same amount of heat energy in water out to a house as can an 8 in. by 14 in. rectangular duct carrying heated air. Piping can be hidden by running through floor joists, whereas heating ducts must be installed below the joists, creating unnecessary drops in ceiling height.

Main Disadvantages

- **Installation cost:** when comparing the installation costs between of a hydronic heating system and a forced-air system, the forced-air system is on average less costly to install.
- **Reaction time:** a forced-air system is quicker to respond to temperature demands in a room due to its lower thermal mass than a hydronic system using convectors or radiant panels; of these two, convectors respond more quickly than radiant panels.
- **Heat emitter intrusion:** aside from radiant floor and ceiling panels, the heat emission units or heat transfer units used in hydronic heating tend to interfere with the aesthetics of a room. Radiators and convectors can affect the placement of furniture and drapes, among other things.

The advantages of hot water heating over forced air are many and contribute toward the general acceptance of hydronic heating as being the system of choice.

Self-Test B-1.4: Hydronic Heating and Cooling Systems

Complete Self-Test B-1.4 and check your answers.

If you are using a printed copy, please find Self-Test B-1.4 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

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Self-Test B-1.1: Heat and Heat Transfer

Complete Self-Test B-1.1 and check your answers.

1. Besides conduction and convection, in what way does most heat travel?
    a. Radiation
    b. Insulation
    c. Gravity
    d. Centrifugal force

2. Which one of the following items does heat travel through most quickly?
    a. Conductor
    b. Radiator
    c. Insulator
    d. Convector

3. What kind of heat moves through air without actually heating the air?
    a. Conduction
    b. Convection
    c. Radiation
    d. Insulation

4. What is the gravity circulation of water between a boiler and a heat transfer unit called?
    a. Convection
    b. Conduction
    c. Radiation
    d. Insulation

5. What is circulation in a gravity system caused by?
    a. The boiler being higher than the emitter
    b. The emitters being above the boiler piping
    c. The difference in the water densities in the system
    d. A pump

6. The density of a liquid or gas is usually increased as its temperature increases.
    a. True
    b. False

7. There is a gradual density loss as water is heated.
    a. True

b. False

8. How does water lose heat through the walls of pipe?
    a. Convection
    b. Conduction
    c. Insulation
    d. Radiation

9. By what process is heat transferred between the Sun and Earth?
    a. Convection
    b. Conduction
    c. Insulation
    d. Radiation

10. What is the heat conductivity of air in BTU/hr per ft^2 per °F per inch of thickness?
    a. 320
    b. 12
    c. 4.1
    d. 0.15

11. A BTU is the measurement of what?
    a. Heat's intensity
    b. Heat's quantity
    c. Heat's conductivity
    d. Heat's reactivity

12. A degree Fahrenheit is the measurement of what?
    a. Heat's intensity
    b. Heat's quantity
    c. Heat's conductivity
    d. Heat's reactivity

13. One kilowatt equals how many BTU/h?
    a. 1,000
    b. 2,520
    c. 3,412
    d. 5,214

14. "The quantity of heat required to raise or lower the temperature of one pound of water by one degree Fahrenheit" is a description of what?
    a. One joule

b. One calorie
c. One watt
d. One BTU

Answer Key: Self-Test B-1.1 (#chapter-answer-key-self-test-b-1-1) is on the next page.

Answer Key: Self-Test B-1.1

1. a. Radiation
2. a. Conductor
3. c. Radiation
4. a. Convection
5. c. The difference in the water densities in the system
6. b. False
7. a. True
8. b. Conduction
9. d. Radiation
10. d. 0.15
11. b. Heat's quantity
12. a. Heat's intensity
13. c. 3412
14. d. BTU

Self-Test B-1.2: Low-Pressure Steam Heating Systems

Complete Self-Test B-1.2 and check your answers.

1. What is the maximum steam pressure that a residential steam heating system should operate at?
    a. 2 psig
    b. 15 psig
    c. 30 psig
    d. 100 psig

2. Latent heat rather than steam pressure does the actual heating work in a residential steam heating system.
    a. True
    b. False

3. What is the name of the control that operates the boiler's burner?
    a. Thermostat
    b. Pressuretrol
    c. Boiler reset
    d. Operating aquastat

4. What is the name of the horizontal steam pipe that joins together the boiler outlets?
    a. Header
    b. Equalizer
    c. Supply main
    d. Hartford loop

5. What is the name of the vertical pipe that balances the pressure between the supply and return side of the boiler?
    a. Riser
    b. Header
    c. Equalizer
    d. Supply main

6. What is the name of the type of system in which steam and condensate travel in opposite directions in the steam main piping?
    a. Two pipe
    b. Wet return
    c. Counterflow
    d. Parallel flow

7. On a gravity return two-pipe steam heating system, what is the minimum height required between the centre of

the gauge glass and the bottom of the lowest steam per psi of boiler pressure?

a. 10 cm
b. 0.433 ft
c. 30 in.
d. 2.31 in.

8. How does the boiler-feed pump activate (not condensate pump)?

a. The pump is activated by the boiler pressuretrol.
b. The pump is activated by a reverse-acting aquastat.
c. A float switch turns the pump on when water level inside the boiler drops.
d. A float switch turns the pump on when water level inside the receiver rises.

Answer Key: Self-Test B-1.2 (#chapter-answer-key-self-test-b-1-2) is on the next page.

Answer Key: Self-Test B-1.2

1. a. 2 psig
2. a. True
3. b. Pressuretrol
4. a. Header
5. c. Equalizer
6. c. Counterflow
7. c. 30 inches
8. c. A float switch turns the pump on when water level inside the boiler drops.

Self-Test B-1.3 Residential Forced Air Heating and Cooling Systems

Complete Self-Test B-1.3 and check your answers.

1. What is the most common reason that forced-air heating systems are installed rather than electric baseboard or hydronic?
    a. The least costly to install.
    b. Filters the air being heated.
    c. Provides the most comfort.
    d. Operates without any noise.

2. What is the term for when the airflow through the system is adjusted in an attempt to deliver an even heat throughout the building?
    a. Air throttling
    b. Equalization
    c. Balancing
    d. Evening out

3. What is another term for airflow regulators?
    a. Valves
    b. Regulators
    c. Air stops
    d. Dampers

4. What is the current minimum required efficiency for new furnaces?
    a. 100%
    b. 90%
    c. 80%
    d. 78%

5. New furnace installations must be of which type?
    a. Evaporating
    b. Condensing
    c. Convecting
    d. Conducting

6. What is produced when carbon dioxide is allowed to mix with water in the flue of a gas-fired appliance?
    a. Carbon black
    b. Carbohydrates

c. Carbonic acid
d. Carbon tetrachloride

7. What category do high-efficiency furnaces fall under?
    a. I
    b. II
    c. III
    d. IV

8. What is the term for the style of burners used by mid- and high-efficiency furnaces?
    a. In-shot
    b. Up-shot
    c. Side-shot
    d. Buck-shot

9. What type of forced-air furnace would be used in a rancher-style house where the furnace sits on the main floor and the warm air ductwork is below the floor in the crawl space
    a. Up flow
    b. Top flow
    c. Down flow
    d. Horizontal flow

10. Which one of the following is not a type of furnace filter?
    a. Media
    b. Electronic
    c. Electrostatic
    d. Electromagnetic

11. Which one of the filters below generates a static charge when air flows through it?
    a. Media
    b. Electronic
    c. Electrostatic
    d. Electromagnetic

12. Where is the furnace blower located?
    a. Between the filter and heat exchanger
    b. Between the heat exchanger and the supply plenum
    c. Upstream of the return air plenum connection to the furnace
    d. Downstream of the supply air connection to the heat exchanger

13. How do you adjust the speeds of a belt-driven blower?

a. Plug in different wires from speed taps on the motor
b. Adjust a pulley attached to the blower wheel
c. Adjust a pulley attached to the motor
d. Replace the pulley on the blower

14. Which one of the following would not contain a heat exchanger of some variety?
    a. Gas furnace
    b. Oil furnace
    c. Heat pump
    d. Electric furnace

15. Which one of the following gains its heat by extracting it from the ground or outside air and transferring it to a refrigerant coil?
    a. Heat pump
    b. Gas furnace
    c. Hydronic coil
    d. Fuel oil furnace

16. What is the sequence of heated airflow in a trunk and branch duct system?
    a. Trunk, plenum, register, branch
    b. Plenum, trunk, branch, register
    c. Branch, plenum, trunk, register
    d. Register, plenum, trunk, branch

17. If zoning is desired in a forced-air system, what components must be installed?
    a. Heat exchangers
    b. Electronic air cleaners
    c. Motorized automatic dampers
    d. Condensers and evaporators

18. What is the main comfort control for a forced-air heating system?
    a. Thermostat
    b. High-limit switch
    c. Direct-drive motor
    d. Motorized damper

19. What component oversees the operation of the entire furnace and is found on most newer furnaces?
    a. Gas pressure regulator
    b. Blocked vent safety switch
    c. Motorized automatic damper
    d. Integrated furnace control

Answer Key: Self-Test B-1.3 (#chapter-answer-key-self-test-b-1-3) is on the next page.

Answer Key: Self-Test B-1.3

1. a. The least costly to install.
2. c. Balancing
3. d. Dampers
4. b. 90%
5. b. Condensing
6. c. Carbonic acid
7. d. IV
8. a. In-shot
9. c. Down flow
10. d. Electromagnetic
11. c. Electrostatic
12. a. Between the filter and heat exchanger
13. c. Adjust a pulley attached to the motor
14. d. Electric furnace
15. a. Heat pump
16. b. Plenum, trunk, branch, register
17. c. Motorized automatic dampers
18. a. Thermostat
19. d. Integrated furnace control

Self-Test B-1.4 Hydronic Heating and Cooling Systems

Complete Self-Test B-1.4 and check your answers.

1. Why is water a good medium for transporting thermal energy?
    a. It can exist in all three states.
    b. It can only exist as a liquid.
    c. It has a low heat-storage ability.
    d. It has a high heat-storage ability.

2. With the ideal heating or cooling system, the occupants would not be conscious of either warm or cold sensations.
    a. True
    b. False

3. The purpose of a building's heating system is to raise the temperature of the building.
    a. True
    b. False

4. What is the best definition of "comfort"?
    a. The absence of discomfort
    b. When your feet are warm
    c. When your face is cool
    d. It is too vague to define.

5. Approximately how many British thermal units (BTU) will an adult generate every hour through normal indoor activity?
    a. 200
    b. 400
    c. 600
    d. 1,000

6. What are the three main ways that a person loses heat?
    a. Convection, conduction, and respiration
    b. Conduction, respiration, and perspiration
    c. Radiation, convection, and evaporation
    d. Radiation, perspiration, and respiration

7. Where was the expansion tank located in the old gravity hot water heating systems?

a. In the basement
b. In the attic
c. Below the boiler
d. Beside the boiler

8. What addition to hydronic systems, brought about by the supply of electricity, allowed the use of smaller piping than that used in gravity systems?
    a. Copper tube
    b. Natural gas
    c. City water
    d. Pumps

9. Approximately what percentage of a person's heat is lost through convection?
    a. 22%
    b. 30%
    c. 48%
    d. 55%

10. A $\frac{3}{4}$ in. copper pipe can carry as much heat out into the building as what size hot air duct?
    a. 3 in. round
    b. 6 in. by 6 in.
    c. 8 in. by 14 in.
    d. 16 in. round

11. What is the term given to the bands of temperature in a room caused by warm air rising and collecting at the ceiling and cold air falling to the floor?
    a. Stratification
    b. Ramification
    c. Collection
    d. Conduction

12. What feature of a forced-air system allows it to have a quicker response time than a hydronic heating system?
    a. High-velocity airflow
    b. High thermal mass
    c. Low-velocity airflow
    d. Low thermal mass

13. What is an area of control known as?
    a. Zone
    b. Pass
    c. Section

d. Wing

Answer Key: Self-Test B-1.4 (#chapter-answer-key-self-test-b-1-4) is on the next page.

Answer Key: Self-Test B-1.4

1. d. It has a high heat storage ability
2. a. True
3. b. False
4. a. The absence of discomfort.
5. b. 400
6. c. Radiation, convection, and evaporation
7. b. In the attic
8. d. Pumps
9. b. 30
10. c. 8 in. by 14 in.
11. a. Stratification
12. d. Low thermal mass
13. a. Zone

B-2 HYDRONIC HEATING AND COOLING GENERATING EQUIPMENT

Plumber Apprenticeship Program – Level 2

Boiler with piping. (TRU Open Press) CC BY-NC-SA (https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en)

B-2 Hydronic Heating and Cooling Generating Equipment Introduction

In this section, you will look at the range of heating and cooling sources and the different aspects of installing heating and cooling sources.

Learning Objectives

After completing the chapters in this section, you should be able to:

- Describe a variety of heating and cooling equipment, including different types of boilers, chillers, heat pumps, and solar energy sources.
- Identify installation considerations for hydronic heating and cooling systems.

Terminology

The following terms will be used throughout this section. A complete list of terms for this section can be found in the **Glossary**.

- **aquastat:** A device used in heating systems to control the temperature of the water. It works like a thermostat but specifically for water, turning the boiler on or off to keep the water at the desired temperature. (Section B-2.1)
- **authority having jurisdiction (AHJ):** An organization or person responsible for enforcing safety and building codes. They make sure that buildings and structures follow the law and safety standards, such as proper electrical wiring and fire safety measures. (Section B-2.2)
- **backflow preventer:** A device installed in plumbing systems to prevent water from flowing backward into the potable water supply. (Section B-2.2)
- **dedicated branch circuit:** An electrical circuit that supplies power to only one specific piece of equipment or appliance, without sharing the circuit with other devices. (Section B-2.2)
- **floor drain:** A plumbing fixture installed in the floor of a building, typically found in areas like basements, bathrooms, or utility rooms. Its purpose is to remove excess water and prevent flooding by directing water into the building's drainage system. (Section B-2.1)
- **header:** Boilers, depending upon their size, have one or more outlet tappings. The vertical steam piping from the tapped outlet joins a horizontal pipe called a header. The steam supply mains are connected to this header. If the boiler has more than one outlet, it is important to remember to pipe the headers with swing joints. This will help alleviate any stress on the boiler when the header heats up and expands.

(Section B-2.1; Section B-4.2)

- **housekeeping pad:** A raised concrete platform on which mechanical equipment, such as a boiler, is mounted. (Section B-2.2)
- **input (boilers):** the amount of energy the boiler consumes in order to produce heat. (Section B-2.1)
- **low-water cut-off:** The job of the low-water cut-off is to shut off the burner should the water level fall to an unsafe level. The boiler manufacturer determines this level, but it is usually within one-half inch of the bottom of the gauge glass. (Section B-2.1)
- **output (boilers):** The amount of energy that is actually transferred to the medium being heated (water, heating fluid, glycol, etc.). (Section B-2.1)
- **passive (solar water heating) systems:** Solar water heating systems that move water or heat-transfer fluid without pumps. There are two types of passive systems: Integral collector storage (ICS) and thermosiphon systems. (Section B-2.1)
- **potable water system:** A water supply system that provides water safe for drinking and other domestic uses, free from harmful contaminants. (Section B-2.2)
- **push nipples:** Small connectors used in boilers and heating systems to join sections of piping together securely. They allow for easy assembly and disassembly when maintaining or repairing the system. (Section B-2.1)
- **thermosiphon systems**: This type of passive solar watering heating system relies on convection created between the fluids in the tank and in the collector. The fluid in the collector becomes less dense and rises into the tank above, while the denser fluid in the bottom of the tank falls through piping into the bottom of the collector to be reheated. The fluid to be heated is circulated through a separate path within the tank (heat exchanger) where it absorbs the heat created and returns to the building for use. (Section B-2.1)
- **tridicator:** A device that measures and displays three different things at once: pressure, temperature, and altitude (or level) of a liquid in a system. It's commonly used in heating systems to monitor these conditions and ensure everything is working properly. (Section B-2.1)
- **waste heat (or waste energy):** Energy that is produced but not used efficiently, often escaping as heat during processes like running machines or producing electricity. Instead of being used, this energy is usually lost to the environment. (Section B-2.1)

B-2.1 Heating and Cooling Sources

The heating or cooling source can be considered the heart of the operation. This is where the heating or cooling is generated. The heat energy is transported throughout the building through a piping distribution system and finally released by heat emitters. There are many different types of heating and cooling sources, and the use of any particular type usually depends on the application. Some examples include:

- Boilers
  - Conventional gas- and oil-fired boilers and condensing gas-fired boilers
  - Electric resistance boilers
  - Wood-fired boilers
- Solar energy heating
- Chillers
- Heat pumps
- Heat exchangers

Boilers

A boiler can be defined as a closed vessel that heats water or other fluid. This heated fluid is then distributed to the rest of the system through piping networks.

In North America, gas- and oil-fired boilers are currently used in the majority of residential and light commercial hydronic systems. Until recently, conventional (non-condensing) boilers were the most common, but as technology advances and laws are passed requiring boilers to be more efficient, condensing boilers are becoming more widely adopted.

Electrically-powered heat sources, such as electric boilers and hydronic heat pumps, and sources relying on renewable energy have not yet gained a market share comparable to fossil fuel boilers. With the increasing movement to “go green,” however, that will undoubtedly change in the future.

Boilers fall into two broad categories based on temperature and pressure:

- **Low-temperature boilers:** have a maximum temperature of 120°C (250°F) and a maximum pressure of 1,100 kPa (160 psig), except for cast-iron boilers, which have a maximum pressure of 207 kPa (30 psig).
- **High-temperature boilers:** are any boilers exceeding the above low temperatures or pressures.

Types of Boilers

The two types of boilers are hot water and steam.

Boilers can be further classified in various ways, the most common of which are:

- Heating method (fire tube or water tube)

- Material used in construction
- High mass or low mass
- Non-condensing or condensing
- High-pressure and low-pressure

Hot-Water or Steam Boilers

Boilers are pressure vessels that produce either hot water or steam. Some boilers can be used for both purposes. Hot water boilers are completely filled with water and require a circulator to move the water around the system. Steam boilers are only partially filled with water to allow steam to build. Steam boiler systems do not need pumps for circulation, but pumps are often installed to return condensed steam (condensate) to the boiler.

A boiler used to produce hot water has different accessories mounted on and around it than one used to produce steam. For instance, a steam boiler has a sight tube or “gauge glass” that visually indicates the water level within the boiler. A hot water boiler does not have these features.

Hot water boilers with over 400,000 BTU/h of input and all steam boilers, regardless of input, have a **low-water cut-off** mounted near the sight tube. A low-pressure steam boiler’s burner fires to maintain an operating pressure of 105 kPa (15 psig) or less, which is evident on a pressure gauge. A hot water boiler fires in response to its operating temperature, displayed on a thermometer or a **tridicator**.

Hot-Water Boilers

Hot-water boilers can be classified by:

- Pressure (low or high)
- Temperature (low or high)
- Materials of construction (cast iron, copper, or steel)
- Mass (low or high)
- What is carried in its tubing (fire tube or water tube)

Boilers for heating hot water may have to withstand very high pressures or heads due to the height of the water in the distribution system above them, which can often be as high as 1,120 kPa (160 psig). These would typically be steel-tube boilers, whereas cast-iron boilers normally operate at pressures not exceeding 210 kPa (30 psig) due to their brittleness and large surface area in contact with the pressurized water.

High-temperature water, defined as exceeding 121°C (250°F), is not normally used for hot-water heating because it requires greater pressure to maintain its liquid state. Hot water boilers normally operate at average temperatures of 82°C (180°F) to stay below water’s atmospheric boiling point. Hot-water boilers are known as “low thermal mass” if they contain very little water and “high thermal mass” if they have a large water content.

Hot-water boilers use an **aquastat** to control the burner. An aquastat is a switch that reacts to the temperature of water, which opens to de-energize the burner circuit when the water reaches its operating temperature. The system pressure is set and maintained by a pressure reducing valve on the boiler’s inlet water makeup, and the pressure setting depends on the height of the system. This section will discuss boiler construction later on.

Steam Boilers

In steam boilers, water must boil to produce steam. Steam boilers may be made of cast iron or steel tube. Steel-tube boilers may be fire-tube or water-tube.

Steam boilers are categorized as low-pressure or high-pressure. The production of steam increases pressure. The American Society of Mechanical Engineers's (ASME) regulations require that steam for heating does not exceed 105 kPa (15 psig) of pressure. In fact, most steam systems operate between 0.5 and 2 psig of steam pressure. Therefore, all steam boilers for heating systems are low-pressure boilers. Water boils at 121°C (250°F) at 105 kPa (15 psig) of pressure. To keep steam boilers at or below the specified maximum pressure, a pressure switch, rather than an aquastat, is used to control the boiler burner.

Heating Methods

Boilers heat water by using one of three methods:

- **Fire-tube boiler**: heated flue gases travel through tubes that are surrounded by the water in the boiler.
- **Water-tube boiler:** water travels through tubes that are surrounded by the hot flue gases within the fire chamber.
- **Cast-iron sectional boiler**: water is contained in tanks called sections, with hot flue gases passing around the sections.

Fire-Tube Boilers

Fire-tube boilers (Figure 1) are made of steel tube and can produce hot water and steam equally well. They can be low-pressure or high-pressure, but high-pressure fire-tube boilers are rare.

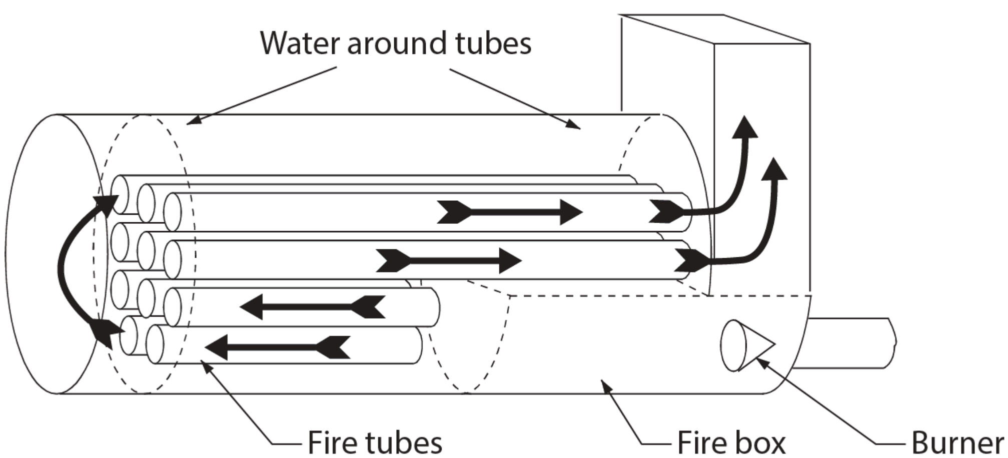

Figure 1 *Fire-tube boiler. (Skilled Trades BC, 2021) Used with permission.*

A fire-tube boiler consists of a water chamber that contains a number of tubes, called fire-tubes, that carry heated flue gases. Fire-tubes form horizontal passages through the water chamber and are vented into the atmosphere. The arrows in Figure 1 show the direction of movement of the heated flue gases through the fire tubes.

The firebox contains a burner and a flame. The firebox and the lowest level of fire tubes together are called the fire chamber. Flame and hot gases from the firebox travel through the fire tubes and heat the surrounding water by conduction. Due to the large surface area of tube in contact with the water, a high percentage of heat is transferred by conduction through the tube walls to the water.

Fire tubes contain baffles to guide the hot flue gases through the fire tubes and help spread the heat evenly throughout the tubes. Some of these baffles are visible when opening the access door at the end of the boiler to inspect the boiler's condition or remove soot (Figure 2).

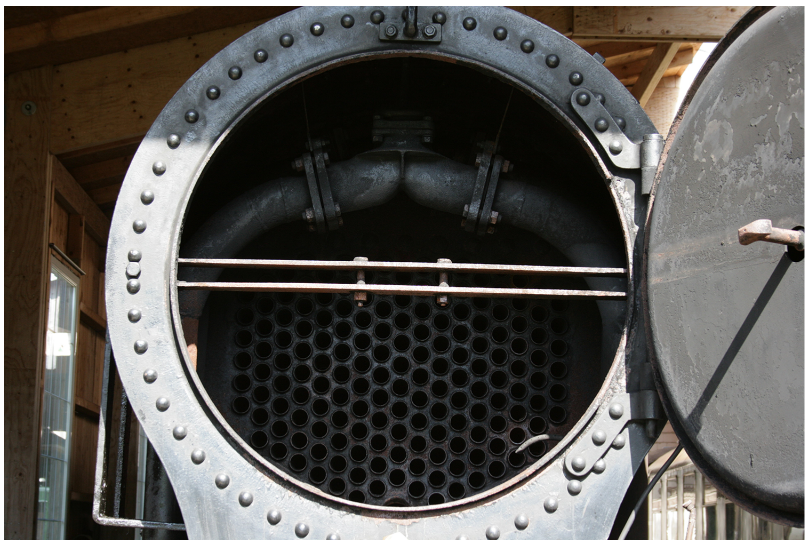

Figure 2 *Outdoor boiler with baffles visible. (Frank Vincentz/ Wikimedia Commons) CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/deed.en)*

The path that the heated flue gases take through the length of the boiler depends on the layout of the fire tubes. Fire-tube boilers are identified by the number of "passes" that the heated gases make. For example, a three-pass boiler (Figure 3) has the heated flue gases passing through the firebox once and through the water chamber twice. Two-, three-, and four-pass boilers are common. The "Scotch," or "Scotch marine," boiler (Figure 4) is a large, two-pass fire-tube boiler.

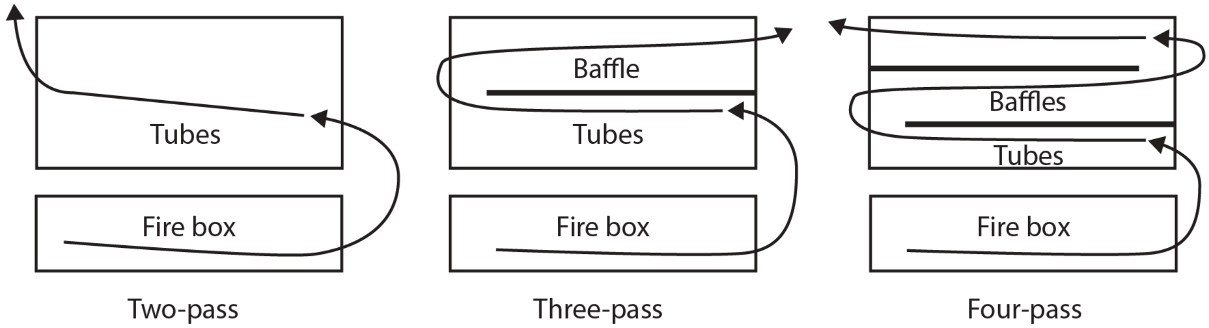

Figure 3 *Two-, three-, and four-pass boilers. (Skilled Trades BC, 2021) Used with permission.*

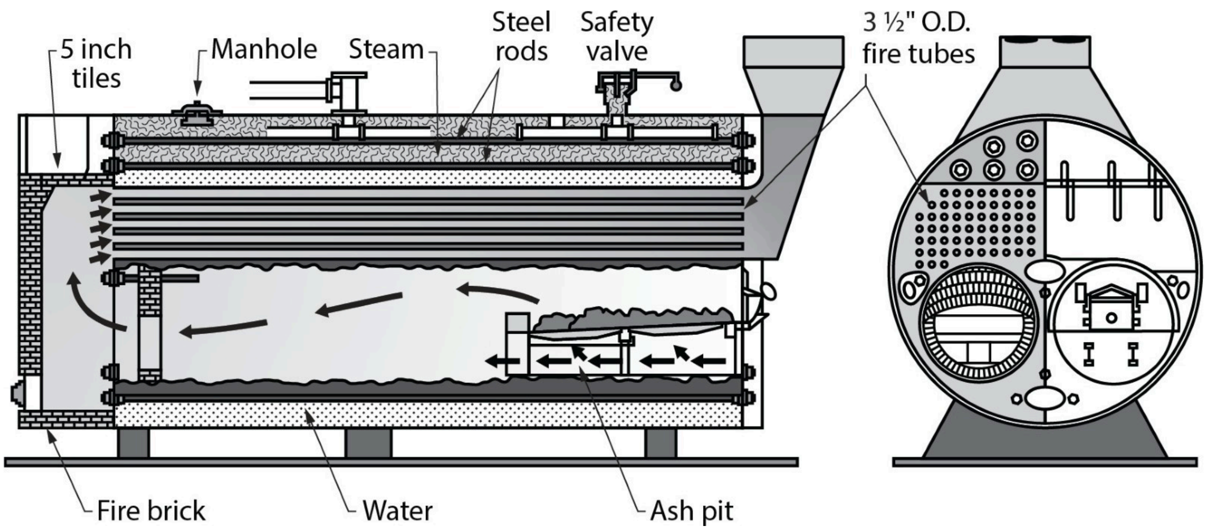

Figure 4 *Scotch marine two-pass fire-tube boiler. (Skilled Trades BC, 2021) Used with permission.*

Water-Tube Boilers

Steel water-tube boilers (Figure 5) can produce both hot water and steam and can be low-pressure or high-pressure. A steel water-tube steam boiler consists of a system of nearly vertical pipe exposed to heated flue gases in a fire chamber. The water tubes are connected to a cylindrical steam drum at the top and a feedwater drum at the bottom.

In large-scale applications, water-tube boilers are considered safer than fire-tube boilers. If a single water tube should leak during the boiler's operation, the only water immediately affected is from that single water tube. If a fire-tube boiler should leak during operation, the entire water mass will be affected, sometimes with cataclysmic results.

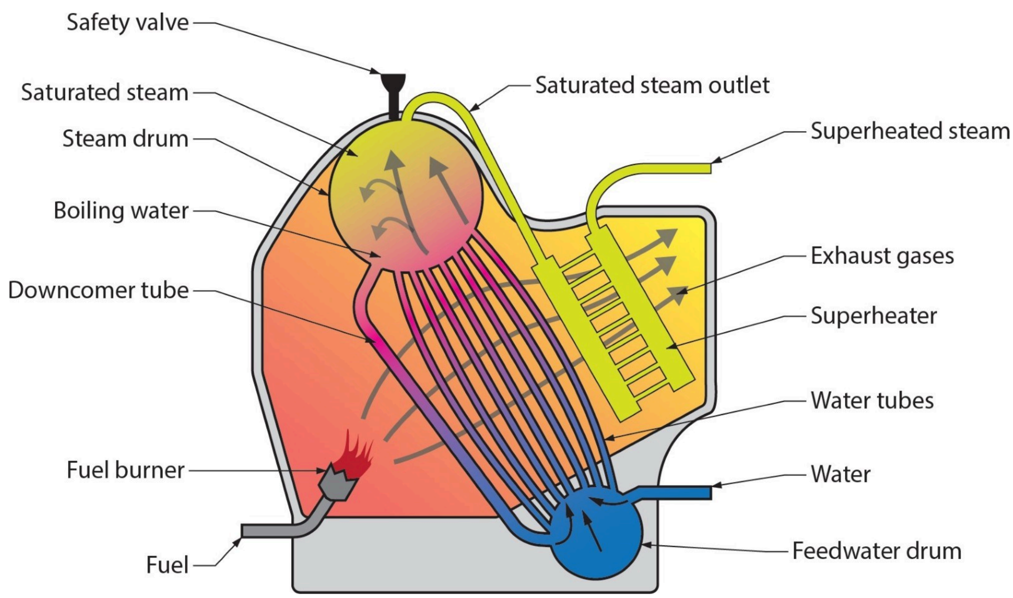

Figure 5 *Water-tube boiler with feedwater piped into feedwater drum. (Skilled Trades BC, 2021; adapted original by Jooja/ Wikimedia Commons) CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0/deed.en)*

Steel water-tube boilers are well suited for producing steam in great volumes and at high pressures and are normally used for power or process applications. Pipe arrangements inside many small low-pressure water and steam boilers are quite similar to the internal configurations of water-tube boilers. Water-tube boilers may be constructed of steel or copper tube. Copper water-tube boilers typically have fins attached to them to greatly increase their surface area, which increases heat transfer. These boilers can also be used to directly heat domestic water because of their high corrosion resistance.

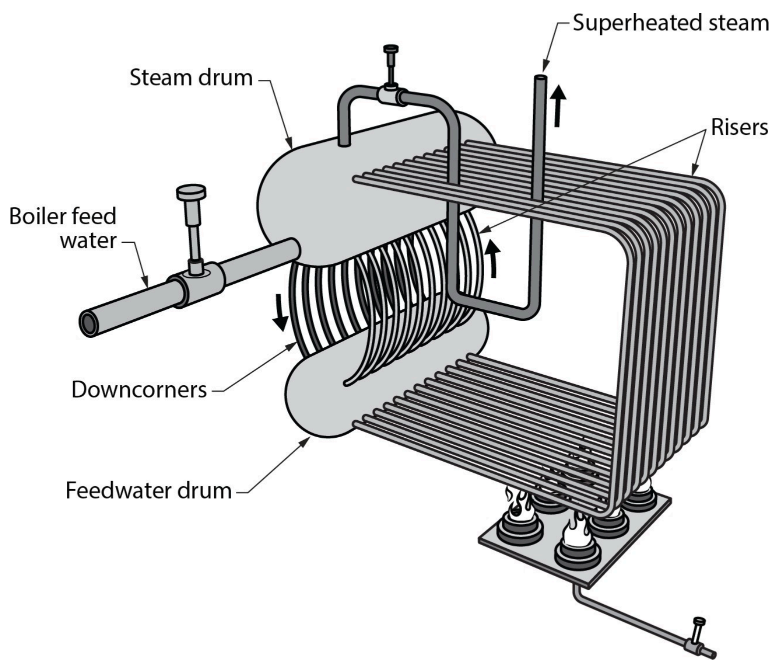

Figure 6 *Large water-tube boiler with feedwater into steam drum. (Skilled Trades BC, 2021) Used with permission.*

Cast-Iron Sectional Boilers

Cast-iron boilers can be used to produce hot water or steam and are classed as low-pressure boilers. Cast-iron boilers for hot water heating can be identified by the letter “H” on their rating plate.

A cast-iron boiler has a number of chambers, known as sections, that fit together in a sandwich pattern (Figure 7). Each section consists of a grid of water tubes. Small fins and a **header** on each end of the tubes allow the water to be routed from one section to the next. As the hot exhaust from the burner passes through the grids, it heats the water in the tubes.

Push nipples connect the sections together and seal the water passages between them. The sections are held together with tie rods that pull the sections together. This makes it possible to replace cracked sections without needing to replace the entire boiler. This sectional design also enables the manufacturer to supply a range of boiler sizes (outputs) for a particular model by varying the number of sections.

The amount of metal in them makes cast-iron boilers very heavy. Even a small residential boiler can weigh 130 kg to 180 kg (300 lb to 400 lb), and such boilers typically contain 40 L to 64 L (10 gal to 16 gal) of water. Cast-iron boilers are classified as high mass boilers due to their large water volume.

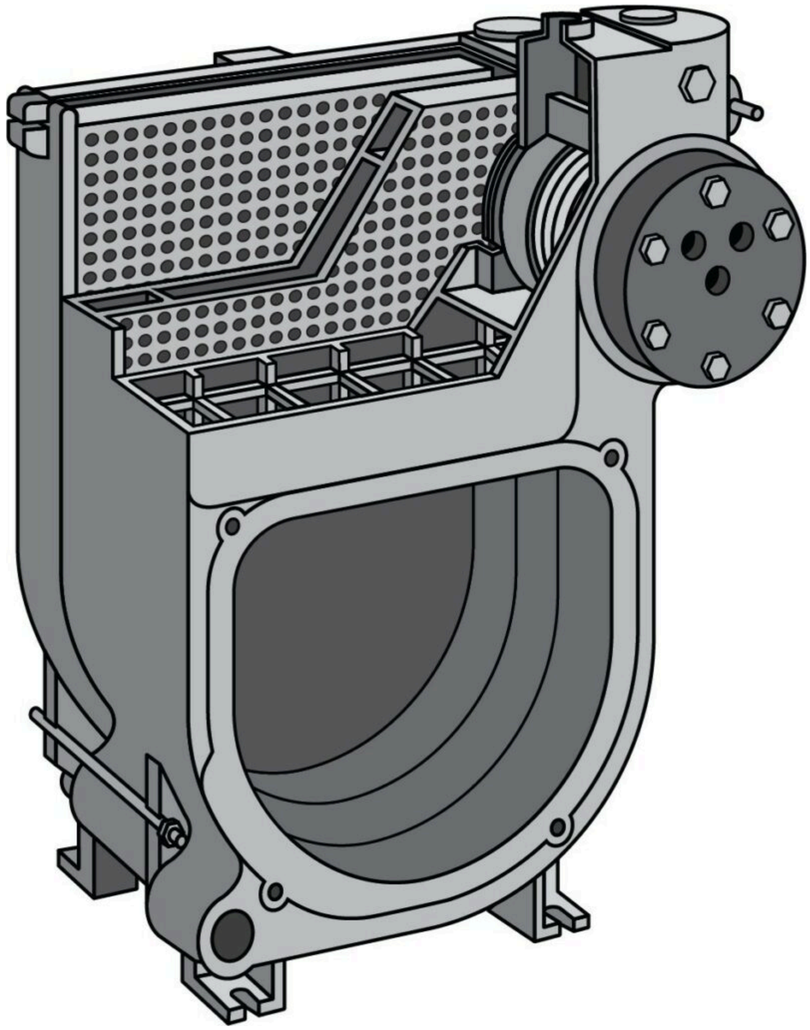

Figure 7 *Cast-iron sectional boiler cutaway. (Skilled Trades BC, 2021) Used with permission.*

Boiler Materials

Boilers can be made from a variety of metals, but the three most common are steel, copper, and cast iron. Water-tube boilers are either copper water-tube or steel water-tube. Fire-tube boilers are generally steel tube, while cast iron is only used for sectional boilers.

Stainless steel's resistance to corrosion makes it ideal for use in condensing boilers. It was rarely used as a construction material for non-condensing boilers due to its cost, but with the trend these days leaning toward high-efficiency condensing boilers, its use is rapidly increasing.

High Thermal Mass Boiler vs. Low Thermal Mass Boiler

Traditional large boilers are classified as high mass boilers. They are made from heavy steel or cast iron and outfitted with large-diameter pipes that hold large volumes of water. These two facts combined mean that high mass boilers are large, weigh a lot, and take a long time to heat up; however, they also hold a lot of heat and retain it for a long period of time.

By comparison, low mass boilers hold far less water. They are generally constructed of steel, copper, or stainless steel. The low volume of water means that low mass boilers can react more quickly to different situations and are generally more efficient than high mass boilers. Another point to be aware of is that water must always be flowing through a low mass boiler while the burner is firing. If water is not flowing, the boiler will quickly overshoot its operating and high-limit setpoints, and the water within the tubing will boil, causing noise and stress on the boiler and much anxiety for people around it.

Non-Condensing Boilers

Non-condensing (conventional) boilers (Figure 8) have traditionally been the mainstay of the hydronics industry, but this has changed in the last few decades. Traditional boilers typically heat water to a temperature between 77°C and 88°C (170°F to 190°F). In a properly designed heat distribution system, the water temperature drops approximately 6.5°C (20°F) before the water returns to the boiler.

A non-condensing boiler is made of materials that cannot maintain their integrity if the return water temperature is any lower than 60°C (140°F). Water returned to a boiler below this temperature will cause the vaporized water in the flue gases to condense. Because non-condensing boilers are not equipped to withstand the condensate, which is typically acidic, the **heat exchanger** and other parts of the boiler will start to deteriorate.

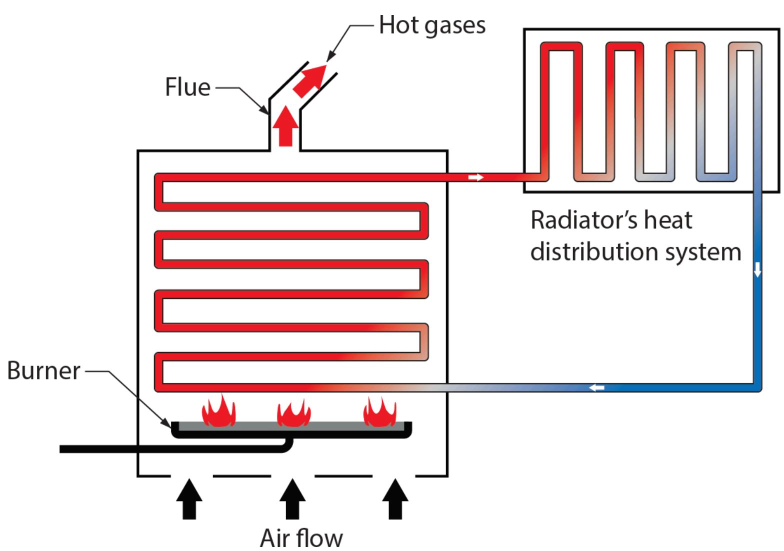

Figure 8 *Non-condensing boiler. (Skilled Trades BC, 2021) Used with permission.*

The return water temperature is what distinguishes a non-condensing boiler from a condensing boiler.

Condensing Boilers

Condensing boilers remove more heat from the flue gases than non-condensing boilers. This means the return water temperature going into the boiler is below 60°C (140°F).

Figure 9 *Condensing boiler. (Skilled Trades BC, 2021) Used with permission.*

Today's condensing boilers are designed to function with low return water temperatures that condense within the combustion chamber of the boiler. The condensate is put through an acid neutralizer before being drained into the building's sanitary drainage system (Figure 10). The increase in efficiency is offset by the need to construct the boiler with corrosion-resistant material, such as stainless steel and titanium alloys. Nearly all modern condensing boilers can modulate their heat output to better match the system demand. They do this by turning down the gas input as much as $\frac{1}{5}$ (20%) of their rated maximum input. This amount of modulation would be called a five to one turndown ratio. These boilers are often referred to as ModCon boilers.

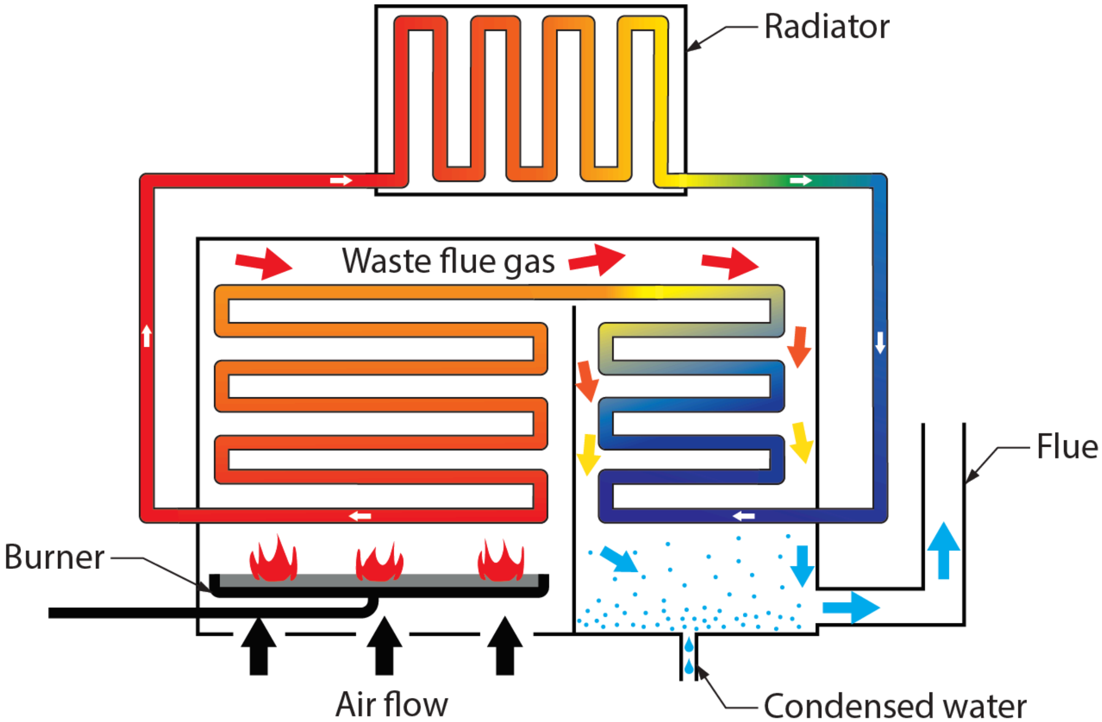

Figure 10 *Condensing boiler; condensate is put through an acid neutralizer before being drained into the building's sanitary drainage system. (Skilled Trades BC, 2021) Used with permission.*

Packaged Boilers

In the past, boilers and their associated components were obtained piece by piece, assembled and tested at the job site. These were originally cast-iron sectional boilers that were often massive in size, very heavy once assembled, and unable to fit through conventional room openings. Industrial cast-iron boilers are still shipped and installed in this manner. When the building boom of the post-war 1940s hit North America, hot water heating took off in a big way. Boiler manufacturers, looking to sell more product, realized that by installing more components onto the boilers at the factory, more installers would buy them, and the result was "packaged" boilers.

Since then, most boilers for residential and small commercial use have been fully assembled and tested at the factory. Packaged boilers can be made of cast iron, copper tube, steel tube, or stainless steel. They have an insulated cover (jacket) and normally come with the minimum-size circulator and electrical controls required to operate it already attached and wired.

Because the boiler is assembled, tested, and adjusted at the factory, the only onsite connections required are:

- Water makeup
- External electrical controls (e.g., thermostats, additional transformers, and zone valves)
- Supply and return piping mains
- Fuel supply
- Venting system
- Air supply (if applicable)

***Figure 11** Boiler with piping. (TRU Open Press) CC BY-NC-SA (https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en)*

Note in Figures 11a and 11b that the circulator is likely not mounted in the best position for system performance. Mounting the circulator on the return of the boiler took care of a couple of problems present at the time. One was that the pump seals at that time could not take the high temperatures of the boiler supply piping, so it was mounted where the water would be the coolest. As well, the packaging for the boiler did not have to be as tall if the pump was mounted low on the boiler return. A later section will cover these points, but common practice is to remove the circulator from a packaged boiler and install it on the boiler supply piping downstream of the expansion tank connection.

Boiler Ratings

All boilers must be marked with important information for installation and operation purposes. This information is found on what is known as a rating plate. It must be indelible and able to remain attached to the boiler throughout its operational life.

Boiler ratings consist of the boiler's gross output and input, in either BTU/h or kW. **Input** is the amount of energy the boiler consumes to produce heat. **Output** is the amount of energy actually transferred to the medium being heated (water, heating fluid, glycol, etc.). The ratio of output-to-input energy represents the efficiency of the boiler. All boilers that burn fossil fuels have a loss of efficiency because of their inability to transfer all of the heat produced into the water. Some of it will always be lost through the venting system into the atmosphere. This is called **waste heat** or **waste energy**.

Efficiency is a percentage that is calculated as follows:

$$(\text{output} \div \text{input}) \times 100$$

For example, a house might have a boiler that has an input rating of 59 kW (200,000 BTU/h) and a gross output rating of 47 kW (160,000 BTU/h). Therefore, the efficiency of this boiler is:

$$(47 \text{ kW} \div 59 \text{ kW}) \times 100 = 79.7\%$$

or

$$(160\,000 \div 200\,000) \times 100 = 79.7\%$$

In economic terms, one could say that efficiency is an expression of how much of a dollar spent on fuel actually goes into heating the building and how much ends up as waste heat.

Efficiency can be estimated in numerous ways. The accepted benchmark for efficiencies in heating equipment is called annual fuel utilization efficiency (AFUE). This method tracks the appliance's use over a year and is the most realistic expression used. Another expression of appliance efficiency is steady state efficiency, where an appliance operates for eight hours continuously while heat-transfer readings are taken. Because most appliances do not normally operate this way, steady state efficiencies are not seen as representative of the actual operation of an appliance.

Until the late 1980s, most boilers operated at efficiencies of a little less than 80%. The addition of vent dampers, which close off the boiler from its flue to prevent heat being lost up the vent when the burner is not firing, helped retain much of the heat produced during the run cycle and gained some points of efficiency. Modern conventional boilers now exceed 80% efficiency (known as "mid-efficiency"), and condensing boilers can exceed 90% efficiency (known as "high-efficiency") by passing the hot flue gases through a second heat exchanger. Therefore, the amount of heat wasted is greatly reduced. Because the flue gases have now lost their heat and cannot float up through the venting system on their own, they must be forced out with a fan.

The current edition of the BC Building Code, which reflects the National Building Code, publishes the minimum acceptable AFUE for new installations of gas-fired boilers not over 88 kW (300,000 BTU/h) of input to be ≥90%. This would encompass the range of almost all residential boilers. New installations of gas-fired boilers that exceed 88 kW (300,000 BTU/h) input must have a minimum thermal efficiency of ≥83%.

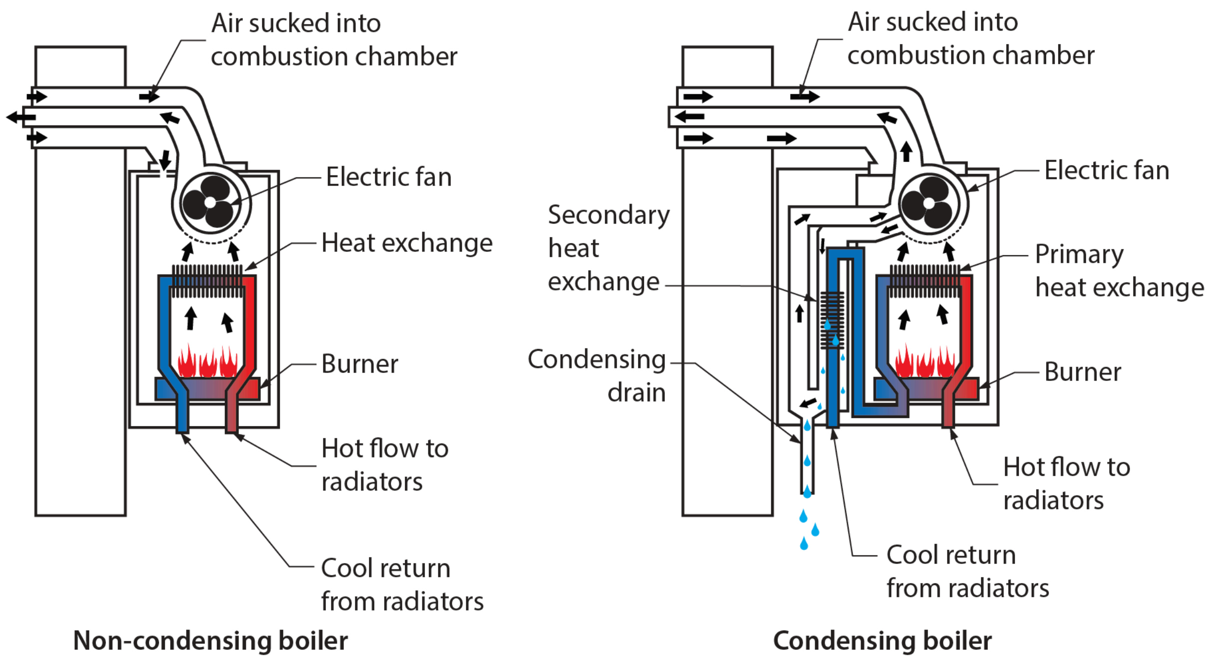

Figure 12 *Non-condensing vs. condensing boiler. (Skilled Trades BC, 2021) Used with permission.*

Solar Thermal Hydronic Heating

Solar thermal technologies use the free, renewable, non-polluting power of the sun to heat water and air in commercial and residential buildings. Panels called solar collectors use the infra-red rays from the sun to heat either water or a heat-transfer fluid circulating within them. The target for the heat from the collectors could be the domestic hot water system or for assisting heat pumps used in ground source heating systems. Systems can be classed as active or passive and either direct or indirect.

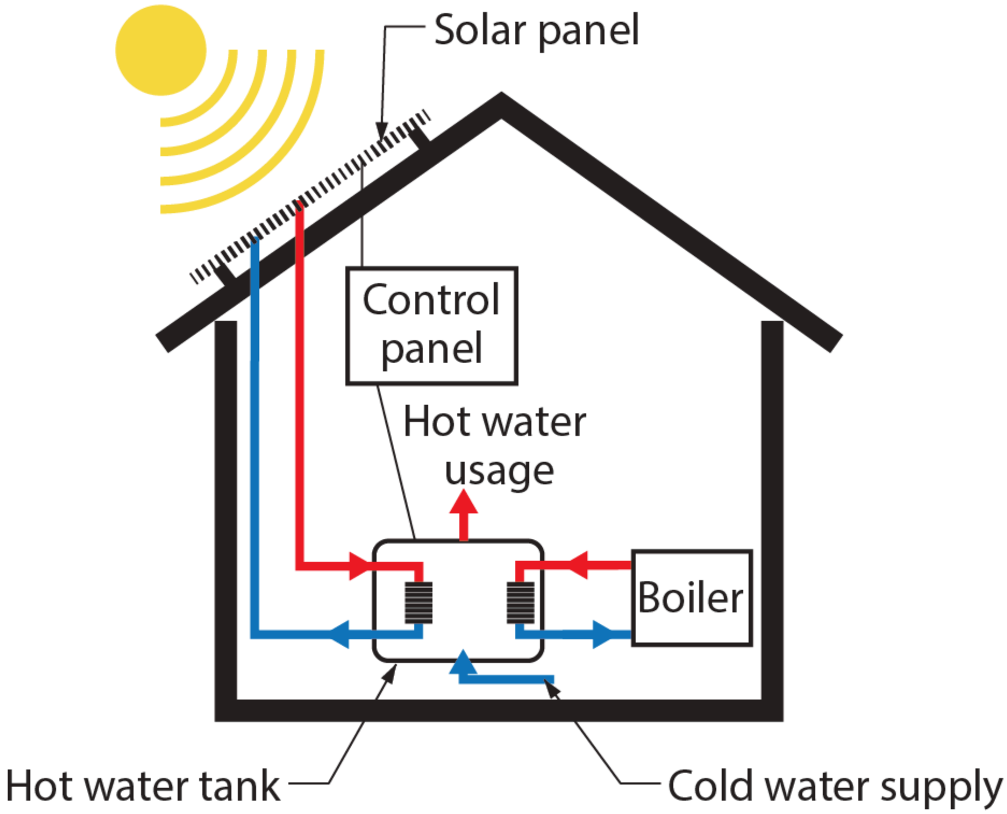

Figure 13 *Solar thermal system. (Skilled Trades BC, 2021) Used with permission.*

Active Solar Watering Heating Systems

Active systems use electric pumps, valves, and controllers to circulate water or other heat-transfer fluids through the collectors. There are three types of active systems:

- **Direct systems:** use pumps to circulate water through the collectors. These systems are appropriate in areas that do not freeze for long periods and do not have hard or acidic water. Systems installed in hard or acidic water conditions may not survive the "payback period" if care is not taken to address water chemistry. In off-grid situations where solar energy may be the only option, water chemistry must be considered.
- **Indirect/closed-loop systems:** pump heat-transfer fluids, such as a mixture of glycol and water, through collectors. Heat exchangers then transfer the heat from the fluid to the water within the heating system. These systems are used in climates subject to freezing.
- **Drainback systems:** are direct systems that use pumps to circulate water through the collectors, then drain themselves automatically to prevent freezing. Because the water in the collector loop drains into a reservoir tank when the pumps stop, this is still a good system for colder climates and does not require antifreeze and a heat exchanger.

Solar Collectors

Solar thermal collectors are the key component of active solar watering systems and are designed to meet the specific temperature requirements and climate conditions for different end-uses. There are several types of solar collectors:

- Flat-plate collectors
- Evacuated-tube collectors
- Concentrating collectors
- Transpired-air collectors

Residential and commercial building applications that require temperatures below 93°C (200°F) typically use **flat-plate (or transpired-air collectors)**, whereas those requiring temperatures greater than 93°C use evacuated-tube or concentrating collectors.

Flat-Plate Collectors

Flat-plate collectors (Figure 14) are the most common collectors for residential water heating and space heating installations. A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-coloured absorber plate. These collectors heat either liquid or air at temperatures less than 82°C (180°F).

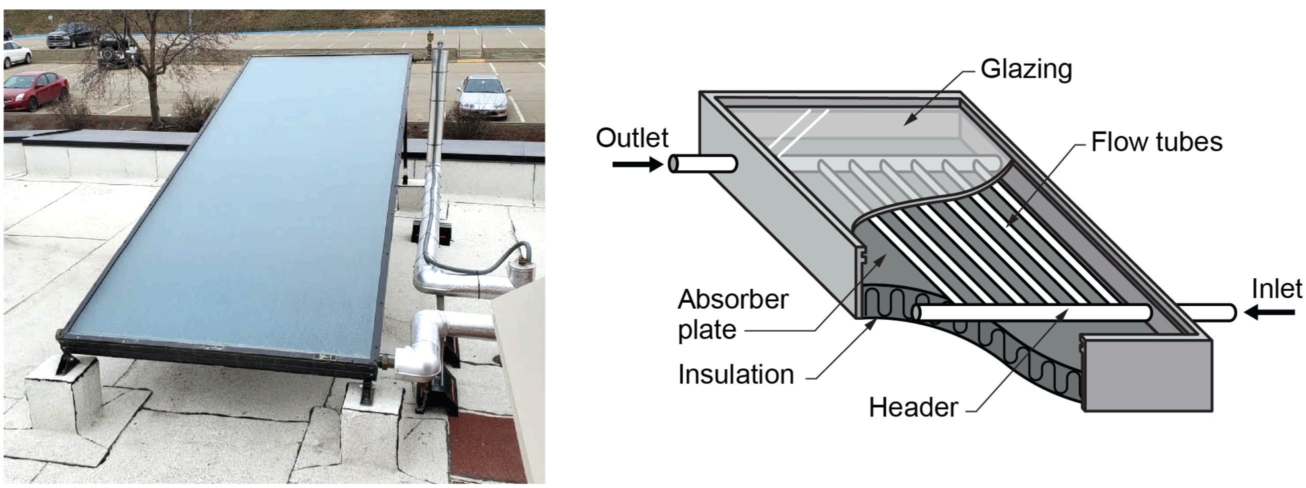

Figure 14 *Flat-plate collectors. (Skilled Trades BC, 2021) Used with permission.*

Liquid flat-plate collectors heat liquid as it flows through tubes in or adjacent to the absorber plate. The simplest liquid systems use potable household water, which is heated as it passes directly through the collector, then flows to the house.

Swimming pool heating systems (Figure 15) use liquid flat-plate collector technology. The pool's existing filtration system pumps water through the solar collectors, and the collected heat is transferred into the pool. Because solar pool collectors operate just slightly warmer than the surrounding air temperature, these systems typically use inexpensive, unglazed, low-temperature collectors made from specially formulated plastic materials.

Glazed (glass-covered) solar collectors are usually not used in pool heating applications, except for indoor pools, hot tubs, and spas in colder climates. In some cases, unglazed copper or copper-aluminum solar collectors are used.

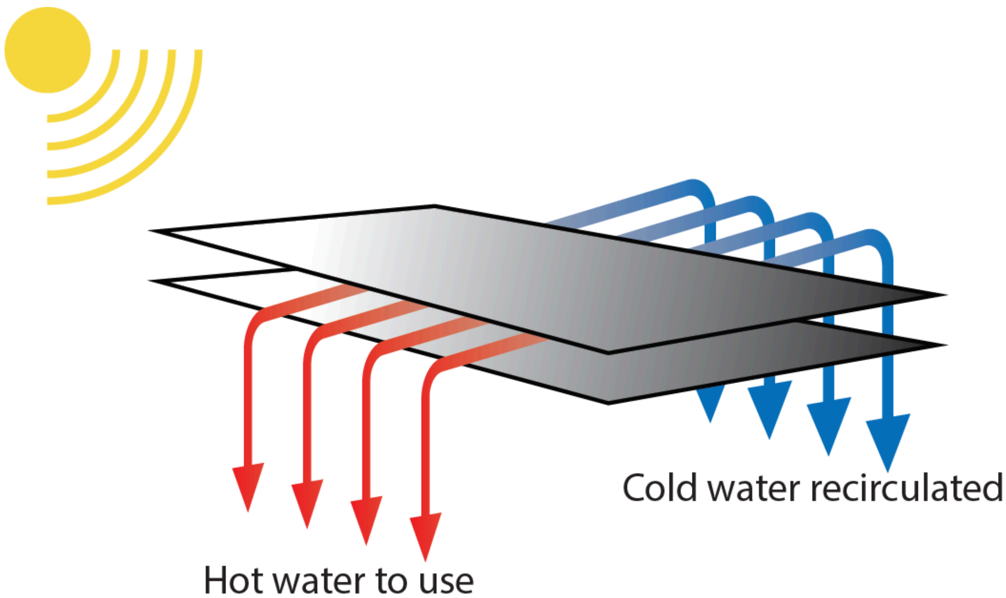

Figure 15 *Unglazed swimming pool collector. (Skilled Trades BC, 2021) Used with permission.*

Integral collector storage (ICS) collectors (also called batch or breadbox water heaters, Figure 16) combine the collector and storage tank into an insulated box with a glazed side facing the sun. The sun shining into the collector strikes the storage tank, directly heating the water inside it. In colder climates, the use of double glazing and selective surfaces prevents freeze damage to the collector. In even mildly cold climates, insulation needs to be installed and maintained to prevent supply and return pipes from freezing.

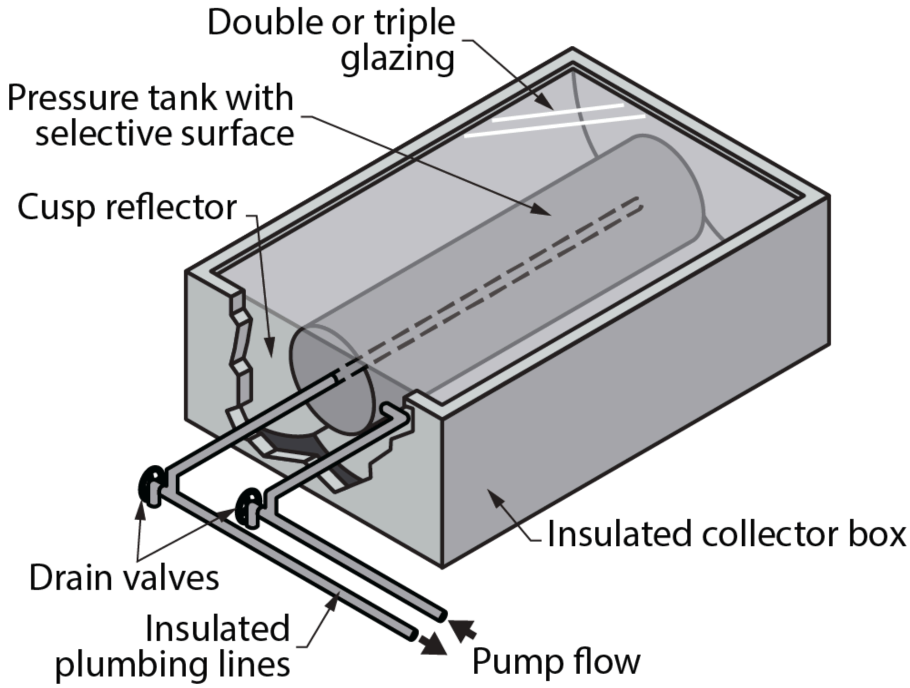

Figure 16 *ICS collector. (Skilled Trades BC, 2021) Used with permission.*

Evacuated-Tube Collectors

Evacuated-tube collectors (Figure 17) are typically more efficient at higher temperatures than flat-plate collectors. In an evacuated-tube collector, sunlight enters through the outer glass tube and strikes the absorber, where the energy is converted to heat. The heat is transferred to the liquid flowing through the absorber. The collector consists of rows of parallel transparent glass tubes, each of which contains an absorber covered with a selective coating. The absorber typically has a fin-tube design (fins increase the absorber surface and heat-transfer rate), although cylindrical absorbers can also be used.

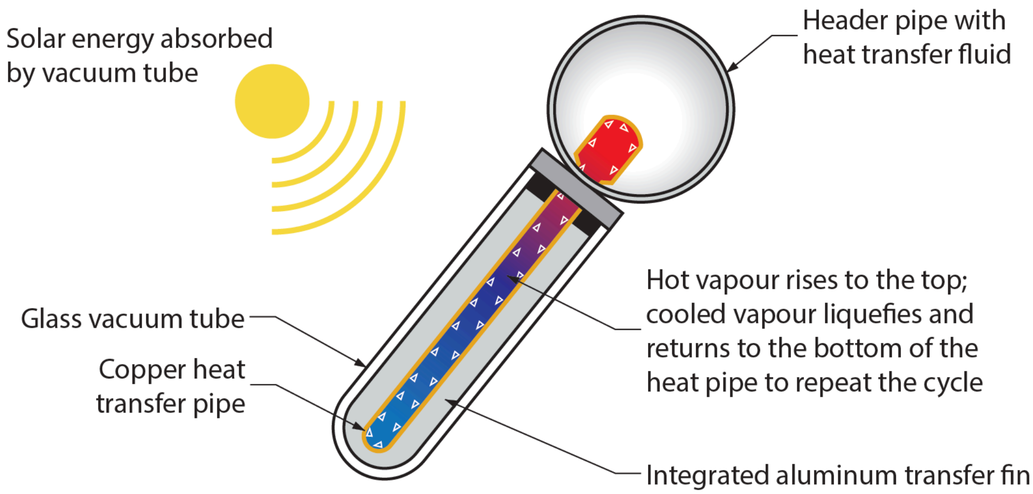

Figure 17 *Evacuated-tube collector. (Skilled Trades BC, 2021) Used with permission.*

When evacuated tubes are manufactured, air is evacuated from the space between the two tubes, forming a vacuum. The vacuum is important because the liquid within it boils and the vapour rises to the top of the tube, where it contacts the metal tip of the tube. The tip is pushed into the collector manifold, where it transfers its heat by conduction to the fluid flowing through the manifold.

Evacuated tubes can be replaced simply by pulling them out of the manifold. The two heating mediums never mix together so the system does not need to be drained to replace a damaged tube. Heat losses are greatly minimized because there is no air to convect or conduct heat away, so evacuated-tube collectors are efficient at higher temperatures and perform well in both direct and diffuse (cloudy day) solar radiation.

Evacuated-tube collectors are more appropriate for most commercial and industrial applications because they can achieve extremely high temperatures of 77°C to 177°C (170°F to 350°F). However, evacuated-tube collectors are more expensive and produce higher temperatures than needed in residential settings, so most residential systems use flat-plate collectors. Because the glass vacuum tube emits no heat, snow is able to accumulate on them, which insulates the vacuum tube from the solar energy. This can be a problem in low temperature regions. In such cases, some commercial and institutional buildings have integrated liquid flat-plate collectors and evacuated tube collectors in the same system.

Concentrating Collectors

Concentrating collectors (Figure 18) use curved mirrors to concentrate sunlight on an absorber, called a receiver, at up to 60 times the sun's normal intensity. These high-temperature systems are used primarily in commercial and industrial applications.

Figure 18 *Concentrating collector. (Skilled Trades BC, 2021) Used with permission.*

Passive Solar Water Heating Systems

Systems that move water or heat-transfer fluid without pumps are called passive systems. There are two types of passive systems:

- **Integral collector storage (ICS):** consists of one or more storage tanks placed in an insulated box with a glazed side facing the sun (mentioned above, Figure 16). During the winter, the connecting piping must be protected from freezing or be drained.
- **Thermosiphon systems**: (Figure 19) rely on convection created between the fluids in the tank and in the collector. The fluid in the collector becomes less dense and rises into the tank above, while the denser fluid in the bottom of the tank falls through piping into the bottom of the collector to be reheated. The fluid to be heated is circulated through a separate path within the tank (heat exchanger), where it absorbs the heat created and returns to the building for use.

Figure 19 *Thermosiphon system. (Skilled Trades BC, 2021) Used with permission.*

Commercial Cooling Equipment

Cooling equipment used in air conditioning equipment or process industries relies on the refrigeration cycle. Vapour-compression mechanical refrigeration systems, as they are known, may differ in size and appearance of their components, but they all operate in the same way. Compressors, condensers, expansion devices, evaporators, and refrigerants are all used in the process of cooling.

Chillers

Chillers are the core of commercial cooling systems. It is important to remember that the refrigerant and the cooling medium (chilled water) never mix in a cooling system; heat transfer occurs solely through conduction in heat exchangers. The next section first looks at what happens in the chilled water piping and then examines the operation of the refrigeration system within a chiller.

The Refrigeration System

The refrigeration system in a chiller is similar to that in a refrigerator, with the main exception being its size. The actual cooling of the chilled water is done by the evaporator. After cooling the chilled water in the evaporator, the low-temperature, low-pressure refrigerant is pulled into a compressor, where both the pressure and temperature are increased (Figure 20).

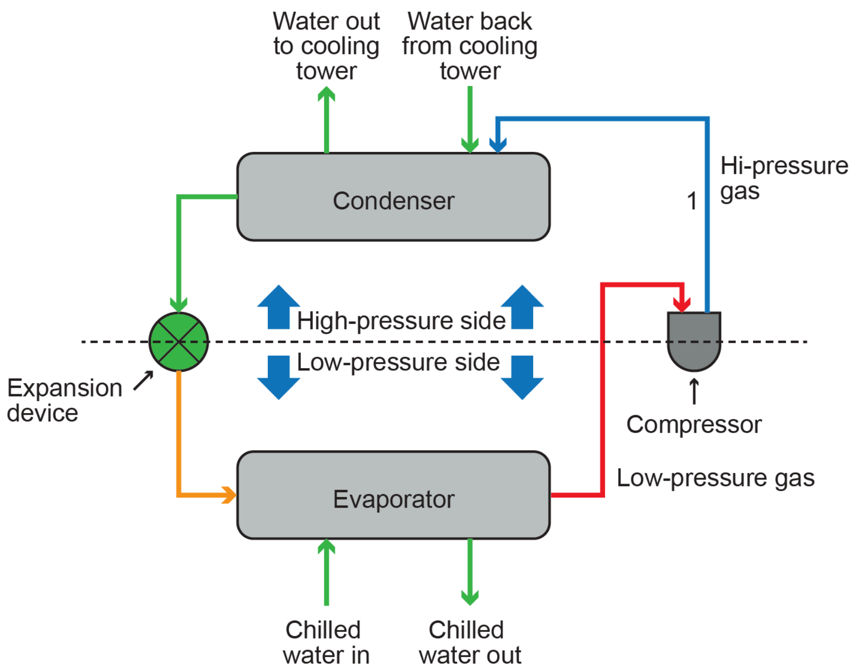

Figure 20 *Refrigeration system Stage 1. (Skilled Trades BC, 2021) Used with permission.*

The refrigerant is pushed into the condenser, where enough heat is removed through the condenser's coils so that the vapour condenses back into liquid form (Figure 21).

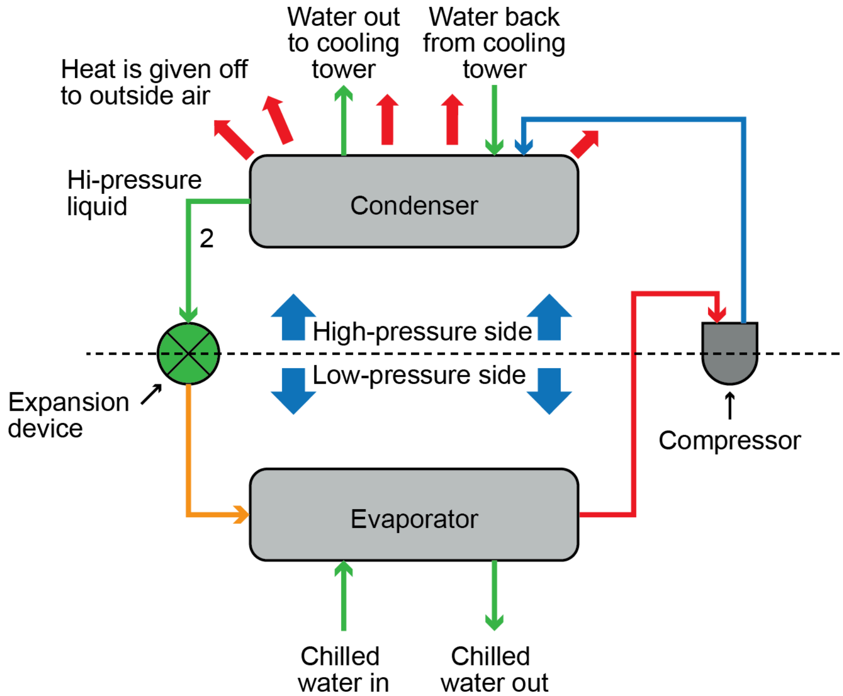

Figure 21 *Refrigeration system Stage 2. (Skilled Trades BC, 2021) Used with permission.*

The high-pressure liquid refrigerant is then pushed through an expansion valve, which drops the pressure of the refrigerant on its way to the evaporator (Figure 22).

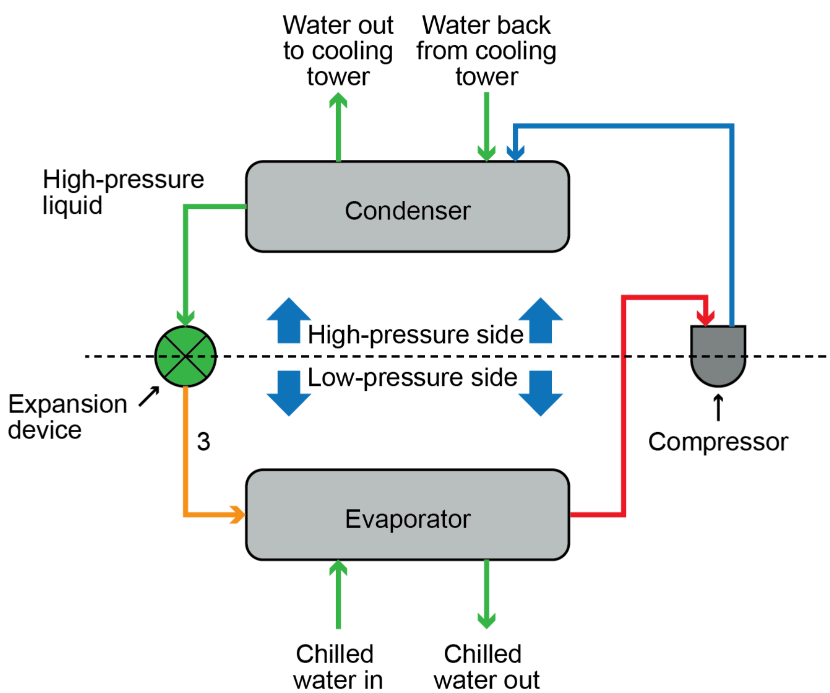

Figure 22 *Refrigeration system Stage 3. (Skilled Trades BC, 2021) Used with permission.*

Once in the evaporator, the heat from the chilled water return is absorbed into the low pressure liquid refrigerant, boiling it, which, in turn, cools the chilled water (Figure 23). Then, the process repeats.

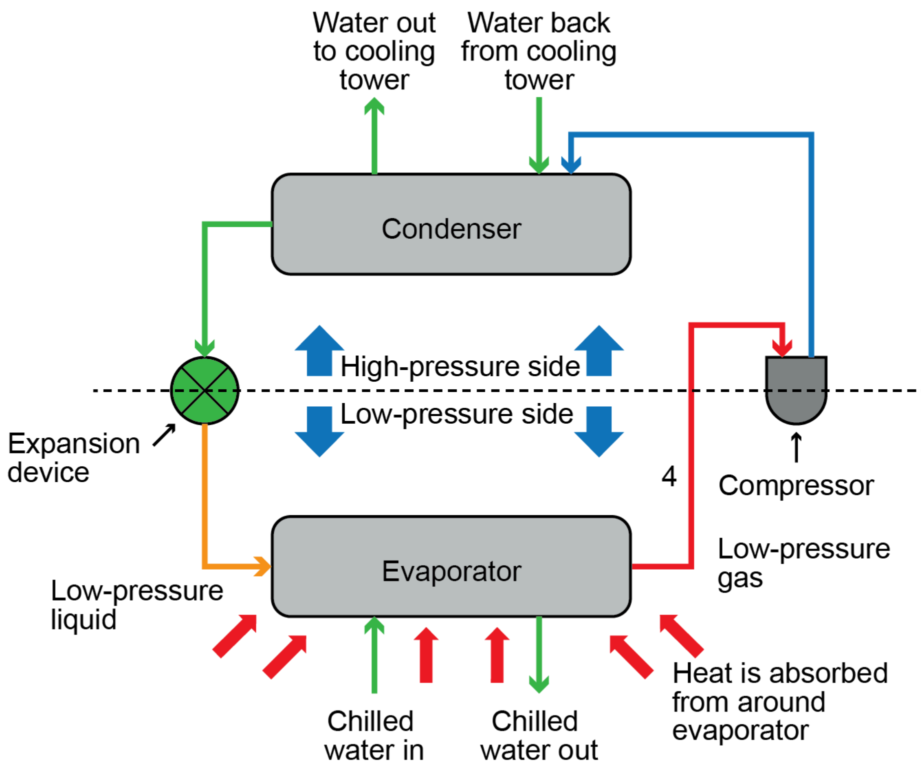

Figure 23 *Refrigeration system stage 4. (Skilled Trades BC, 2021) Used with permission.*

Figure 24 shows the entire process in one view.

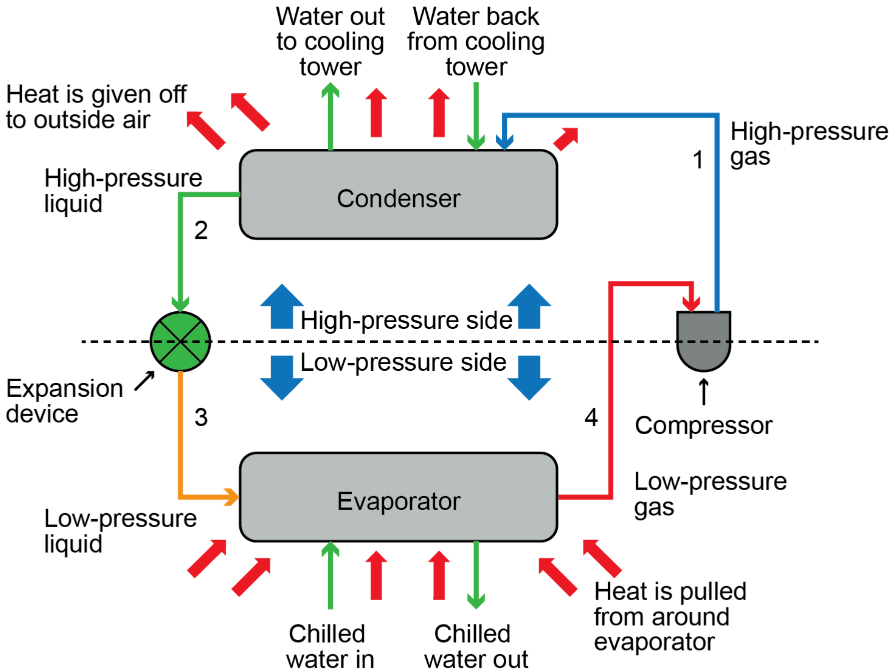

Figure 24 *Refrigeration system: All stages in the process. (Skilled Trades BC, 2021) Used with permission.*

Chilled Water System

The chilled water supply and return piping is a closed loop, which means that the system has no openings. The chilled water supply becomes the chilled water return after the water passes through the cooling coils, and the chilled water return becomes the chilled water supply after the water passes through the chiller.

Cold (or chilled) water is supplied to cooling coils in ductwork by a "chilled water supply" pipe from the chiller. In the ductwork, air is blown through a cooling coil, with the chilled water flowing through it. Heat from the air is transferred to the cooling coils and, in doing so, the chilled water lines absorb the heat from the air. The now-warmed chilled water is returned to the chiller through the "chilled water return" piping to be recooled.

At the chiller, the return water from the ductwork coils enters the evaporator section, which is a heat exchanger. The heat from the return water, in contact with the walls of the evaporator, is transferred to the refrigerant and causes it to boil. Because the heat in the water has been used to boil the refrigerant in the evaporator, the water temperature drops back to approximately 10°C (50°F). The now-chilled water is pumped back out into the system to the cooling coils, and the process is repeated until the call for cooling is satisfied.

The condenser section of a chiller can be either air-cooled or water-cooled.

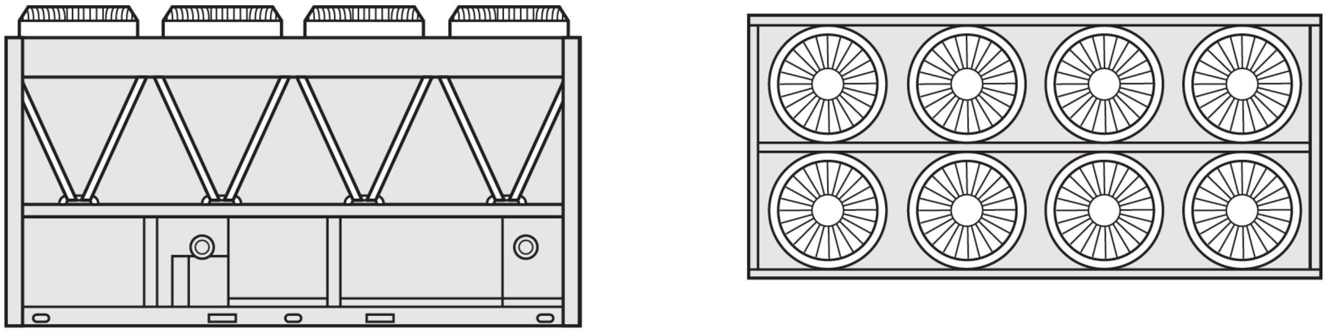

Figure 25 *Air-cooled chiller. (Skilled Trades BC, 2021) Used with permission.*

Air-cooled chillers function exactly the same as refrigerators, with the exception that an air-cooled chiller must be installed outdoors to be able to dissipate enough heat. The condenser has piping coils that the refrigerant flows through; these coils are attached to a network of fins that are usually made of aluminum. The fins greatly enlarge the surface area in contact with the air and increase the effectiveness of heat transfer to the air.

Water-cooled chillers use an extra piece of equipment called a cooling tower. A water-cooled chiller is normally installed indoors (Figure 26), which increases the expected lifespan of the chiller. Water, rather than air, is circulated over the condenser coils within a condenser heater exchanger, then pumped to a cooling tower, where heat is taken out of the water (called “condenser water”), then returned to the chiller condenser section. The chiller can be located inside buildings because the cooling tower does the heat transfer from the condenser water to the atmosphere and the cooling tower is located outdoors.

Figure 26 *Water-cooled chiller. (Skilled Trades BC, 2021) Used with permission.*

A cooling tower is simply another heat exchanger normally installed on the roof of the building or in a parking lot near the building, if the building is very tall. Parking lot locations are favoured because the noise and vibration caused by the cooling tower operation is not transferred to the building.

There are two different types of cooling towers: closed-circuit and open-circuit. Both types of towers serve the same purpose, but they cool the water in different ways.

A direct, open-circuit cooling tower is an enclosed structure that distributes the warm process water — in this case, condenser water (Figure 27) — over a labyrinth-like packing or fill, which provides an expanded air-water interface for heating the air and evaporating a portion of the condenser water. The condenser water is cooled as it falls through the fill and is then collected in a basin below. The heated moisture-laden air leaving the fill is discharged into the atmosphere, and the cooled process (condenser) water collected in the basin is returned to the chiller condenser to remove more heat.

Although open-circuit towers use an efficient, simple, and economical design, they expose condenser water to the atmosphere. All components in an open-circuit system, especially the chiller condenser section, must be compatible with the oxygen and other contaminants introduced via the cooling tower.

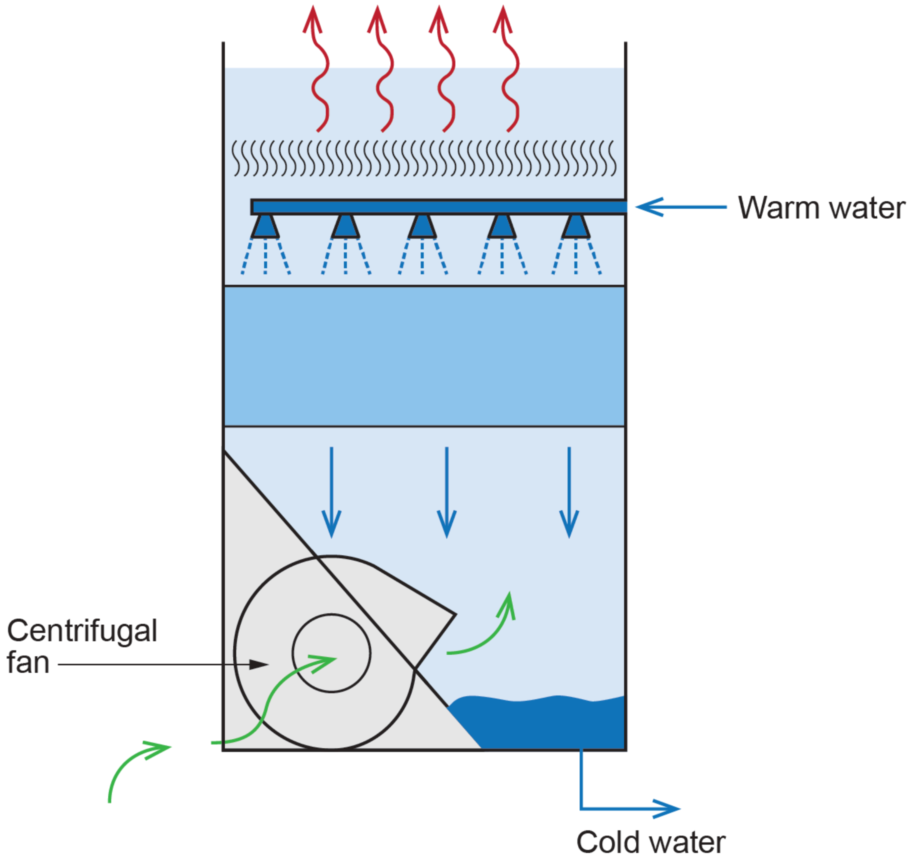

Figure 27 *Open-circuit cooling tower. (TRU Open Press; [modified] from Skilled Trades BC, 2021) Used with permission.*

A closed-circuit cooling tower, or dry cooling tower, involves no contact between the air and the fluid being cooled (Figure 28). This type of tower has two separate fluid circuits: one where condenser water flows through a coil pipe located in a fan-forced air stream and the other where cool or cold water sprays into the air stream that flows around the condenser water coil. The air drawn through this cascading water spray provides evaporative cooling, similar to that in an open cooling tower, except that the condenser water never makes direct contact with the cooling air/water mixture. A closed-circuit cooling tower protects the quality of the condenser water, reduces system maintenance, and provides operational flexibility at a slightly higher initial cost than that of an open-circuit tower.

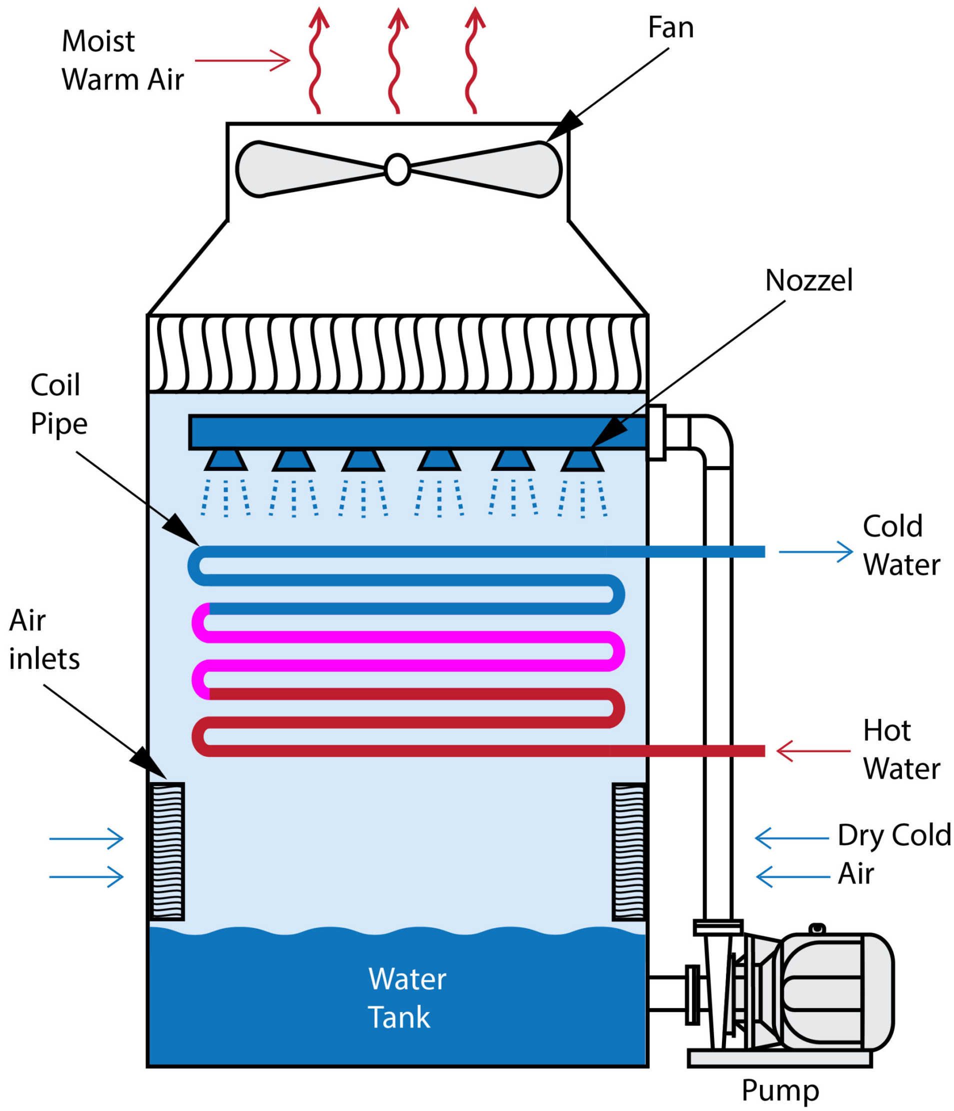

Figure 28 *Closed-circuit cooling tower. (TRU Open Press; [modified] Huatal, 2019) CC BY-NC-SA (https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en)*

Heat Pumps

Heat pumps work on the same refrigeration cycle previously described with chillers. One significant difference is their ability to reverse the cycle using an electrically operated reversing valve, which can change the direction of the refrigerant flow. The reversing valve effectively swaps the functions of the condenser and evaporator making the heat pump either a heating or cooling source (Figure 29).

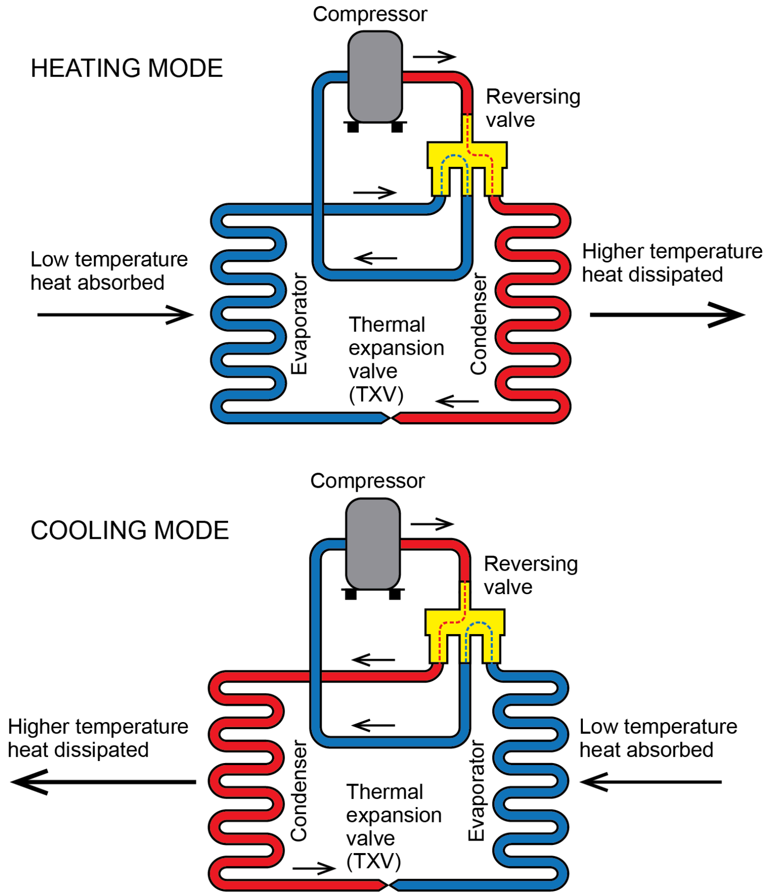

Figure 29 *Reversible heat pump. (Skilled Trades BC, 2021) Used with permission.*

Heat pumps that extract low-temperature heat from the outside air and deliver higher-temperature heat through a forced-air distribution system, or vice versa, are relatively common in North America. When used to heat buildings, heat pumps can gather low-temperature heat from sources, such as outdoor air, groundwater, lakes or ponds, or tubing buried within the earth.

In a hydronic system using a heat pump as the heat source, the heat present in the refrigerant is transferred to the water that moves throughout the heating system. This is done through the compression cycle within the heat pump. The hot refrigerant leaving the compressor moves into a water-cooled condenser (Figure 30). The water within it absorbs the heat and carries it off to be used to heat the house and/or domestic water. Remember that the condenser and evaporators in a refrigeration system are simply heat exchangers. Hydronic systems, such as radiant systems that operate at low water temperatures, are always preferred from the standpoint of heat pump performance.

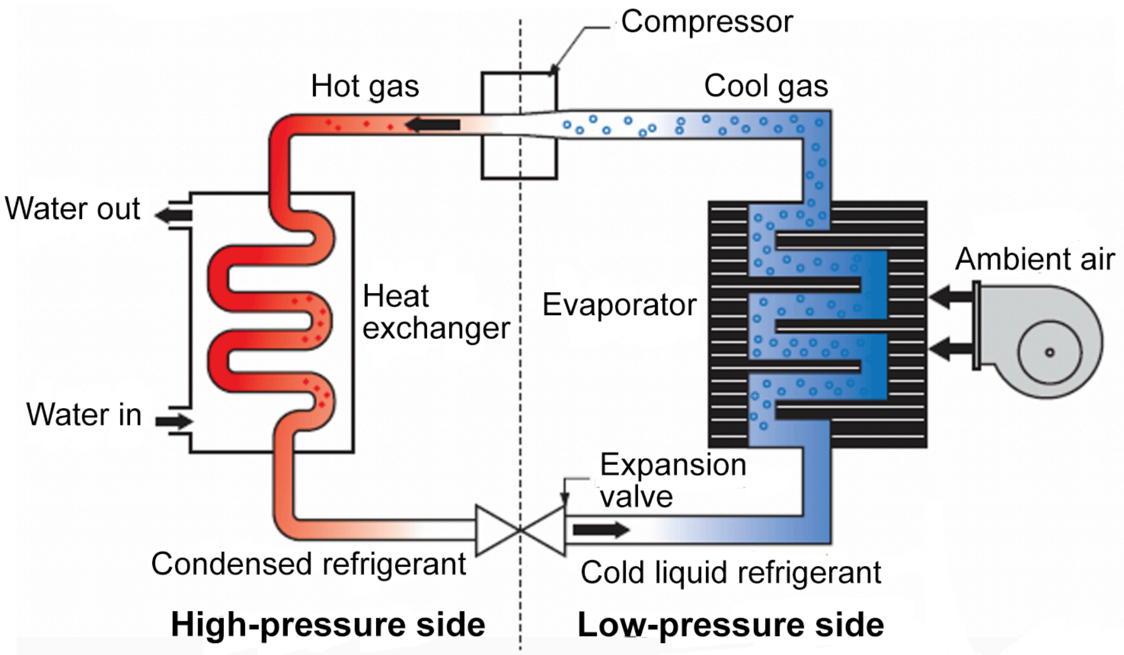

Figure 30 *Air-source heat pump showing a water-cooled condenser. (Skilled Trades BC, 2021) Used with permission.*

Air-To-Water Heat Pumps

Recent developments have made it possible to use air-source heat pumps in combination with hydronic distribution systems. Since these units use water as their means of heat delivery, they are classified as air-to-water heat pumps.

Air-to-water heat pumps (Figure 31) use the outside air as their source of heat. Even when it is very cold outside, the heat pump can extract heat from the air and move it into the building. The energy from the air is transferred via refrigerant to the water, which is then distributed through the piping. During the summer months, the system can work in reverse: cool water is run through the piping, absorbing heat as it goes.

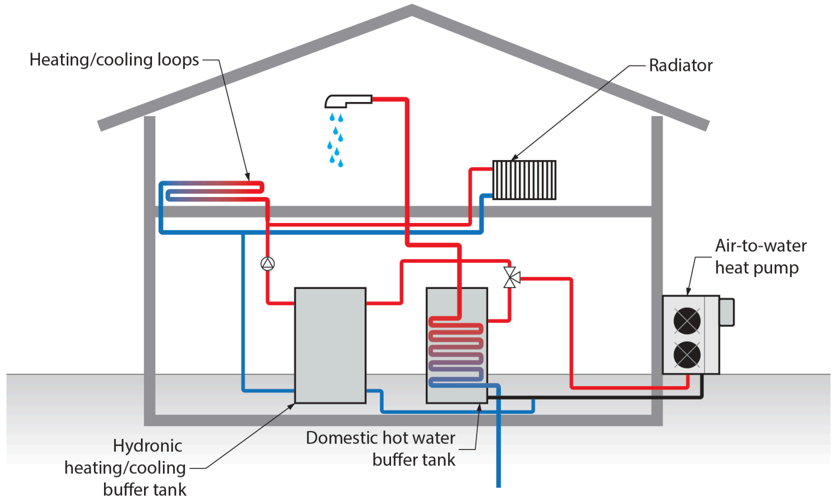

Figure 31 *Air-to-water heat pump. (Skilled Trades BC, 2021) Used with permission.*

This water then goes back to the heat pump, where the refrigerant cycle removes the heat from the water by transferring it to the air outdoors. Note that if a heat pump uses the same open air heat transfer units to supply cooling water, they will require controls that monitor the dew point of the ambient air. This is necessary to avoid condensation forming on the cool surfaces of the heat transfer unit, which, in turn, promotes dampness and mould. This limits the minimum temperature of the cooling loop and cooling capacity of a radiant hydronic cooling system.

Water-To-Water Heat Pumps

A more fitting term for a water-to-water heat pump (Figure 32) would be a ground source heat pump, although the term geothermal is often extended to this type of system. A true geothermal system taps into heat emitted from underground hot springs, whereas a ground source heat pump conducts latent heat from below the surface of the earth.

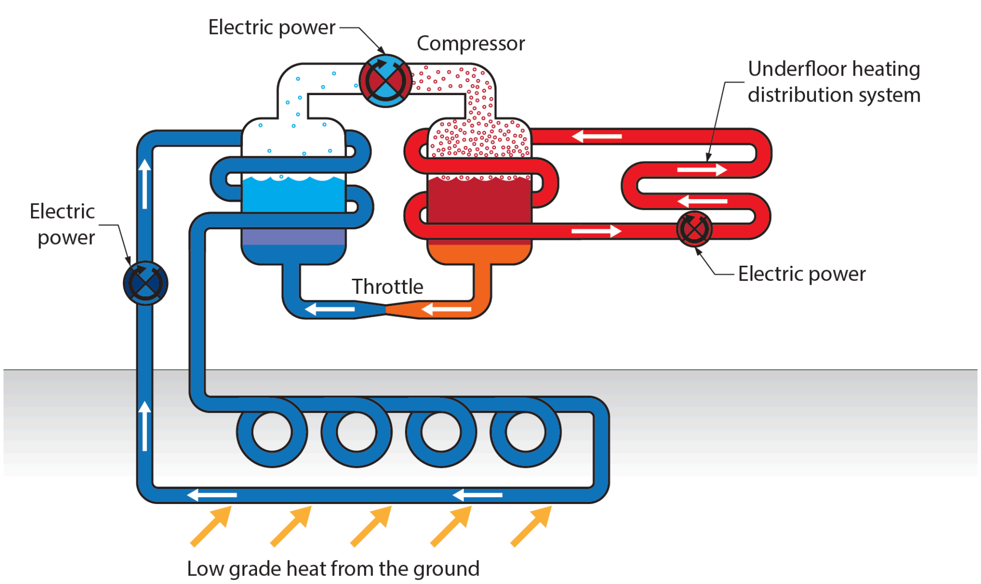

Figure 32 *Water-to-water heat pump. (Skilled Trades BC, 2021) Used with permission.*

A closed-loop water-to-water heat pump has piping containing a heat-transfer solution, such as glycol or brine, running through the ground either vertically through a bored hole (if space is limited) or horizontally through trenches (e.g., on an acreage). The glycol or brine solution is the heat-transfer medium between the refrigeration cycle of the heat pump and the ground. In this case, the piping can be defined as a heat exchanger.

When the heat pump is in heating mode, heat from the ground is absorbed by the cool solution within the piping and transferred by the heat pump into the heating water for the building. Note that the fluids in the underground and in-house piping do not come into contact with each other; they are kept separated by the heat pump.

Similar to air-to-water heat pumps, the cooling cycle of water-to-water heat pump works in reverse. A reversing valve causes the refrigerant to move in a reverse direction within the heat pump, and heat is extracted from the building and deposited into the ground. These systems must be carefully sized and installed; the cost for installation is normally more than that for a conventional system, but they can easily cost even more to operate and maintain if not installed and sized correctly.

An open-loop system takes advantage of the heat retained in an available large body of water. The water is drawn from a well or pond directly to the heat pump. After extracting the heat, the system discharges the water back into the ground through a separate well or directly back into the pond.

Heat pumps are generally less costly to operate than any fossil-fuel-fired systems. In any properly designed heat pump system, the only operational energy cost should be the electricity needed to run the motors that power the pumps, compressors, and fans.

Heat Exchangers

Heat exchangers warrant mention because they come in various forms and can themselves be a source of heating or cooling. A heat exchanger is a device that transfers heat from one fluid to another without allowing the two fluids to make physical contact. Typically, both fluids in the system must be moving for heat exchange to take place. There are many types and styles of heat exchangers.

Water-To-Water Heat Exchanger

Water-to-water heat exchangers (Figures 33 and 34) are normally used to heat domestic water with a boiler but can also transfer heat between any two liquid mediums. Boiler water is sent into one side of the heat exchanger and transfers its heat to the coil surrounded by water within the tank. The boiler water and the water to be heated do not come in contact; instead, heat is transferred through the walls of the heat exchanger.

Heat exchangers are used to prevent mixing between potable water, like domestic hot water, and non-potable mediums, such as boiler water or a water/glycol mixture.

Figure 33 *Cutaway of an indirect domestic water-to-water heat exchanger (left); flat-plate water-to-water heat exchanger (right) (Skilled Trades BC, 2021) Used with permission.*

Watch the following video by Rinnai America Corporation (2021) on YouTube to see how Rinnai boilers work.

If you are using a printed copy, you can scan the QR code with your digital device to go directly to the video: How Rinnai I-Series Boilers Work (https://www.youtube.com/watch?v=TvCc3noYin4)

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=46#oembed-1 (#oembed-1)

Air-To-Water Heat Exchanger

An example of an air-to-water heat exchanger would be the exchanger within a boiler, where water within steel or copper tubing or cast-iron sections is heated by hot flue gases produced by the burning of a hydrocarbon fuel, such as natural gas, propane, or fuel oil. The heat from the flue gases is transferred by conduction through the walls of the pipe or sections into the water, while the two mediums are kept separate.

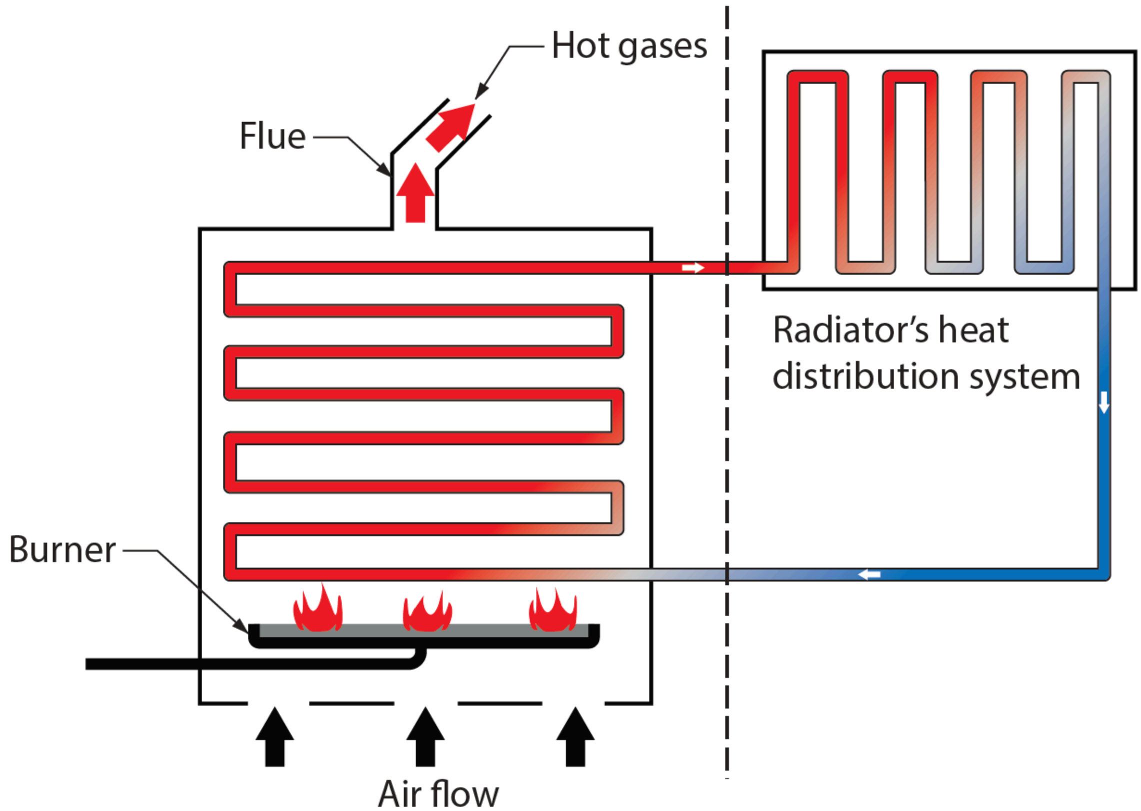

Figure 34 *Air to water heat exchanger commonly found in a water tube boiler. (Skilled Trades BC, 2021) Used with permission.*

Water-To-Air Heat Exchanger

The heater emitters that release heat from the boiler water into the space being heated are examples of water-to-air heat exchangers. Figure 36 is a fan coil type where hot boiler water is piped to an exchanger, similar to a radiator in a car. An axial fan mounted behind the exchanger pushes air through the finned coils.

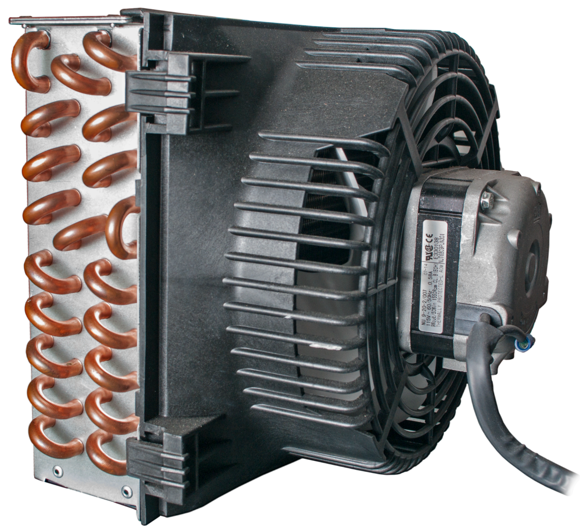

Figure 35 *Water-to-air heat exchanger. (Rod Lidstone)* CC BY *(https://creativecommons.org/licenses/by/4.0/)*

Air-To-Air Heat Exchanger

An example of air-to-air exchanger is a heat recovery ventilator (HRV). These are mandated by building codes for most new single-family house construction to get the necessary fresh air change. They can recover heat while exchanging stale indoor air with fresh outdoor air.

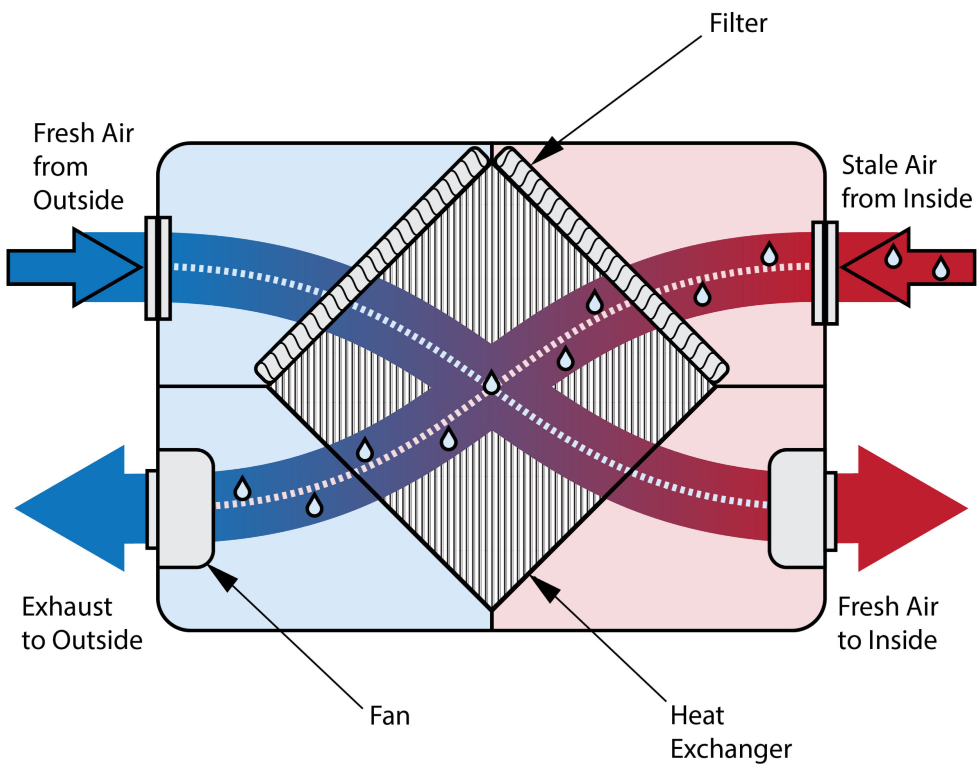

Figure 36 *HRV unit. (TRU Open Press; [modified] Adobe Stock #461693074) CC BY-NC-SA (https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en)*

Self-Test B-2.1: Heating and Cooling Sources

Complete the chapter Self-Test B-2.1 and check your answers.

If you are using a printed copy, please find Self-Test B-2.1 and Answer Key in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=46#h5p-5 (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=46#h5p-5)

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- **Figure 26** Closed-circuit cooling tower (adapted for educational purposes under Fair Dealing guidelines), is from Skilled Trades (2021). The original image (https://www.htcoolingtower.com/hbw-closed-circuit-counter-flow-cooling-tower) is from Jiangsu Huatal Cooling Technology Co., Ltd.
- **Figure 34** Water-to-air heat exchanger is by Rod Lidstone and is used under a CC BY (https://creativecommons.org/licenses/by/4.0/) licence.
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B-2.2 Installation of Heating and Cooling Sources

Regardless of whether a building is being newly constructed or a renovation is planned, you must be familiar with all documents that specify the minimum system requirements. This may include the manufacturer's installation instructions and specifications as well as all pertinent codes, regulations, and standards.

Equipment Inspection Before Installation

Heating and cooling equipment may be damaged during shipping from the factory to its final destination, where it is to be installed. When equipment arrives on site, it is important to visually check the equipment (if possible) and packaging for damage. Damaged packaging may indicate internal damage, even if the outside surfaces seem unaffected. Internal parts may be cracked, broken, or shifted out of alignment.

If equipment with unnoticed deficiencies is installed, two issues arise:

1. The equipment must now be either fixed or replaced, costing the installer money.
2. It becomes harder to identify when the equipment was damaged.

If you suspect damage of any type, be sure to take pictures, make notes, and notify the appropriate parties involved. It is also a good idea to have an impartial third party witness the unpacking of the equipment to be able to verify that the equipment was in fact damaged before installation.

Codes and Regulations

All heating equipment must be installed according to the codes and regulations specified by the region in which they are installed. The Canadian Standards Association (CSA) B214 Code is the Installation Code for Hydronic Heating Systems in Canada. This code covers many different areas of hydronic heating installations, including heating equipment. Section 5 covers heating equipment, and within this section, references are made to other standards that may have more specific installation guidelines. For example, Clause 5.2.1 of the B214 specifies that all gas-fired equipment and installations shall be installed in accordance with the B149.1 code, while Clause 5.2.5 indicates that all solar heating installations shall be installed in accordance with CSA F379 series and CAN/CSA-F383.

The person installing heating equipment may have to reference more than one code. For example, boilers must meet requirements of the applicable boiler and pressure vessel regulations as well as requirements found in boiler, building, plumbing, electrical, gas, and fire codes.

Codes and regulations that may specifically apply to the boiler may include:

- ASME Boiler and Pressure Vessel Code
- Canadian Gas Code (CSA B149)
- Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation
- CSA Standard B51 (the Boiler, Pressure Vessel and Pressure Piping Code)
- The Institute of Boiler and Radiator Manufacturers (IBR)

- Fire Marshalls Act of BC
- National Fire Protection Association (NFPA)

Although codes are similar throughout the province and across Canada, they frequently change to reflect new and specialized equipment, changes in safety practices, and previously unidentified hazards. Before installing a boiler or other equipment, installers must be familiar with code requirements and local by-laws that may affect installation.

It is also important to consult the **authority having jurisdiction (AHJ)**. The AHJ will use the codes and regulations as a guideline but may also require the installer to comply with more region-specific installation practices.

The AHJ also issues installation permits. Contractors are required to apply for an installation permit before doing the work. For every installation permit, there must be an inspection of the installation by the designated AHJ. For large commercial applications, an occupancy permit is required, and it is issued after inspection by the fire marshal and building inspection authority.

In all cases, it is important to follow the manufacturers' installation literature and specifications when installing any equipment. Note that that the literature that accompanies the equipment is certified along with the equipment.

Not following the manufacturers' installation specifications may void the warranty and cause damage and personal injury. In most situations, the manufacturers' installation specifications, the authority having jurisdiction, and the codes and regulations are fairly harmonized.

Layout

The installer must always consider the location of the heating and cooling equipment when installing it. When laying out the installation, the installer must consider supply of power, water, fuel, and air, as well as equipment clearances and venting requirements when deciding where to locate the heating and cooling equipment.

Clearances and Access

Understanding the equipment clearances required will help the installer to get a better picture of the layout of the equipment. Installation clearances are specified by both the manufacturer and the specific installation code that governs the equipment, and they are important for two main reasons. One is to ensure necessary access to all parts of the equipment during installation and later when the equipment may need servicing. Insufficient space for service access will undoubtedly create problems. This applies to both the equipment itself and the general area where the equipment is installed, such as a crawl space or mechanical room.

The other main consideration when installing equipment is clearances to combustibles. All appliances have clearances listed on their rating plates as well as in the manufacturers' literature, and these clearances must be observed to guarantee a safe operating situation in regard to fire prevention.

Section 7.1 of the B149 Gas Installation Code specifies minimum boiler clearances from combustible materials as:

- Vertical: 45 cm (18 in.)
- Sides and rear: 45 cm (18 in.)
- Front: 120 cm (48 in.)

Always check the manufacturers' instructions and use the most restrictive clearances.

Electrical Connections

While gasfitters may be permitted to work on some aspects of the electrical system associated with a gas heating system, a certified electrician working for an electrical contractor will often be involved in any electrical work.

The Canadian Electrical Code states that all heating equipment must have a **dedicated branch circuit**. This means that a 120-volt circuit from the breaker panel must only serve one source of heating equipment. The intent is to limit the possibility that other items sharing such a circuit might have a negative effect on the operation of the heating equipment, which during the colder winter months could prove disruptive at best. A qualified gasfitter with an electrical endorsement may perform electrical work from the wall disconnect switch to the gas appliance but may not install the branch circuit itself; this is the work of an electrical contractor.

Water Supply and Fuel Supply

All hydronic equipment requires both fuel and water to function properly. When installing hydronic equipment, make sure that both are readily available and relatively easy to incorporate into the system. Although this may sound fairly logical, oftentimes getting fuel or water to the heating and cooling equipment can be more challenging than it seems.

The water source used to supply the equipment is going to be the same water source that is used to supply the domestic water for the building. The water that is used to fill the hydronic system must not be allowed to come back into the domestic **potable water system**. If that happens, the best case scenario would be aesthetically unpleasing water (taste, appearance and odour) created by stagnation or leaching of metals; the worst one would be death caused by chemical additives. Makeup water must be supplied through a **backflow preventer** to maintain the integrity of the building's potable water system.

The main issue regarding the fuel supply is availability. British Columbia's natural gas transmission pipelines service much of the province, but many areas are still out of reach, and other fuels (e.g., propane, fuel oil, and electricity) and forms of solid fuel (e.g., wood) must be used. Always make sure that the equipment being installed works with the fuel sources available.

Air Requirements and Venting

All hydrocarbon fuel sources require air for the combustion process. Allowing for an adequate source of air ensures proper combustion and, ultimately, that the heating or cooling equipment operates in a safe manner. The air used for the combustion process must come from a permanent air intake directly from the outdoors and must not be taken from a carport or temporary intake, such as a window into a mechanical room, which could limit or negate the air supply if closed.

Section 8 of the B149.1 Natural Gas and Propane Installation Code sets the requirements for both combustion air supply and venting requirements for gas-fuelled appliances.

Housekeeping Pads

Section 7.1 of the B149.1 Natural Gas and Propane Installation Code requires that a gas boiler shall conform to the requirements of the provincial boiler and pressure vessel regulations as applicable. Section 7.1 also states that a boiler shall be installed on a firm and level base, which can include **housekeeping pads**; this requirement is consistent with the other applicable codes.

A housekeeping pad (Figure 1) is a raised concrete platform on which the boiler is mounted. It minimizes the possibility of dust, dirt, or other litter that might be on the mechanical room floor being swept under or into the boiler. It also elevates the boiler above any water that might be on the floor that could corrode the boiler's frame.

Figure 1 *Industrial boiler mounted on housekeeping pad. (Skilled Trades BC, 2021) Used with permission.*

Self-Test B-2.2: Installation of Heating and Cooling Sources

Complete the chapter Self-Test B-2.2 and check your answers.

If you are using a printed copy, please find Self-Test B-2.2 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=52#h5p-6 (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=52#h5p-6)

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Self-Test B-2.1 Heating and Cooling Sources

Complete Self-Test B-2.1 and check your answers.

1. Why would the area of a boiler's water chamber be increased?
    a. Withstand greater pressures
    b. Withstand higher temperatures
    c. Heat the water more quickly and efficiently
    d. Heat the water more evenly

2. What are large water-tube boilers normally used for?
    a. Producing high-pressure steam in large volumes
    b. Producing low-pressure steam in large volumes
    c. Producing steam in small volumes
    d. Space heating with water or steam

3. What are fire-tube boilers well suited for?
    a. Hot water heating only
    b. Steam heating only
    c. Forced-air, hot water heating, or steam heating
    d. Hot water heating or steam heating

4. How are sections of a cast-iron boiler connected together?
    a. Supply and return headers
    b. Couplings
    c. Push rods
    d. Push nipples

5. Low-pressure steam boilers can reach temperatures of 135°C (275°F).
    a. True
    b. False

6. At what temperature do conventional non-condensing boilers in hot water heating systems usually operate?
    a. 82°C (180°F)
    b. 121°C (250°F)
    c. 140°C (284°F)
    d. 160°C (320°F)

7. What are high-pressure boilers usually made of?
    a. Cast iron

b. Vitrified porcelain
c. Stainless steel
d. Steel tube

8. What type of boiler were the original “package” boilers?
    a. Water tube
    b. Fire tube
    c. Cast iron
    d. Modular

9. What makes a condensing boiler different from a conventional (non-condensing) boiler?
    a. Achieves over 90% efficiency
    b. Accepts cooler return water
    c. Has stainless steel or titanium internal components
    d. All of the above

10. Complete the following statement: “High-efficiency boilers require_________.”
    a. More maintenance
    b. An occupancy permit
    c. A floor drain
    d. Vents made of steel pipe

11. Complete the following statement: “A ground source heat pump is a type of __________.”
    a. Control system
    b. Well pump
    c. Heat exchanger
    d. Piston pump

12. How does a ground source heat pump system heat a building?
    a. Generates heat from the ground
    b. Generates heat by the movement of a coolant
    c. Transfers residual heat from the ground
    d. Transfers residual heat from the building

13. Which type of active solar heating system would work well in colder climates?
    a. Direct system
    b. Closed loop
    c. Indirect system
    d. Drainback system

14. What type of collector is typically used for most residential and commercial building applications that require

temperatures below 93°C (200°F)?

a. Flat-plate or transpired-air collectors
b. Evacuated-tube or concentrating collectors
c. Flat-plate or concentrating collectors
d. Evacuated-tube or transpired-air collectors

Answer Key: Self-Test B-2.1 (#chapter-answer-key-self-test-b-2-1) is on the next page.

Answer Key: Self-Test B-2.1

1. c. Heat the water more quickly and efficiently
2. a. Producing high-pressure steam in large volumes
3. d. Hot water or steam heating
4. d. Push nipples
5. b. False
6. a. 82°C (180°F)
7. d. Steel tube
8. b. Fire tube
9. d. All of the above
10. c. Floor drain
11. c. Heat exchanger
12. c. Transfers residual heat from the ground
13. d. Drainback system
14. a. Flat-plate or transpired air collectors

Self-Test B-2.2 Installation of Heating and Cooling Sources

1. What should the installer do before installing any heating or cooling equipment?
   a. Check all equipment for damage done during shipping.
   b. Get an installation permit from the authority having jurisdiction (AHJ).
   c. Check local codes for specific installation requirements.
   d. All of the above

2. The B214.1 Installation Code for Hydronic Heating is a code that has been developed specifically for use in British Columbia.
   a. True
   b. False

3. Installation clearances are specified by both codes and manufacturers. Why is it important to maintain clearances when installing equipment?
   a. Allows the service technician to work on the equipment without space issues
   b. Keeps the mechanical room from becoming overcrowded
   c. Allows people to walk past the equipment when going through the mechanical room
   d. Keeps the equipment from overheating

4. Who is allowed to work on the 120-V connection from the wall disconnect to a gas-fired heating appliance?
   a. Certified plumber only
   b. Certified B gasfitter only
   c. Certified electrician only
   d. Either a certified B gasfitter with an electrical endorsement or a certified electrician

5. Section 7 of the Natural Gas and Propane Installation Code specifies minimum clearances from combustibles for boilers. What are the minimum clearances from the front of the boiler?
   a. 30 cm (12 in.)
   b. 60 cm (24 in.)
   c. 90 cm (36 in.)
   d. 120 cm (48 in.)

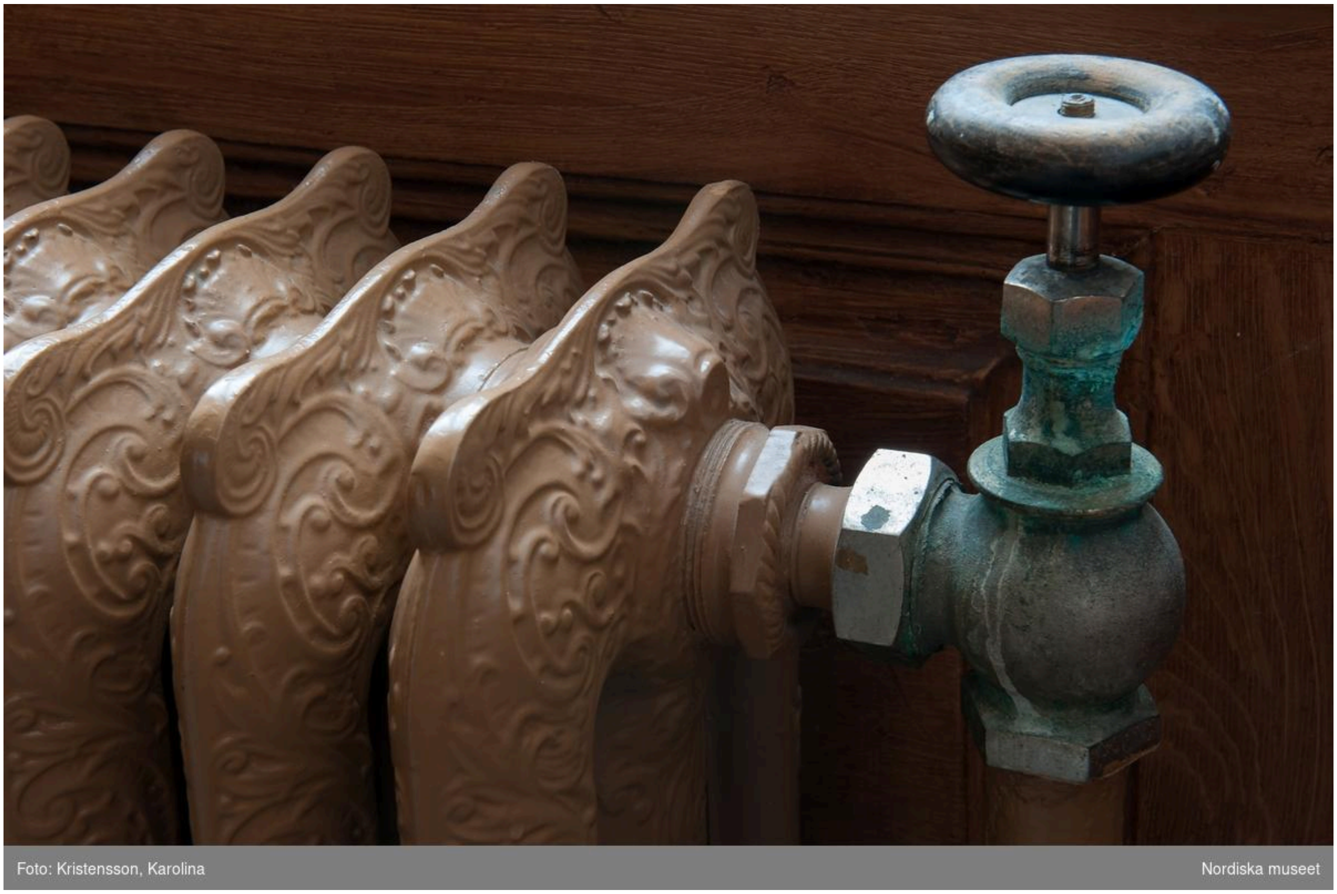
Answer Key: Self-Test B-2.2 (#chapter-answer-key-self-test-b-2-2) is on the next page.

Answer Key: Self-Test B-2.2

1. d. All of the above
2. b. False
3. a. Allows the service technician to work on the equipment without space issues
4. d. Either a certified B gasfitter with an electrical endorsement or a certified electrician
5. d. 120 cm (48 in.)

B-3 HYDRONIC TRANSFER UNITS

Plumber Apprenticeship Program – Level 2



Freestanding cast iron radiator. (Karolina Kristensson/DigitaltMuseum) CC BY-NC-ND 4.0 (https://creativecommons.org/licenses/by-nc-nd/4.0/deed.en)

B-3 Hydronic Transfer Units Introduction

Because heat always moves from an area of higher temperature to an area of lower temperature, all buildings either gain or lose heat depending on their surrounding environment. Buildings must have their rate of heat transfer estimated before a means of adding or removing that heat can be specified.

The rate of heat transfer depends on two factors. One is the temperature difference between two bodies or areas. The greater the temperature difference (ΔT or "Delta T"), the faster the rate of heat transfer or flow.

The second factor is the material through which the heat moves. For instance, heat moves through a well-insulated wall much more slowly than through an uninsulated wall. Copper is generally used in the hydronic heating industry because it is a good conductor of heat. This means that heat moves through copper quite easily and has a high rate of heat transfer. By comparison, plastic is more of an insulator, and less heat is lost through the walls of plastic tubing than through copper.

Heat in buildings can only be transferred by three means: conduction, convection, and radiation. Heat transfer units are designed to operate using these three methods.

Heat transfer units are also referred to as heat emitters. In this section we will look at the different types of **heat emitters** and some general installation guidelines for each type. Although the installation of site constructed in floor wall and ceiling radiant panels will be covered in Level 3 studies.

Learning Objectives

After completing the chapters in this section, you should be able to:

- Name types of heat transfer units.
- Describe heat transfer units, including the following:
    - In-floor heating
    - Radiant panels
    - Heat exchangers
    - Force flow units
    - Unit heaters
- Explain considerations for selecting and installing heat transfer units.

Terminology

The following terms will be used throughout this section. A complete list of terms for this section can be found in the **Glossary**.

- **adjustable louvre:** A type of window or vent with slats that can be moved or tilted. These slats can be adjusted to control the amount of light, air, and noise that comes through, making them useful for ventilation and privacy. (Section B-3.1)
- **air vents:** Steam cannot circulate, nor can radiators emit heat until air has been vented from the system. Thermostatic air vents are installed on each radiator and at the end of each steam main. Thermostatic steam traps also act as air vents. (Section B-3.1 and Section B-3.2)
- **baseboard wallfin units:** Heating devices installed along the baseboards of rooms. They use electricity or hot water to produce heat, which is then radiated into the room. These units are effective for heating spaces efficiently and are often controlled by thermostats to maintain desired temperatures. (Section B-3.1)
- **convector:** A heating device that warms up a room by circulating air over a heated surface. The warm air rises and spreads through the room, while cooler air is drawn in to be heated. This process creates a continuous flow of warm air, making the room comfortable. (Section B-3.1)
- **forced circulating convectors:** Heating units that use a fan or pump to circulate air or water through the convector. They are more powerful than gravity systems and can distribute heat more evenly throughout a room. These systems are often used in larger buildings or where rapid heating is required. (Section B–3.1)
- **gravity circulating convectors:** Heating units that use natural convection to circulate warm air. They are typically placed near windows and walls where cold air enters. As the air near the heater warms, it rises, creating a convection current that circulates throughout the room. (Section B-3.1)
- **heat emitters (units):** Steam heating systems use convectors, cast-iron radiators, wall fin tubes, and similar heat-emitting units. (Section B-1.4 and Section B-3.1)
- **heat exchangers:** Devices designed to transfer heat between two fluids or between a fluid and a solid surface. They facilitate the exchange of thermal energy without the fluids coming into direct contact with each other. They work by maximizing surface area contact between the fluids to efficiently transfer heat from a warmer fluid to a cooler one, or vice versa, depending on the application's requirements. (Section B-3.1)
- **hot flue gases:** The exhaust gases produced from combustion processes, such as those in furnaces, boilers, or industrial equipment. These gases are typically very hot and contain by-products of combustion, such as carbon dioxide, water vapor, carbon monoxide, and other pollutants. Hot flue gases are often directed through flues or exhaust pipes to safely remove them from the combustion chamber or heating system. They may also be used in heat exchangers to recover some of their thermal energy before being vented to the atmosphere. (Section B-3.1)
- **hydronic fan coil:** A unit that uses circulating water to heat or cool air by passing it over coils, adjusting the room temperature efficiently. (Section B-3.1)
- **hydronic heating:** A system that uses water to heat a building. Water is heated in a boiler and then pumped through pipes to radiators or underfloor tubing. As the hot water moves through these pipes, it releases heat into the rooms, keeping them warm. (Section 3.1)

- **radiant panels:** Heating devices that are installed in ceilings, walls, or floors of buildings. They emit infrared radiation, which directly heats objects and people in the room without heating the air. This method of heating is efficient and provides comfortable warmth evenly throughout the space. (Section B-3.1)
- **radiators:** Heating devices that use hot water or steam to warm a room. They consist of metal panels, electrical coils, or hot water pipes that emit heat through radiation and convection. Radiators are commonly found under windows or along walls and are controlled by thermostats to maintain desired temperatures. (Section B-3.1)

B-3.1 Hydronic Heat Transfer Units

Heat in a hydronic heating system is generated at the heat source. Consider a boiler as an example. A boiler heats water to temperatures as high as 88°C (190°F), then the distribution piping system carries this heated water throughout the building. At some point along the way, a portion of that heat is released into the space that requires it. This is the point where heat transfer units, aka **heat emitters**, are installed. They take the heat out of the water and transfer it into the room.

Hydronic heating has the advantage of offering many options to choose from when selecting heat transfer units. Small **baseboard wallfin units** operating at high temperatures can do the same job as low-temperature **radiant panels** that use a large surface area. Designers take into account variables such as comfort, aesthetics, and control when designing systems and choose transfer units accordingly. Because of the wide variety of heat transfer units available, designers are also able to choose transfer units that meet the architectural requirements of a building. The ductwork involved with forced-air heating systems may require dropped ceilings in the room below, whereas a radiant panel in-floor heating system requires no additional space to be used.

Although there are many classifications of heat emitters, this section will group them into four categories:

- **Gravity circulating convectors**
- **Forced circulating convectors**
- **Radiators**
- **Radiant panels (in-floor heating)**

Gravity Circulating Convectors

Convectors are so named because they operate on the principle that when air is heated, its density decreases, and colder, denser air will force the heated air upward. Gravity or "passive" convectors (Figure 1) use natural air currents to move heated air through them. The coldest air in a room is near the floor, so the cabinet of a gravity circulation convector is open at the bottom to allow cold air to enter. Hot water flowing through the tube heats the fins by conduction.

The large surface area of the fins transfers the heat to the air in contact with them, also via conduction. The now-warmed air rises due to its buoyancy and mixes with the rest of the room air. The design of the gravity circulation convector is such that the cabinet does not become hot, so it will transfer very little heat through radiant means.

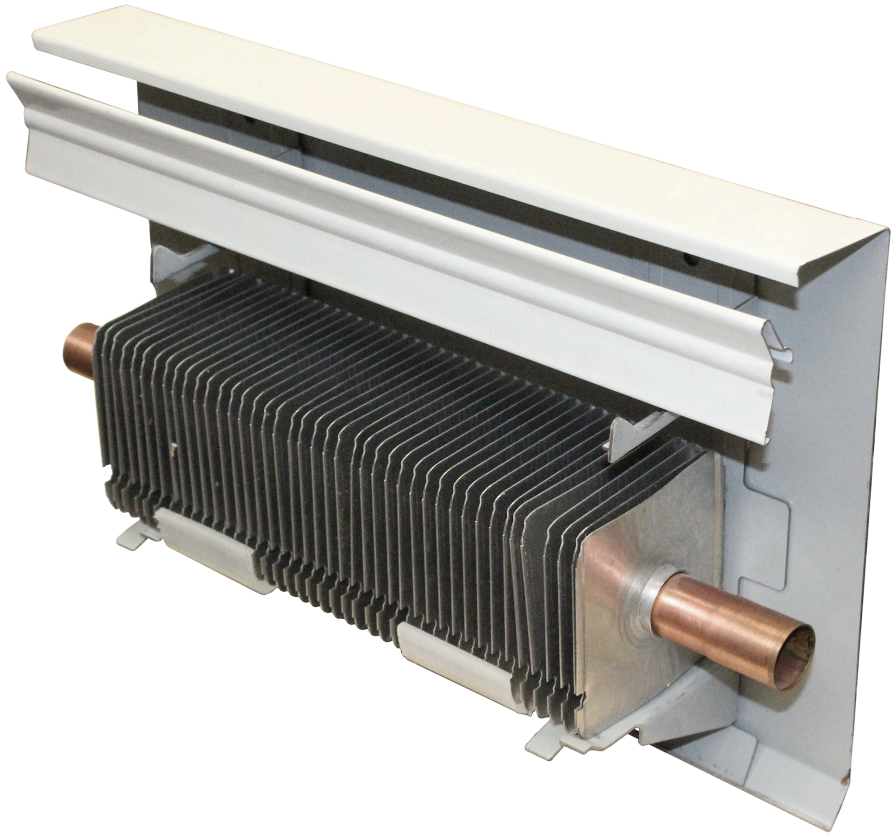


Figure 1 *Residential gravity circulating convector. (Skilled Trades BC, 2021) Used with permission.*

Gravity circulation convectors are either surface-mounted or recessed into the wall. Insulation behind the back of the cabinet prevents heat loss through the wall. Brackets attached to the back of the cabinet support the finned tube. The front panel of the cabinet can be removed for access to the tube and air vent, and the pivoting damper can be adjusted to allow more or less air to flow across the fins

Residential circulating convectors are mounted at baseboard level, beneath windows. Commercial-grade convectors are normally found in stairwells and common areas.

Finned Tube Baseboard Convectors

The finned tube baseboard convector (also known as "baseboard wallfin") has historically been the most common hydronic heat emitter used in residential and small commercial applications. Figure 2 shows two views of a typical finned tube convector (with a back panel or cabinet).

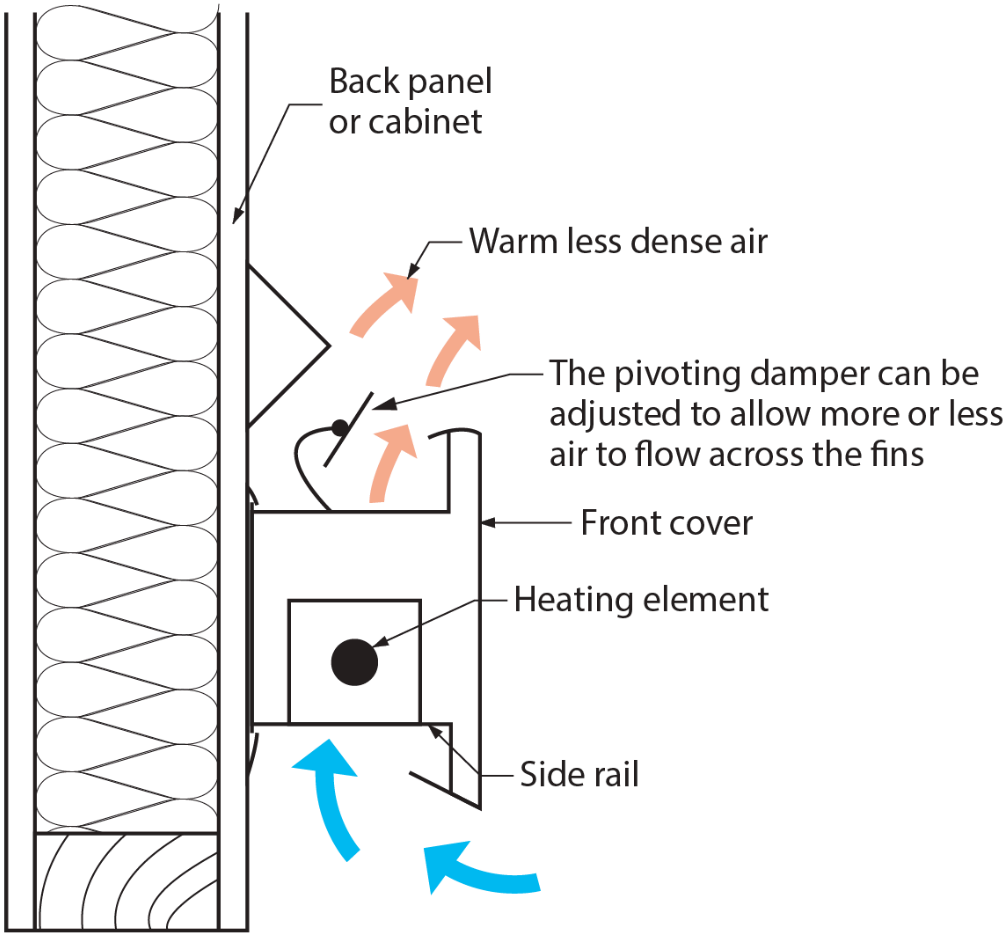


Figure 2 *Finned tube baseboard convector. (Skilled Trades BC, 2021) Used with permission.*

The heating element is a single copper tube with aluminum fins. When heated water is moved through the copper tube, heat is transferred by conduction to the aluminum fins. The cold air that has been trapped between the fins begins to warm through contact with the fins, and eventually this warm, less dense air rises. Colder, denser air displaces the warm air and thus begins the convection currents that warm the room. Because the heat is quickly moved away from the convector, there is not enough time for the convector to warm up and create radiant heat, so almost all of the heat created for the room is through air convection. As well, the white cabinet tends to reflect the heat back into itself rather than absorb the heat, so it emits very little radiant heat.

The finned tube baseboard convector is encased in a housing, also known as a cabinet, designed to allow for airflow in and out of the unit. Movable brackets attached to the back panel of the cabinet support the heating element or finned tube, the front panel, and the **adjustable louvre**. The adjustable louvre regulates airflow. Closing the louvre slows or stops the flow of air and eventually stops or slows down the flow of heat. Figure 3 shows how the heat is transferred from the water into the convector and then into the room.

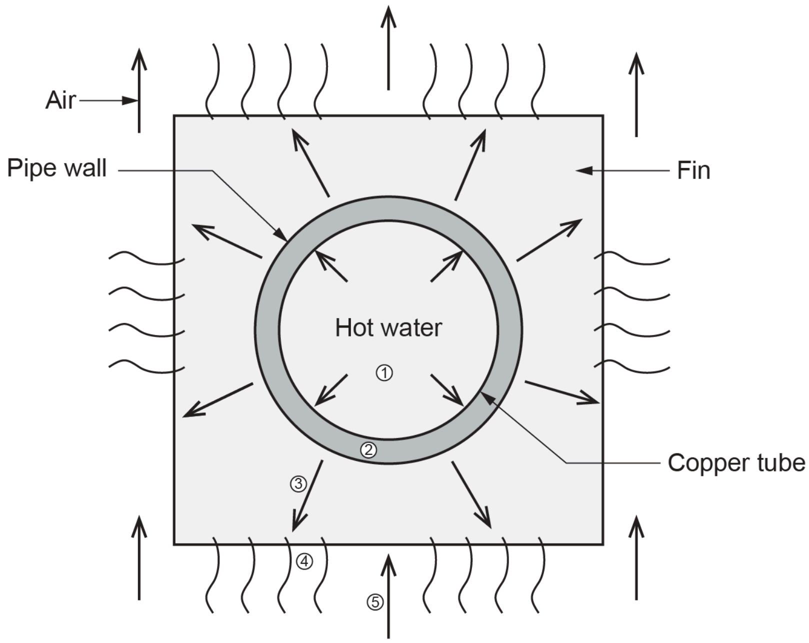


Figure 3 *Finned tube baseboard convector. (Skilled Trades BC, 2021) Used with permission.*

Baseboard convectors for residential use are typically 230 mm (9 in.) high and extend less than 100 mm (4 in.) from the wall. However, they do come in various sizes. Convectors should be mounted below windows to balance the cold drafts from the windows. When the air in contact with the window is cooled by heat loss through the glass, it moves downward. If a convector is mounted below the window, the cool downdraft will mix with the warm air that is rising from the convector. Together these drafts produce a more even room temperature. To allow the convector to function as designed, nothing should obstruct the movement of air through the unit and the room. Homeowners must keep this in mind when placing furniture and drapery near the baseboard wallfin.

Commercial-Grade Wall-Mounted Convectors

Commercial wall-mounted convectors are the modern counterpart of the cast-iron radiator. A wall-mounted convector is not nearly as heavy as a cast-iron radiator and typically extends only about 125 mm (5 in.) from the wall, however, the sizes may vary. Wall-mounted convectors are used in commercial applications and large buildings, such as schools. They are normally installed below windows, in stairwells, and in stairway landings.

The heating element of the wall-mounted convector has a manifold and several tubes running through the fins.

Figure 4 shows a multi-tube wall-mounted convector. A wall-mounted convector works in the same manner as a finned tube baseboard. Cool air enters the bottom opening and gets trapped between the aluminum fins. As this air is warmed, it rises and exits through the top of the unit. Cool air replaces this warm air, establishing convection currents.

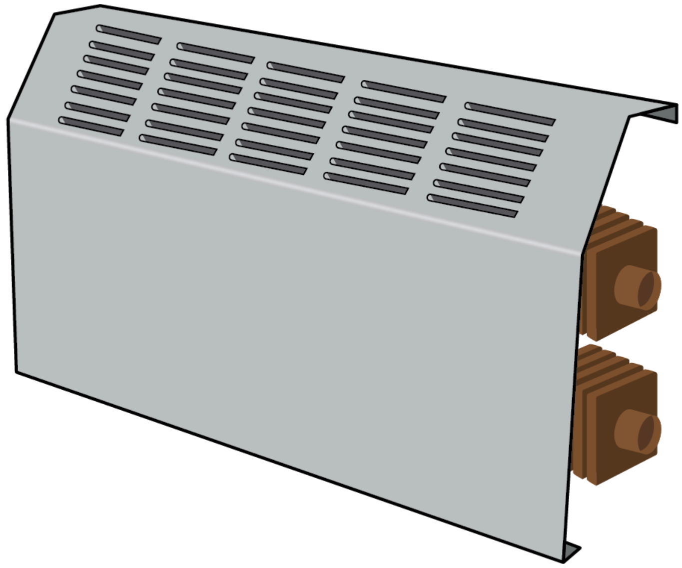


Figure 4 *Wall-mounted convector and finned tube. (Skilled Trades BC, 2021) Used with permission.*

Forced Flow Systems or Fan Coils

Gravity convectors rely on the differences in temperature and density of the air to create convection air currents that move the heat. Forced flow systems combine a heating element, which is a finned tube heat exchanger, similar to those in the gravity convectors, and a fan or blower to move the air. The concept is similar to that of a forced-air furnace — in both cases, warm air is circulated using a fan, but the heat sources differ. A furnace uses **hot flue gases** on the inside of its heat exchanger, whereas, in a forced flow convector, the hot water inside the tubing is the heating medium.

A **hydronic fan coil** (Figure 5) is a type of forced flow convector that can best be compared to a radiator in a car. It consists of small-diameter tubing with a large surface area of aluminum fins attached to it and uses a fan to push air through it. The principle of heat transfer is similar to that of the baseboard wallfin, except the fan coil has more tubing of smaller diameter that the water has to push through. Rather than relying on air currents, the air is forced over the finned tubes using a fan. This increases the heat transfer rate but also increases the resistance to flow that the circulator has to overcome.

Consequently, stronger pumps may be required on fan coils than on baseboard wallfin or convectors. When heating is required, a fan on the upstream side of the coil pushes air across the coil. The air picks up heat and is pushed out directly into the room or into ductwork. Other names used to describe particular types of fan coils are unit heaters, duct heaters, and kickspace heaters. The different names generally relate to their location, but essentially, they all work on the same principle.

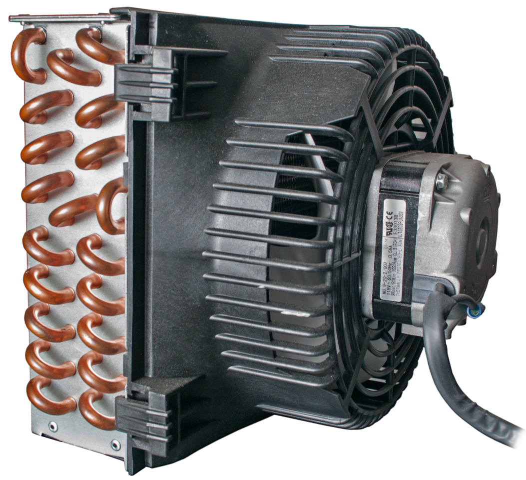


Figure 5 *Fan coil heater. (Skilled Trades BC, 2021) Used with permission.*

Because forced flow systems use a fan to transfer heat from the coil surface to a room, these systems are much more responsive than gravity convection systems. They generally have little thermal mass and low water content, which allows them to respond to a call for heat quickly.

Forced-air heating can cause more dust movement and more noise from the fan than a gravity system. An installer must also consider the fact that as forced flow systems are equipped with a fan, a source of line voltage, wiring, and other electrical controls associated with the fan are required.

Unit Heaters and Overhead Fan Coils

Unit heaters and overhead fan coils are mainly used in commercial buildings, where it may be advantageous to deliver heat from above. This allows the hydronic piping to be kept close to the ceiling and avoids having to run piping down to the floor level in areas where that might be difficult. An example of this would be a large open space, such as a warehouse. Machine shops, service garages, and supermarkets are all areas that would benefit from the installation of unit heaters.

Unit heaters have closely spaced fins on their tubing, much the same as fan coils. The fan forces air between the fins, allowing unit heaters to transfer great quantities of heat, making them suitable for large commercial and industrial applications.

Unit heaters are installed high above the floor. The warmed air is directed downward by a series of louvres attached to the discharge side of the unit. Because they are mounted high in a room, they do not produce uncomfortable drafts at head level. The heat from one unit heater can be circulated through a large area by the action of a few well-placed ceiling fans.

Unit heaters can be either vertical or horizontal. Horizontal units are less expensive, but vertical units will heat a larger area. Smaller units are less expensive than larger ones, although smaller units require higher water flow rates, larger pipes, and a stronger pump to achieve the same level of heat transfer.

Vertical Unit Heaters

Vertical unit heaters, also called projection unit heaters, push air downwards and are mounted near the ceiling. The vertical unit heater has a circular heating element. This element has a manifold tube running through the vertical fins that allows air to flow through the unit (Figure 6). The fan draws the air in through the heating element then forces the heated air toward the floor. Deflecting louvres below the fan can be adjusted to direct the air, or a diffuser cone can be used to decrease drafts.

Figure 6 *Vertical unit heater. (Skilled Trades BC, 2021) Used with permission.*

Vertical unit heaters create downdrafts and updrafts; however, they can often produce warmer and cooler spots within a room. Warm downdrafts occur directly under the unit, and updrafts occur in other areas. Well-positioned vertical unit heaters can mix the air to give even temperatures throughout, and will not create excessive drafts near the floor.

Horizontal Unit Heaters

Horizontal unit heaters (Figure 7) move air at a lower velocity than vertical unit heaters. In situations where unit heaters must be installed at lower levels, horizontal units provide more comfort due to their ability to direct airflow via adjustable discharge deflectors. Horizontal unit heaters should be used in areas less than 4.5 m (15 ft) high, where there is no permanent obstruction to airflow.

Figure 7 *Horizontal unit heater. (Skilled Trades BC, 2021) Used with permission.*

Because of their lower velocity, horizontal unit heaters are used in groups to circulate air throughout a large area. Normally, a fan is mounted behind the heating element, and adjustable air deflectors are mounted in front of the heating element.

Kickspace Heaters or Under-Cabinet Fan Coils

Kickspace heaters (Figure 8) are also referred to as under-cabinet fan coils. These transfer units are designed to be installed in kitchens or bathrooms in the “kickspace” below cabinets. They heat a room in which wall space is limited, and serve as supplementary heat for a radiant floor system. They operate similarly to a unit heater in that hot water is circulated through a finned tube coil. A fan draws air into the kickspace heater and across the coil and moves the heated air out into the room.

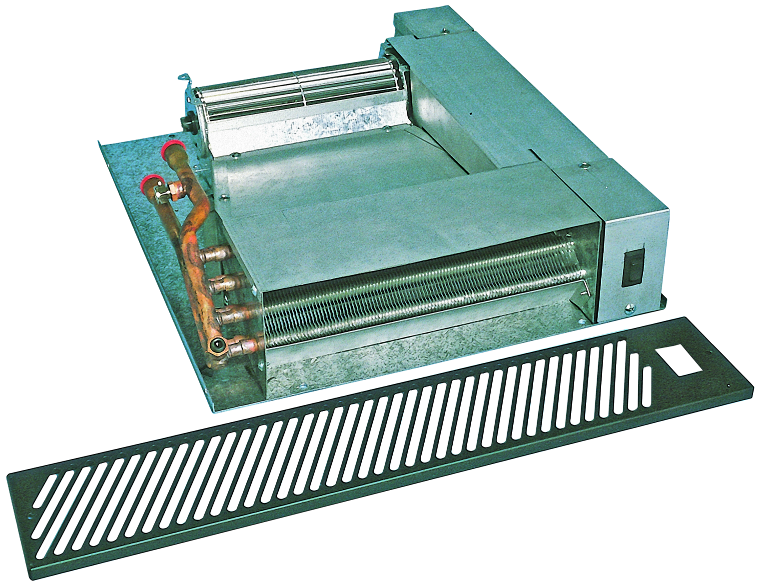


***Figure 8** Kickspace heater. (Skilled Trades BC, 2021) Used with permission.*

Forced-Flow Wall-Mounted Convectors

Forced-flow wall-mounted convector units can also be called wall-mounted fan coils. They are identical to a wall-mounted gravity convector except for the addition of a fan that draws air in through the bottom and moves heated air out through the top. Another version of the convector is recessed into the wall (Figure 9).

Figure 9 *Forced-flow wall convector. (Skilled Trades BC, 2021) Used with permission.*

Using Fan Coils for Cooling

Some hydronic systems can supply heating and chilled water to fan coils in ductwork, but these installations are normally limited to commercial buildings with more sophisticated control systems. Residential and smaller commercial buildings will often install a heat/cool device, such as a heat pump, which is an air conditioner with a reversible function for heating. These units use a single coil in order to provide both heating and cooling.

A hydronic cooling fan coil operates the same as a heating coil, except that chilled water is circulated through the coil rather than warm water. A fan then pushes air past the coil and sends cool air into the room.

Most of the heat transfer units discussed in this section are heat-only, and any unit designated for heating and cooling must also install a drip pan and piping to collect and drain away any condensate (Figure 10) that will form on the coil while in the cooling cycle.

Figure 10 *Condensate drain for a cooling fan coil.*

Radiators

Radiators are so named because of the main way that they emit heat. The term radiator traditionally refers to both freestanding cast-iron radiators and baseboard radiators. The hot water inside the radiator warms its outside surface via conduction, then the warm outer surface of the radiator emits heat to objects in the room via radiation. The warmed objects then emit heat via radiation as well, heating the air in contact with their surface by conduction. As the water temperature inside a radiator increases, the amount of heat it can transfer increases as well. The amount of heat transmitted is also proportional to the overall surface area of the radiator.

Freestanding Cast-Iron Radiators

Cast-iron radiators are highly effective due to their rough, black material. However, they are unpopular today mainly because they are heavy, costly, intrusive, often unsightly, and slow to respond to heating needs.

A freestanding cast-iron radiator (Figure 11) emits about 60% of its heat by radiation and the remaining 40% by convection currents. Other types of radiators may heat more by convection than by radiation. Depending on the location, colour, texture, and temperature of a radiator, the transfer of heat from it may be almost entirely by convection, with only a small amount by radiation.

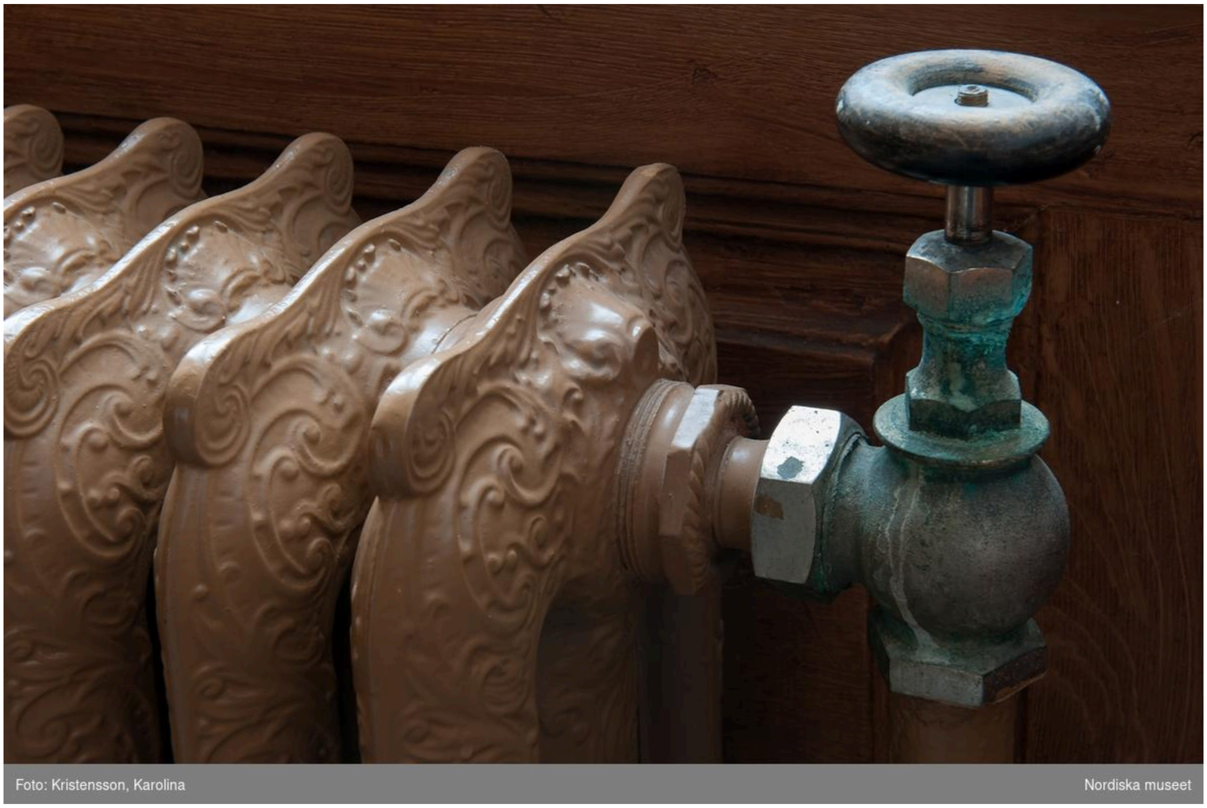


Figure 11 *Freestanding cast iron radiator. (Karolina Kristensson/DigitaltMuseum)* CC BY-NC-ND 4.0 *(https://creativecommons.org/licenses/by-nc-nd/4.0/deed.en)*

Freestanding cast-iron radiators for hot water heating have vertical sections that are interconnected at the top and at the bottom. These interconnections allow water to flow from one section to the next. Cast-iron radiators used for steam systems do not need to be interconnected at the tops, so they will not work if used for hot water heating. Older units have only two large tubes to carry the water from the top to the bottom of the section. In newer units, a section can have many small vertical pipes to perform this function. More pipes increase the surface area from which heat can be radiated.

Generally, the surface area of a section ranges from 0.09 m^2 (1.2 ft) to 0.36 m^2 (4.2 ft). Sections may be connected together by push nipples and bolts in a manner similar to cast-iron sectional boilers. Alternatively, the sections may be connected together by left- and right-hand nipples that have left- and right-hand threads at opposite ends. Left- and right-hand nipples can be tightened by turning them with a bar placed against the lugs within the nipple. This will pull the two sections together simultaneously. Gaskets are used as seals between the sections.

Freestanding radiators are typically 1 m (3 ft) high, 1 m (3 ft) or more long, and 125 mm to 200 mm (5–8 in.) wide; however, sizes may vary. They are well suited for window locations. In most cases, they are constructed to be no wider than a window in order to maximize the use of convection currents within the room.

Freestanding radiators take up a large amount of space. In addition, care must be taken to avoid obstructing these radiators with furniture. Also, because the radiators can be very hot, skin can burn on contact.

Radiant Baseboards

The large amount of space required for freestanding radiators prompted the innovation of cast-iron baseboard radiators. In a cast iron baseboard radiator (Figure 12), each section has a hollow core and is typically 0.3 or 0.6 m (1 or 2 ft) long and about 0.2 m (9 in.) high. Sizes may vary.

The sections are joined together by bolts and push nipples. Baseboard radiators are mounted on the outside walls, in the same manner as baseboard convectors. The end sections of a baseboard radiator have tappings (female threaded connections) for connecting supply and return piping.

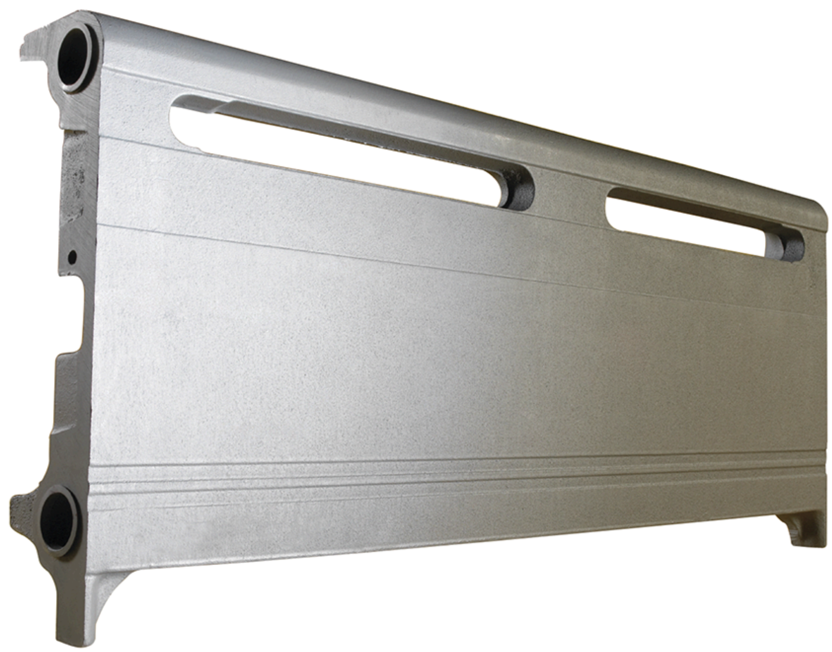


Figure 12 *Section of radiant baseboard. (Skilled Trades BC, 2021) Used with permission.*

The main difference between a radiant baseboard and a finned tube baseboard is that a radiant baseboard contains no fins. Hot water runs through a copper tube within the housing, but rather than heating the air between the fins, it heats the front panel of the housing itself. This heat is then radiated to the objects in the room. Whereas, finned tube convectors do not radiate much heat because the front panel of the housing does not get hot. All the heat within it is trapped between the fins then moved out through convection currents.

Because baseboard units are long, they often extend beyond the dimensions of a window. As a result, there is warmth emitted along more of the cold outdoor wall. This brings a better balance of temperatures to all the cold surfaces of the room. The radiator-convector has air passages that promote some convection.

Panel Radiators vs. Radiant Panels

Although the names sound similar (in fact, there are many similarities between them), panel radiators are very different from radiant panels. Much literature has been written regarding both, and many times the words are used interchangeably. This text will differentiate between the two forms of transfer units.

Panel Radiators

Panel radiators (Figure 13) are factory-made in all shapes and sizes. Panel radiators are mostly constructed from steel, but some are made from aluminum. They contain tubing that circulates hot water, with the tubing pressed into channels in the back side of the panel. The tubing's contact with the panel heats the panel via conduction, which, in turn, emits radiant heat outward into the room. Panel radiators are generally built to project their heat through radiation, but some are built to transfer their heat through convection as well. In that case, the radiator is manufactured to include fins, like a finned tube baseboard, which captures the heat then creates convection currents.

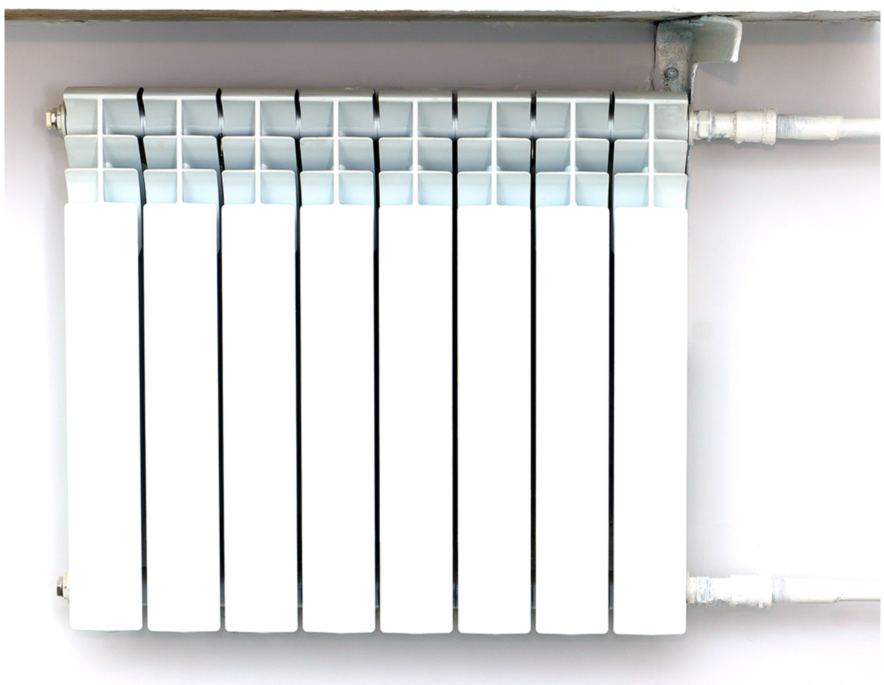


Figure 13 *Wall-mounted panel radiator. (Skilled Trades BC, 2021) Used with permission.*

One of the benefits of panel radiators is the relatively small amount of wall or ceiling space they require. They are available in all shapes and sizes; a situation that could not fit a wallfin baseboard heater due to lack of space will likely accommodate a panel radiator. A good example would be in a kitchen, where wall space is limited.

Panel radiators generally do not contain much water or metal, so they have a low thermal mass. Thermal mass is the ability of a material to absorb and store heat. Heat transfer units with a low thermal mass are less likely to subject the occupants of a room to temperature overshoot.

Radiant Panels

The phrase radiant panel most often refers to heating using the floor as a thermal mass, although there are also situations where either the ceiling or a wall can be used (Figure 14). There are a number of different methods of heating floors through radiant means, and the popularity of these types of systems is growing rapidly in North America.

Figure 14 *Radiant floor panel. (H. Raab (User:Vesta)/Wikimedia Commons) CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/deed.en)*

The practice of using the floor as a thermal mass has been around for thousands of years. Ancient Romans built hypocausts (Figure 15), which took combustion gases from wood fires and ran them underneath a stone floor. Many years later, with advances in technology, hot water was run through piping in the floor. The first piping material used for radiant floors was steel and wrought iron, but in the 1940s, the use of copper became popular. This continued until polybutylene was introduced in the mid-1970s. Polybutylene has since been replaced by cross-linked polyethylene, which is now the material of choice for radiant floor tubing.

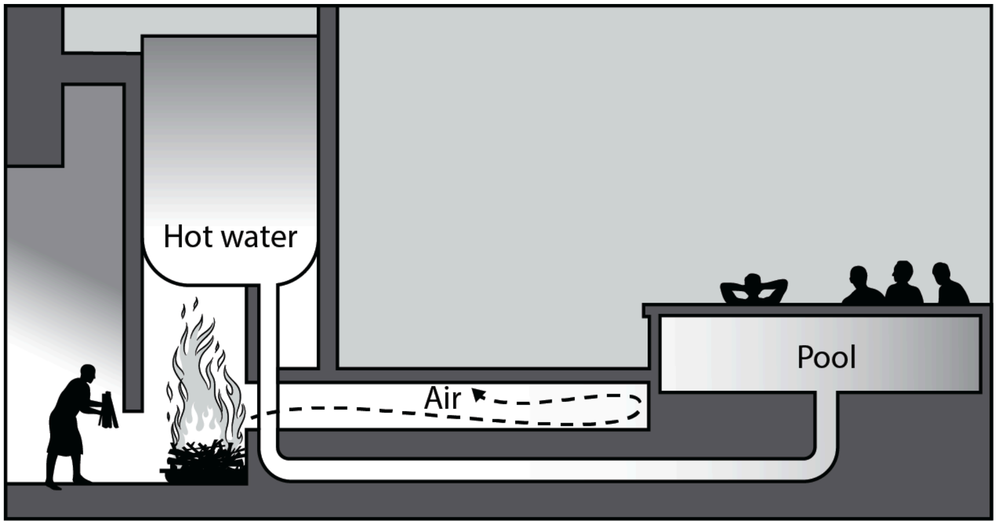


Figure 15 *Roman hypocaust. (Skilled Trades BC, 2021) Used with permission.*

Benefits of Radiant Panels

The main benefit of radiant floor panels is an increased level of comfort. A comfortable room is one in which the temperature "bands" in the room in a way that matches the human body's requirements as closely as possible (Figure 16).

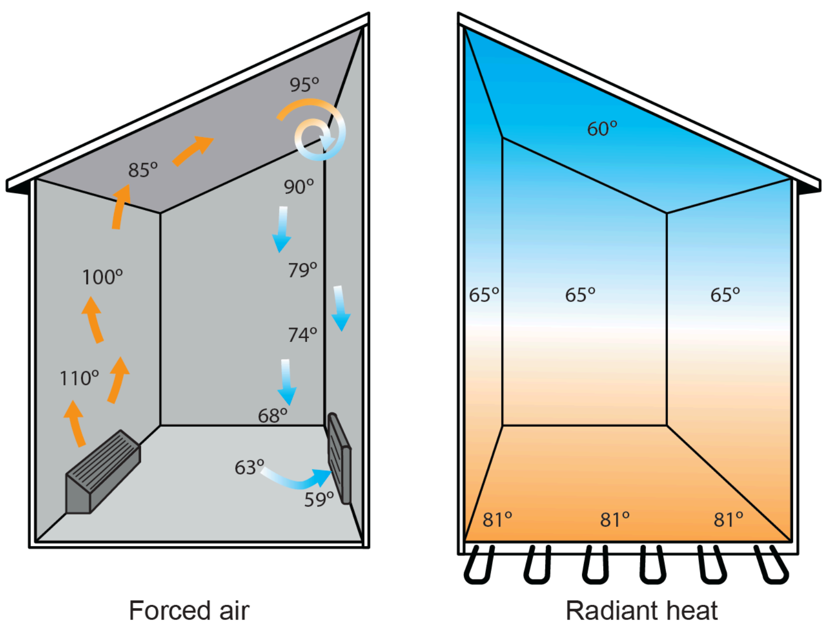


Figure 16 *Forced-air and radiant floor temperatures. (Skilled Trades BC, 2021) Used with permission.*

This is commonly referred to as the ideal heating curve (Figure 17). A room with this curve would be warmest at floor level (where you have contact with the surface), "comfortable" at eye level, and coolest near the ceiling (where not much heat is needed, in any case). The temperature of a "comfortable" room should be approximately 20°C to 22°C (68°F to 72°F) at eye level (approx. 1.5 m or 5 ft above the floor). A radiant floor panel system can deliver this.

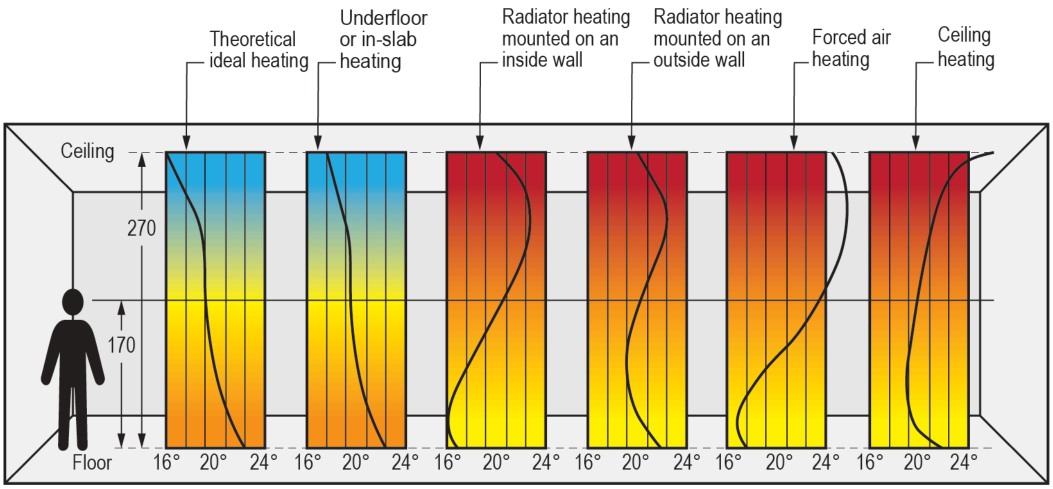


***Figure 17** Heat curves. (Skilled Trades BC, 2021) Used with permission.*

It is important to note that the curve representing forced-air heating is actually in direct conflict with or opposite to what the human body needs to feel comfortable.

Other benefits of radiant floor heating include:

- Does not use or waste interior space.
- Is durable and out of sight.
- Creates minimal drafts.
- Can be used with low-temperature heat sources.
- Can be used to dry floors in an area such as an airplane hangar or truck bay.
- Has a large thermal mass.
- Responds quickly to a loss of heated air such as when a door is opened.
- Has the ability to be "zoned."
- Is the quietest of all heating systems.

Radiant panels can also provide hydronic cooling, but this application is limited to radiant ceiling panels. Circulating chilled water through tubing embedded in a floor would result in people becoming uncomfortable when walking on the floor. Again, hydronic cooling requires more elaborate control strategies to prevent condensation from forming on cool surfaces.

There are many methods of providing radiant heating, some of which include:

- Radiant floor panels
    - Slab-on grade
    - Gypsum thin slab
    - Concrete thin slab
    - Above floor and tube
    - Below floor and tube
    - Suspended tube

- Radiant walls
    - Wall panel radiators
    - Prefabricated radiant wall panels
    - Site-constructed radiant wall panels
- Radiant ceilings
    - Prefabricated radiant ceiling panels
    - Site-constructed radiant ceiling panels

The choice of radiant system depends on many factors, not the least of which is installation cost. Other considerations include:

- Available floor space
- Intended floor coverings
- Amount of glass/doors in outside walls
- Building structural integrity
- Zoning preferences
- Heat source preferences
- Available height

The basics of radiant panel installations are all similar, regardless of which system is chosen. Heated boiler water is pumped through pipes installed on, in, or under the floor. The piping used in most of today's installations is cross-linked polyethylene (PEX). The heat absorbed by the water is released through the walls of the PEX pipe as it travels through the radiant panel and then back to the boiler. It is important to note that the temperature of boiler water used in radiant floor systems is typically no higher than 49°C (120°F). This prevents both the floor and occupants from becoming too warm. Higher-temperature water is used in wall or ceiling panels to increase heat transfer rates, since these areas are usually out of reach and can be hotter.

Some radiant panel systems have the PEX tubing laid in concrete or gypsum (Figure 18). This is known as a "wet system." The concrete or gypsum provides a thermal mass that acts like a big storage tank for heat, absorbing and retaining it. High thermal mass heat transfer units are generally slow to react to a change in temperature, but will hold their heat longer than low-mass units.

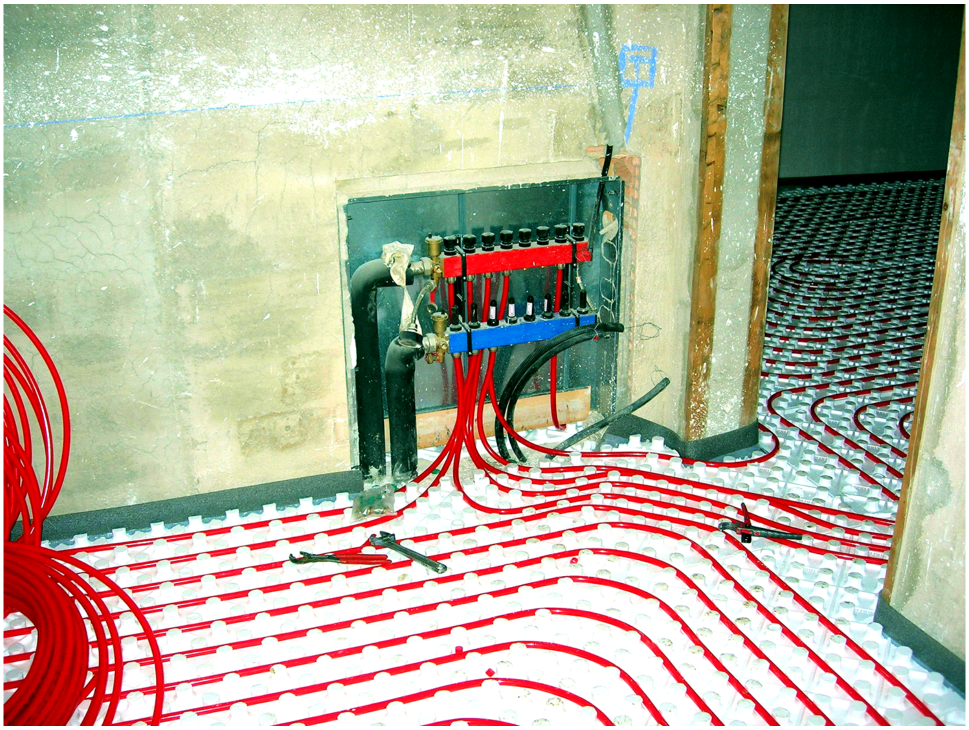


Figure 18 *In-floor radiant tubing connected to manifold. (Chixoy/ Wikimedia Commons) CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/deed.en)*

Self-Test B-3.1: Hydronic Heat Transfer Units

Complete the chapter Self-Test B-3.1 and check your answers.

If you are using a printed copy, please find Self-Test B-3.1 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=54#h5p-7 (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=54#h5p-7)

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B-3.2 Heat Transfer Units Installation

A distinct advantage of hydronic heating is the wide variety of heat transfer units available to suit almost any job requirement.

Selecting Heat Transfer Units

The heat transfer units for a given project must be selected and sized so that comfort and control are achieved in all areas of the building. Economic considerations can greatly expand or restrict heat emitter options. Since most heating systems are designed after the floor plan of the building has been established, the heating design is often a case of making the system fit the plan.

When selecting heat transfer units, the following must be considered:

- Floor and wall finishes
- Blockage of heat movement
- Effects of drafts
- Movement of dust
- Economy
- Design water temperature
- Water temperature drop
- Balancing of heat distribution
- Air elimination

Floor and Wall Finishes

Only radiant panel systems allow complete flexibility in the decoration of the room. All other systems may limit how the room can be arranged or furnished.

All heat transfer units that are baseboard- or wall-mounted are best placed under windows. High units, such as wall-mounted convectors, may be too high and could interfere with the window.

Ideally, heat transfer units should not extend beyond the dimensions of a window because of drapes. When opened, drapes normally hang beside the window. This mass of material above a heat transfer unit would interfere with convection and radiation. Baseboard wallfin convectors are usually used in conjunction with drapery because of their low profile.

There are usually enough exterior walls in a room to fit heat transfer units of sufficient capacity to warm the room. In some situations, it may be necessary to place heat transfer units on an interior wall. This situation occurs in colder climates or if the window location is unsuitable for other reasons.

Consult the owner or architect about where the furniture will be located. They will probably not want the largest clear wall space to be taken up by a heat transfer unit. A larger number of small units on shorter walls may be the better choice.

Manufactured panels have many options for installation location. Ceiling or wall mount locations are used by institutions, such as hospitals and schools, to keep the panels away from contact, avoiding burns and vandalism.

Blockage of Heat Movement

The transfer of heat from a convector is reduced by anything that hinders the movement of air. The transfer of heat from a radiator is blocked by anything that faces the radiator. Instead of heating the intended objects, the object blocking the radiator will absorb the heat.

Because most heat transfer units heat by radiation and convection, it is important to prevent anything from blocking the movement of air or radiated heat. Furniture should not be placed against heat transfer units, nor should the planned placement of heat transfer units ignore possible furnishing intentions.

Radiant panels provide a small amount of heat over a large area, so there is little concern about blockage of heat movement. However, if a significant portion of the floor is covered, the effectiveness of the heat transfer will be reduced. For example, in a warehouse that stacks inventory on the ground, there is little exposed floor space to use as a heat transfer surface. In a home, carpets cover many floors. The radiant panel will warm the carpet through conduction and the carpet will warm the room through radiation. The design of the radiant panels' heat output must take into account the insulating properties of the finished floor covering (carpet, tile, hardwood, etc.).

Effects of Drafts

The installation of heat transfer units must take into account where drafts (infiltration) will take place. The placement of convectors should take into account the movement of cold-air drafts in order to give optimum performance.

Movement of Dust

All heat transfer units that create convection currents will spread dust and other particles. If the movement of dust is a concern, do not use convectors. Radiators that are designed to function with minimum convection are better than those that encourage convection. Manufactured panel radiators and radiant panels cause almost no air and are, therefore, a good choice for dust prevention.

Economy

Radiant systems have advantages in every aspect of installation except initial cost. It is expensive to install a radiant panel and particularly expensive to retrofit them. On the other hand, radiant panels are the least expensive to operate

Design Water Temperature

Hotter water translates into less area of transfer unit needed, and possibly easier placement. For example, running hotter water through baseboard wallfin increases the output in BTU/h per lineal foot, so less wallfin needed.

Alternately, designing a system with a greater area of transfer units will enable the use of lower-temperature heat sources, such as heat pumps and condensing boilers.

Water Temperature Drop

Water temperature drop is also known as a “design temperature difference” or “ΔT.” Most systems are designed to release 20°F (11°C) from the water. If a system is designed for a larger ΔT, the area or length of heat transfer units required will be less.

Balancing of Heat Distribution

If one room has a heat transfer unit that has a higher capacity than necessary, the other rooms may receive less heat than required. Choosing heat transfer units that are suited for the heat demands of the room is an important first step in achieving a well-balanced system.

Air Elimination and Access to Air Vents

The primary function of **air vents** is to rid the system of trapped air. Air vents must be placed at all the high points in a piping arrangement and be accessible for servicing. This will typically be at the return end of every up-fed heat transfer unit. Either manual or automatic air vents can be used.

Installing Heat Transfer Units

> The following includes general installation information regarding different types of heat transfer units. In order to ensure their proper operation, it is important to follow the manufacturer’s installation instructions.

Installing Baseboard Units

Locate baseboard heat transfer units beneath or as close as possible to windows. Baseboard units will often extend beyond the dimensions of the window due to the possible length of wallfin needed.

If a baseboard unit is recessed, it must stay within the dimension of the window. There is little weight carried under a window. The studs on either side of a window will be weight-bearing and will have been strengthened to support the weight that is above the window. The structural integrity of the wall studs cannot be compromised in any way by the installation of heat transfer units.

Because baseboard units can be long, thermal expansion must be considered. Baseboard units will expand 5 mm per 3 m ($\frac{3}{16}$ in. per 10 ft) as they warm from 4°C to 93°C (from 40°F to 200°F).

Drill larger holes through the floor for the piping to allow for this movement. If this is not done, the pipes will rub against the floor and creak loudly. When baseboard units are installed on three adjacent walls, install expansion loops in the piping below the floor at the corners.

The length of the baseboard units required depends on the design's water temperature difference, the heat loss of the room, and the heat output rating of the heat transfer unit. Manufacturer's information will provide the heat output rating based on those criteria. Baseboard units are sold in lengths that are multiples of 2 ft (60 cm). When ordering cabinet and wallfin, use the next longer length available if the length needed falls between two values. The length of wallfin installed inside the cabinet can be shortened so as to not overheat the room.

Do not mix convectors and cast-iron radiators on the same circuit. These heat transfer units heat up and cool down at widely different rates, so the controls will be out of step. If mixing these the two kinds of heat transfer units cannot be avoided, they must be installed on separate piping loops, and each loop must have individual and proper controls.

The baseboard units' location will be mapped out once the building is framed but before it is insulated or drywalled. At that time, make sure that any holes drilled through flooring for pipe penetrations are adequately oversized and that the supply and return piping to the wallfin will end up inside the confines of the cabinets when installed. Testing the installed wallfin will be done through its filling and purging operations.

The installation details for baseboard heat transfer units will vary with the manufacturer's design; however, the following procedures generally apply:

1. Attach the supplied self-adhesive foam strip to the back of the back panel.
2. Attach the back panel to the wall.
3. Attach brackets to the back panel.
4. Attach the fin to the brackets. If using more than one length of fin, connect them together.
5. Install eccentric connectors, valves, and an air vent between the fin pipe and the system piping.
6. Attach the damper assembly.
7. Attach the front cover and the end caps.

The foam strip blocks convection currents from passing through gaps between the panel and the wall. Dust streaks on the wall above the cabinet will be the result of not blocking that air path. If a thermostatic control is being used at the convector, ensure that air can pass freely around the control. If this is not possible (e.g., because of drapes), a thermostatic valve with a remote sensor must be used.

Installing Freestanding Cast-Iron Radiators

Freestanding cast-iron radiators should also be installed under or in front of a window. When installing radiators, they can extend to just under the window sill but never above it. The best place for the unit is at least 100 mm (4 in.) below the sill height. Figure 1 shows the installation of a freestanding cast-iron radiator. If air cannot continuously pass freely over the operator of the thermostatic radiator valve because of curtains or a shelf over the radiator, a thermostatic valve with a remote sensor must be used.

Figure 1 *An installed freestanding cast-iron radiator. (Karolina Kristensson/ DigitaltMuseum)* CC BY-NC-ND 4.0 (*https://creativecommons.org/licenses/by-nc-nd/4.0/deed.en*)

Cast-iron radiators are designated by the square feet of radiation they possess. Radiators are selected from manufacturers' catalogues and specifications.

Installing Panel Radiators

Panel radiators can be installed in a wide variety of ways and be custom built for special situations. Panel radiators come in many configurations. Their selection and installation requirements can differ greatly from those of other heat transfer units, and manufacturers' specific literature must always be consulted.

Figure 2 *An installed panel radiator. (Skilled Trades BC, 2021) Used with permission.*

Installing Unit Heaters

Unit heaters should be selected so that they work at full capacity under design conditions and should not be selected on the basis of floor coverage. Doing so will result in having more heating output than required. In that situation, some units would operate for short periods, while others may not perform as expected, resulting in inconsistent heating.

Horizontal-flow unit heaters are usually suspended from the ceiling by two or four threaded rods, known as "redi-rod" in the industry. Always follow manufacturers' installation guidelines in order to conform to safety and warranty considerations. Normally, unit heaters have attachment points for rods near each of the four corners. The rods should be double-nutted at each connection to ensure that vibration will not loosen the nuts. They may also need to be seismically restrained (see the information later in this section for suspended heating or cooling coils).

Unit heaters can be installed equally well on a direct return or a reverse return piping system. In either case, connect the supply water to the bottom connection on the unit heater and the return to the top connection. This allows air to be vented from the piping and the unit heater in the direction of water flow. Furthermore, counterflow piping direction is promoted for most heat exchangers, and isolation valves should be installed on both supply and return piping connections.

Locate the units in areas of the greatest heat loss, such as by doors and windows. For efficiency and ease of operation, unit heaters should be placed so that they assist each other in stirring the air. Cross-currents of air and fans that oppose one another are counterproductive. The size and discharge capacity of the unit heaters must also be taken into consideration when spacing them for efficient airflow. Consult the manufacturer's guide for placement when designing a system.

On large buildings with open areas, unit heaters can be arranged along the perimeter without being concerned about the building's central area, where heat loss will be minimal. Figure 3 shows a circular installation pattern (or parallel arrangement) used for a perimeter installation. The fans set up a circular flow around the room near the ceiling. Smaller air currents will circle from the front to the back of the fan, producing vertical and horizontal currents that will dampen or de-intensify the main air current.

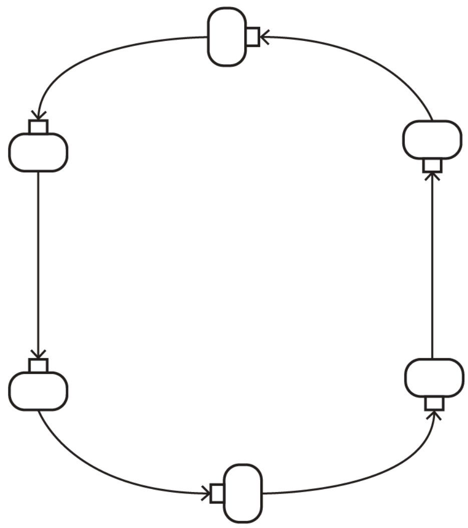

Figure 3 *Circular airflow of unit heaters.*
(Skilled Trades BC, 2021) Used with permission.

Figure 4 shows an installation pattern for a building that has high heat loss on all walls and large doors at either end. The units are installed along two lines down the middle of the building but blowing in opposite directions. Also, the units nearest the doors are positioned to blow air toward the doors.

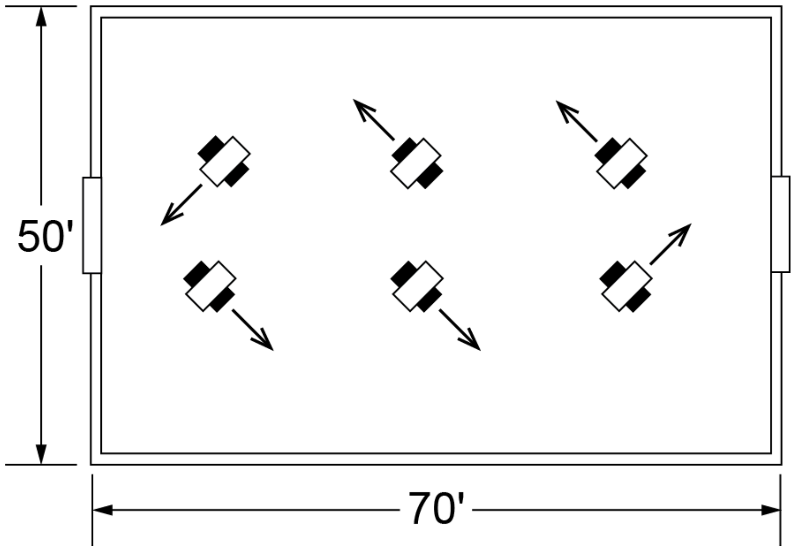

Figure 4 *Horizontal unit heaters arranged for four high heat loss walls. (Skilled Trades BC, 2021) Used with permission.*

Unit heaters are well suited for locations where there is need for quick heat recovery, such as in a service station or other buildings with large and frequently opened doors. Figure 5 shows the installation of three horizontal unit heaters in a service station. In the automobile areas, the units blow air through the entire space toward the door. The office has the third unit. To prevent the air from the service areas from coming into the office, this unit should have a return air plenum or duct. A return air plenum is constructed on-site to move cooler air from the bottom of the room that the unit is installed in to the unit.

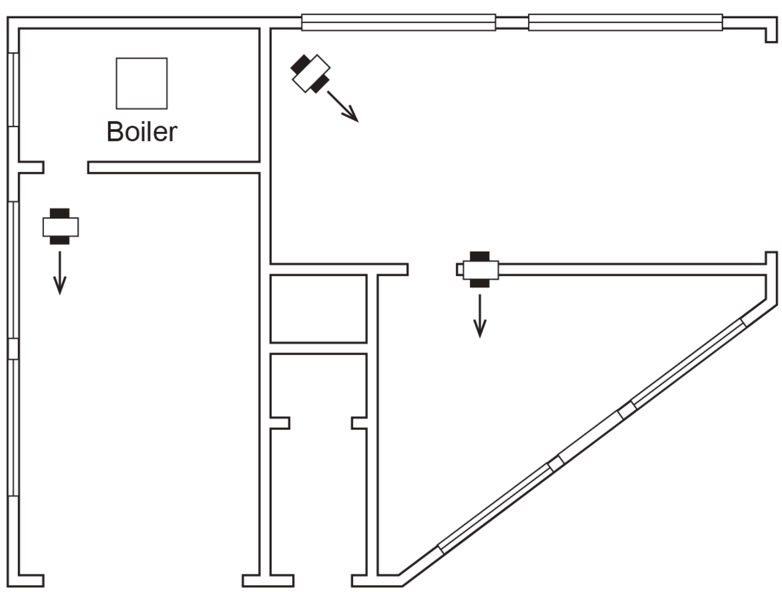

Figure 5 *Horizontal unit heaters in a service station. (Skilled Trades BC, 2021) Used with permission.*

Vertical Unit Heaters

Vertical unit heaters should be installed 17 m (50 ft) apart for best performance. They should be installed high enough that dampers directing airflow cannot be tampered with once they are positioned properly.

Self-Test B-3.2: Heat Transfer Units Installation

Complete the chapter Self-Test B-3.2 and check your answers.

If you are using a printed copy, please find Self-Test B-3.2 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=56#h5p-8 (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=56#h5p-8)

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Trades Training BC. (2021). B-3: Install hydronic transfer units. In: *Plumber Apprenticeship Program: Level 2*. Industry Training Authority, BC.

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Self-Test B-3.1 Hydronic Heat Transfer Units

Complete Self Test B-3.1 and check your answers.

1. How does a convector heat a room?
    a. Heats the air
    b. Heats the objects in the room
    c. Heats the floor
    d. Heats the walls

2. What are convectors that have fans called?
    a. Fan heaters
    b. Baseboard heaters
    c. Unit heaters
    d. Gravity convectors

3. What does a convector that does not depend on gravity for circulation use?
    a. Fan
    b. Baseboard convector
    c. Unit heater
    d. Circulation pump

4. What are convector cabinets usually made of?
    a. Aluminum
    b. Wood
    c. Steel
    d. Plastic

5. Convectors should be installed under windows.
    a. True
    b. False

6. What type of pipe is the heating element of a convector usually made of?
    a. Plastic
    b. Louvred
    c. Finned
    d. Slotted

7. Complete the following statement: "The amount of heat given off by a hot gravity circulation convector is usually regulated by an adjustable _____________ ."

a. Louvre
b. Fin
c. Dial
d. Fan

8. What are the two types of unit heaters?

   a. Water and air
   b. Forward and reverse
   c. Gravity circulation and forced circulation
   d. Vertical and horizontal

9. In which of these heat transfer units is steel **not** used?

   a. Baseboard convector
   b. Wall-mounted convector
   c. Freestanding cast iron radiator
   d. Baseboard radiator

10. What is the most common type of tubing used today in radiant floor installations?

   a. Polybutylene
   b. Polyethylene
   c. Copper
   d. PEX

Answer Key: Self-Test B-3.1 (#chapter-answer-key-self-test-b-3-1) is on the next page.

Answer Key: Self-Test B-3.1

1. a. Heats the air
2. c. Unit heaters
3. a. Fan
4. c. Steel
5. a. True
6. c. Finned
7. a. Louvre
8. d. Vertical and horizontal
9. c. Freestanding cast iron radiator
10. d. PEX

Self-Test B-3.2 Heat Transfer Units Installation

Complete Self Test B-3.2 and check your answers.

1. Which type of heat transfer unit is not normally installed under a window?
   a. Wall-mounted convectors
   b. Unit heaters
   c. Baseboard radiators
   d. Freestanding radiators

2. Complete the following statement: “On the same circuit, do not mix convectors with _____________ .”
   a. Manufactured panels
   b. Unit heaters
   c. Baseboard radiators
   d. Freestanding cast-iron radiators

3. Complete the following statement: “If a baseboard heat transfer unit is to be recessed, it must not _____________ .”
   a. Extend beyond the dimensions of the window
   b. Be installed on an inside wall
   c. Be installed on an outside wall
   d. Be mixed with convectors

4. As the maximum cold temperature drops, what is the effect on the amount of glycol that would be needed for the water/glycol solution?
   a. Becomes unimportant
   b. Becomes less
   c. Stays the same
   d. Becomes greater

Answer Key: Self-Test B-3.2 (#chapter-answer-key-self-test-b-3-2) is on the next page.

Answer Key: Self-Test B-3.2

1. b. Unit heaters
2. d. Freestanding cast iron radiators
3. a. Extend beyond the dimensions of the window.
4. d. Becomes greater.

B-4 HYDRONIC HEATING PIPING AND COMPONENTS

Plumber Apprenticeship Program – Level 2

Hydronic expansion tank. (TRU Open Press) CC BY NC SA (https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en)

B-4 Hydronic Heating Piping and Components Introduction

The purpose of a hydronic piping system is to transport the heated or chilled water to the emitters. This is done through a network of distribution piping and components.

There are many different options when it comes to the installation of a piping distribution system and all of the components that go along with it. A properly designed system will deliver the heating or cooling to where it is needed, in the correct amount, and at the appropriate time. A poor design will detract from the effectiveness of any system and leave the home or building owner with a system that is less than satisfactory. For these reasons, the design of a hydronic system must consider the system as a whole. All too often, the heating or cooling source is given the most attention, and the distribution system becomes more of an afterthought. This inevitably leads to a great many issues that can take time and money to correct.

Learning Objectives

After completing the chapters in this section, you should be able to:

- Describe components involved in planning and installing hydronic heating and cooling piping systems.
- Describe installation requirements for pumps, valves, and components.
- Describe different types of hydronic piping distribution systems.
- Describe installation requirements for hydronic piping systems.

Terminology

The following terms will be used throughout this section. A complete list of terms for this section can be found in the **Glossary**.

- **air purger:** (Also called air separators or air scoops); A device used in heating and cooling systems to remove larger air pockets and air bubbles from water, which can cause problems like noisy pipes or reduced efficiency. The device helps to keep the system running smoothly by ensuring that the water is free from air. Also see **microbubble resorber**. (Section B-4.1)
- **backflow preventer:** A device that stops water from flowing backward into the water supply. It ensures that water doesn't get contaminated by preventing dirty or used water from flowing back into clean water lines. (Section B-4.2)
- **balancing valve:** A valve used in a piping system to control and balance the flow of fluid to ensure that

each part of the system gets the right amount of flow. It also helps to make sure that all sections of the system work efficiently and evenly. (Section B-4.3)

- **ball valve:** A valve that controls the flow of liquid using a ball with a hole through the center. When the ball is turned so that the hole lines up with the pipe, liquid flows through. When the ball is turned so that the hole is perpendicular to the pipe, the flow is blocked. Ball valves are known for their quick and easy on-off operation. (Section B-4.1)
- **bypass valve (quick fill valve)**: A valve that allows water to quickly flow around a system or component. It is used to quickly fill up or bypass parts of the system, making it easier to manage and maintain. (Section B-4.2)
- **cavitation:** The process where tiny bubbles or vapor pockets form in a liquid when the pressure drops below the liquid's vapor pressure. These bubbles can collapse suddenly, creating strong shock waves and high temperatures. Cavitation can occur in pumps, propellers, and other machinery. While it can be useful in some processes (like cleaning or mixing), it can also cause damage to equipment over time. (Section B-4.1)
- **centrifugal pump:** A device that moves liquids by using a rotating impeller. The impeller spins the liquid outward through centrifugal force, pushing it through the pump and into the pipes of a system. Centrifugal pumps are commonly used in water supply, heating, and cooling systems to efficiently move fluids. (Section B-4.1)
- **check valve:** A valve that allows liquid to flow in only one direction. It automatically closes when the liquid starts to flow backward, preventing backflow. Check valves are used to keep liquids from flowing the wrong way in a pipe system. (Section B-4; Section B-4.2)
- **circulating pump (or circulator):** A device that moves water through a heating or cooling system. It helps distribute hot or cold water to different parts of a building, ensuring even temperature control. Circulating pumps are essential for systems like radiators and underfloor heating. (Section B-4; Section B-4.1)
- **component isolation:** The process of shutting off or separating a specific part of a system, like a pipe or valve, from the rest of the system. This is done to allow for repairs or maintenance without affecting the entire system. It ensures that only the isolated part is affected while the rest continues to operate normally. (Section B-4.2)
- **direct return:** A piping system design where the water or fluid returns directly to the source or starting point after passing through each section of the system. This means that each section gets the same temperature fluid and helps in balancing the system evenly. (Section B-4.3)
- **equalizer line:** The vertical piping at the end of the header going back to the boiler return connection. Its job is to return any water that slips out of the boiler with the steam, and to balance the pressure between the supply and the return sides of the boiler. Without a properly sized equalizer, water can back out of the boiler. (Section B-4)
- **expansion tank:** A special tank in a heating or cooling system that helps manage the pressure caused by changes in temperature. When the water heats up and expands, the expansion tank provides extra space for the water to go, so the system doesn't get too much pressure. (Section B-4.1)
- **feedwater valve:** A valve that controls the amount of water that enters a system and lowers the pressure to a safe level. It helps keep the water pressure steady and safe for the system. (Section B-4.2)
- **flow regulation:** The control of how much fluid flows through a pipe or system. It involves adjusting valves or other devices to manage the flow rate, pressure, or speed of the fluid. This helps ensure that the system works efficiently and that different parts of the system receive the correct amount of fluid. (Section B-4.2)

- **gate valve:** A valve that controls the flow of liquid by raising or lowering a gate or barrier inside the valve. When the gate is fully open, the flow of liquid is unimpeded. When the gate is closed, it blocks the flow completely. Gate valves are good for stopping or allowing flow but are not ideal for regulating flow. (Section B-4)
- **globe valve:** A valve that controls the flow of liquid by moving a disc up and down inside the valve. This movement allows for precise control of the flow rate. Globe valves are often used when it's important to adjust or regulate the flow of liquid rather than just stopping or allowing it. (Section B-4; Section B-4.2)
- **hydronic heating:** A system that uses water to heat a building. Water is heated in a boiler and then pumped through pipes to radiators or underfloor tubing. As the hot water moves through these pipes, it releases heat into the rooms, keeping them warm. (Section B-1.4; Section B-2; Section B-4)
- **impeller:** A rotating part of a pump or other machine that moves fluid by spinning. It has blades that push the fluid outward from the center, creating flow and increasing pressure. Impellers are commonly found in devices like centrifugal pumps and are essential for moving liquids efficiently. (Section B-4; Section B-4.1)
- **microbubble resorber:** A device used in heating and cooling systems to remove very tiny air bubbles (microbubbles) from water that may not be captured by standard air purgers. By getting rid of the bubbles, the microbubble resorber may more efficiently help the system work better and more quietly. See also **air purgers**. (Section B-4.1)
- **relief valve:** The relief valve protects the boiler against a runaway fire. On space-heating steam boilers, the relief valve is set to pop open and relieve pressure at 15 psi. This is the limit for any low-pressure boiler. (Section B-4.2
- **reverse-return:** A piping system design where the fluid flows in a way that the return path is the opposite of the supply path. This means that the last section to receive the fluid is the first to return it, helping to balance the system and ensure even heating or cooling throughout. (Section B-4.3)
- **series loop:** A type of piping arrangement where the water or other fluid flows through one section of the system, then directly into the next section, like a chain. In a series loop, all the sections are connected in a single path, so the fluid passes through each one in order. (Section B-4.2)
- **thermosiphoning:** A process where a liquid moves naturally without the need for a pump, because of temperature differences. When a liquid gets heated, it becomes less dense and rises. Cooler, denser liquid then moves in to take its place. This creates a natural circulation of the liquid. It's often used in heating systems and solar water heaters. (Section B-4.3)
- **venturi:** A device that controls the flow of fluid through a pipe by narrowing the pipe at a certain point. This narrowing causes the fluid to speed up and the pressure to drop. Venturis are often used to measure flow rates or to mix fluids. (Section B-4.3)
- **zone valve:** A valve used in heating or cooling systems to control the flow of fluid to different areas or zones of a building. It allows you to control the temperature in each zone separately, so you can heat or cool only the areas that need it. (Section B-4.4)

B-4.1 Hydronic Distribution System Components

This chapter will look at some common components found in a hydronic distribution system.

Circulating Pumps

The **circulating pump**'s job is to pump liquid through the piping system, from the heat source to the heat emitter and back to the source again. Because a hydronic heating system is a closed system, "circulator" is a more accurate description for this device.

The circulator must provide enough flow to meet the heat demands of the system while overcoming the head losses (pressure losses) of the system components. An undersized pump will not move enough water to provide enough heat transfer; an oversized pump will be noisy and cause excessive system pressure, increased water velocities, and higher energy consumption.

Types of Circulators

A hot-water heating system circulator will most likely be a **centrifugal pump**, which consists of an electric motor spinning an **impeller** within a housing (**volute**) containing liquid (Figure 1).

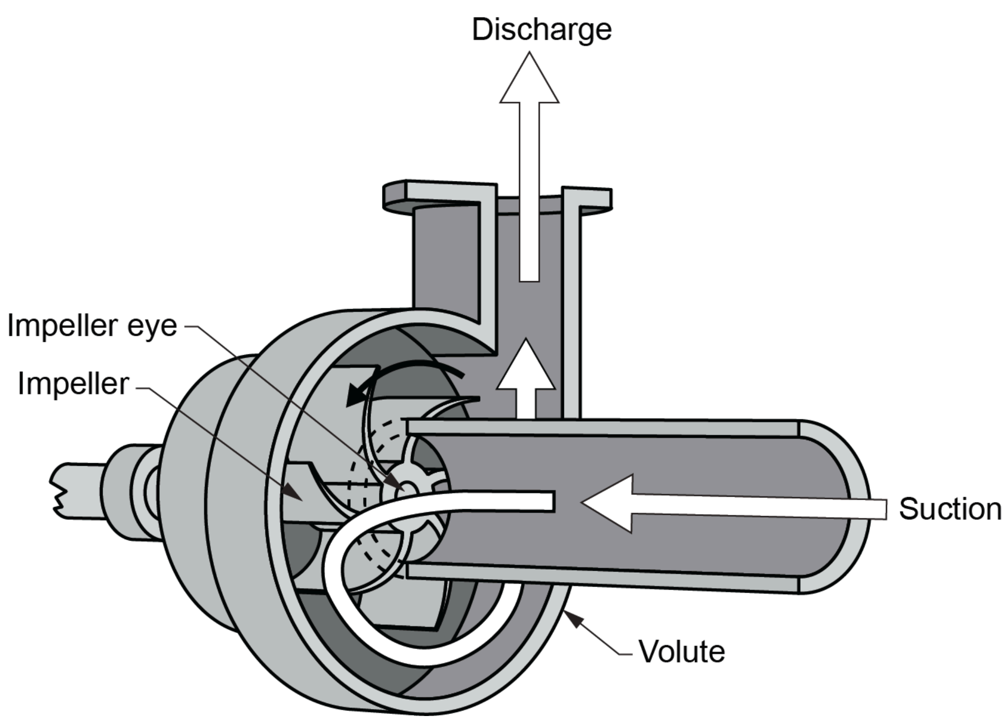

Figure 1 *Centrifugal pump showing the impeller eye and the volute. (Skilled Trades BC, 2021) Used with permission.*

The water enters the circulator's body through the inlet opening, which is very near the centre or **"eye" of the impeller**. This will be the point of lowest pressure in the entire piping system. As the impeller spins, centrifugal force throws the water from the impeller eye out along the blades (vanes) of the impeller to the impeller tips, which will be the point of highest pressure in the system. There is now an imbalance in pressures between the eye and the tips of the vanes of the impeller, and the only way for these pressures to equalize is for the water at the impeller tips to circulate through the system piping, eventually returning to the eye of the impeller.

Pressurized water from the impeller flows between the tips and the widening cavity inside the circulator's casing, known as the volute, until it exits through the discharge port. The construction of the impeller dictates the pressure and volume of water created: the wider the impeller, the higher the volume of water it can move. The longer the vanes and the greater their number, the more pressure the impeller can create. Note that two seemingly identical circulators can have vastly different pressure and volume outputs. Always consult the manufacturers' literature before selecting a circulator.

Wet-Rotor and Three-Piece Circulators

Circulator motors may be water-cooled or air-cooled. Water-cooled circulators are referred to as wet-rotor circulators. Older style conventional circulators are air-cooled; they are also referred to as three-piece circulators or dry-rotor pumps.

Wet-Rotor Circulators

The wet-rotor circulator shown in Figure 2 has a water-cooled motor and water-lubricated bearing. These pump motors must be installed in the horizontal position, regardless of the orientation of the pump body, to ensure that the bearings will always be in contact with the system water. This is how the bearings are kept cool. Some models have a plug at the end of the motor shaft to vent air prior to pump startup.

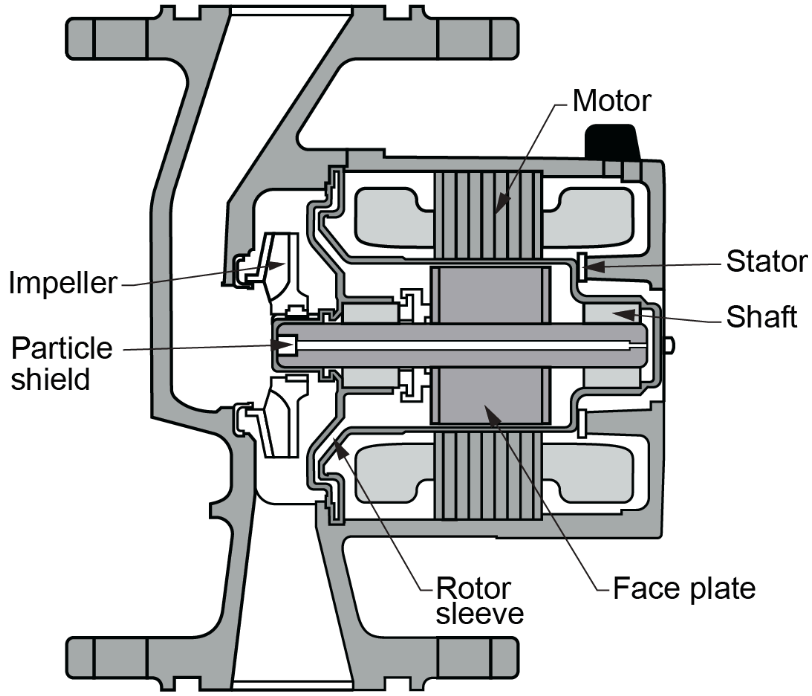

Figure 2 *Wet-rotor circulator cutaway. (Skilled Trades BC, 2021) Used with permission.*

Dry Rotor Circulators

Dry rotor, or three-piece circulators (Figure 3), consist of a motor assembly, pump assembly, and coupling assembly. The motor is air-cooled, while the bearings are oil-lubricated. There are usually three oil filler receptacles for the motor and shaft bearings that must be oriented vertically and faced upward for initial filling and periodic oiling. Facing the oil filler receptacles in a downward position will prevent lubrication and allow any manufacturer's oil to drain out of the bearing assembly, resulting in damage to the bearing. Like the wet-rotor circulators, the three-piece variety requires the shaft to be horizontal unless it is of the vertical shaft design. Dry-rotor pumps must have their bearings oiled upon installation and at regular intervals, as prescribed by the manufacturer.

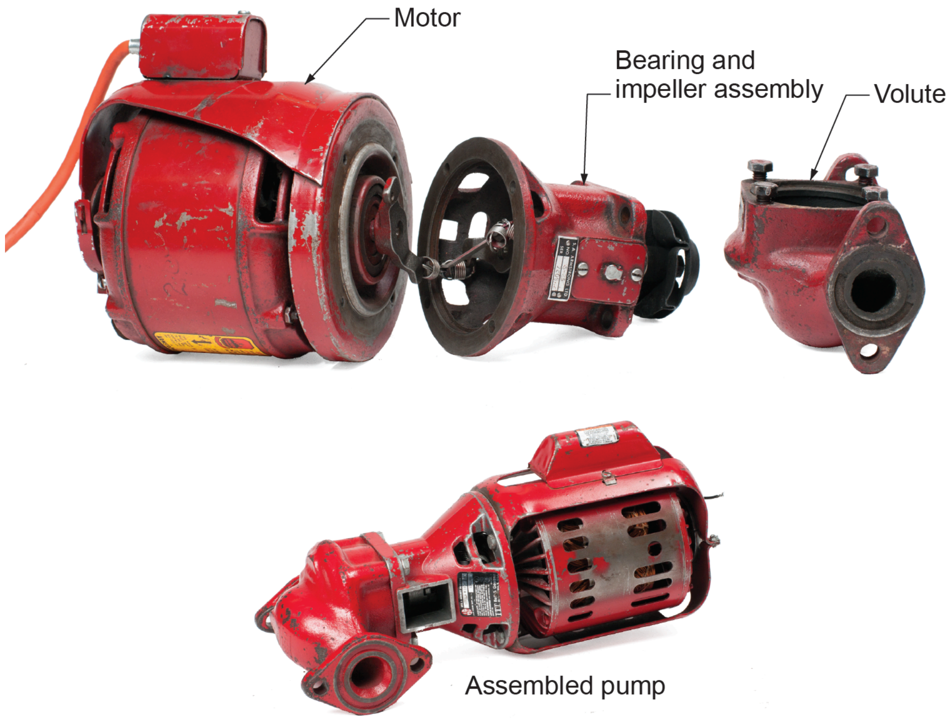

Figure 3 *Three-piece circulator. (Skilled Trades BC, 2021) Used with permission.*

Pump Location

Circulating pumps can be installed anywhere in the piping system because the systems are closed and balanced, but the preferred location is on the supply main immediately downstream of the compression tank.

The pump moves water by developing a difference in pressure between its inlet and outlet. This pressure differential can be either a help or a hindrance to the system. It is extremely important to understand the concept of the "point of no pressure change" (the location where the compression tank or its piping is connected to the system piping) and how the placement of the pump in relation to that point can make an important difference in system operation.

The "point of no pressure change" concept was discovered decades ago by an engineer working for Bell & Gossett, a well-known manufacturer of hydronics and a pioneer of the industry. The concept is simple: to change the set pressure in a piping system with an expansion or cushion tank connected to it, water would have to be added to or drained from the system. Whatever the pressure is in the air side of the **expansion tank** is what the pressure will be at the point of no pressure change on the "water side" of the expansion tank. Where the pump is placed can affect system operation, in particular, air control.

A pump does what it does because it creates a pressure differential between its inlet and its outlet. If the pump is installed immediately downstream of the point of no pressure change, it must add its developed pressure to the system's static fill pressure to create flow.

For example, if the pump can develop a 13 psi (91 kPa) pressure differential between its inlet and outlet where the static fill pressure is 12 psi (84 kPa), then the pressure at the pump's outlet in this position will be 25 psi (175 kPa) (Figure 4).

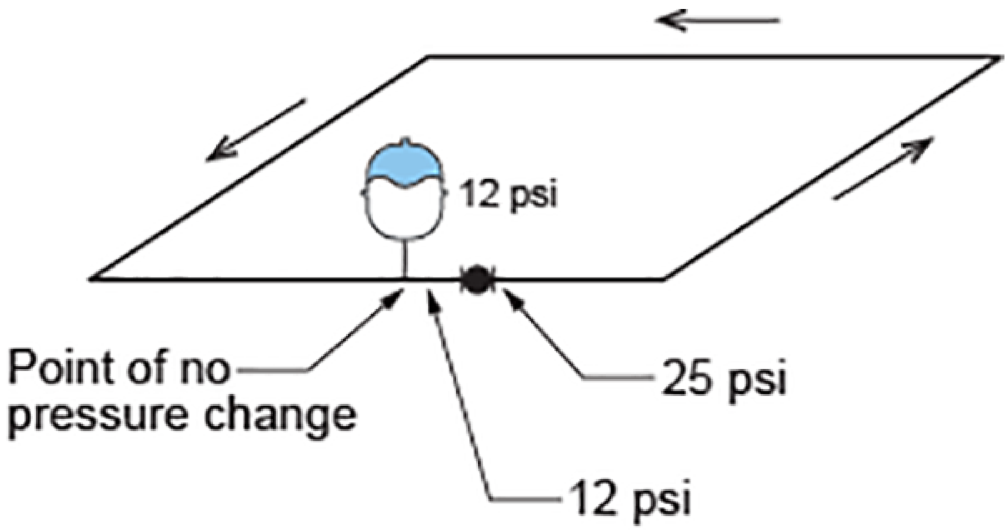

Figure 4 *Pump installed downstream of the point of no pressure change. (Skilled Trades BC, 2021) Used with permission.*

This extra pressure will help keep air entrained in the water, which helps prevent circulation problems caused by air coming out of the water and pocketing. Water cannot move if air is present.

If the pump is installed immediately upstream of the point of no pressure change, the pump cannot add to the system's static fill pressure. To develop a difference in pressure between the pump's inlet and outlet, the pump must drop its inlet pressure. For example, if the pump can develop 13 psi (91 kPa) and the static fill pressure is 12 psi (84 kPa), then the pressure at the pump inlet will be −1 psi (−7 kPa) (Figure 5). This pressure is below atmospheric pressure, so air will be pulled into the system wherever possible, such as through the automatic air vents, the stem packing on the valves near the pump, or the pump's mechanical seal. This also contributes to pump cavitation. Cavitation is a phenomenon where air bubbles are pulled out of water through high temperature and sub-atmospheric pressure, which allows steam to be generated within these air bubbles. The vapour pockets or cavities travel along the impellor vanes and slam back into the water at the impellor tips. Besides the popping, churning, and banging noises this creates, it also causes a lot of wear on the impellor and will greatly harm or destroy it in a very short period of time. Avoid this situation.

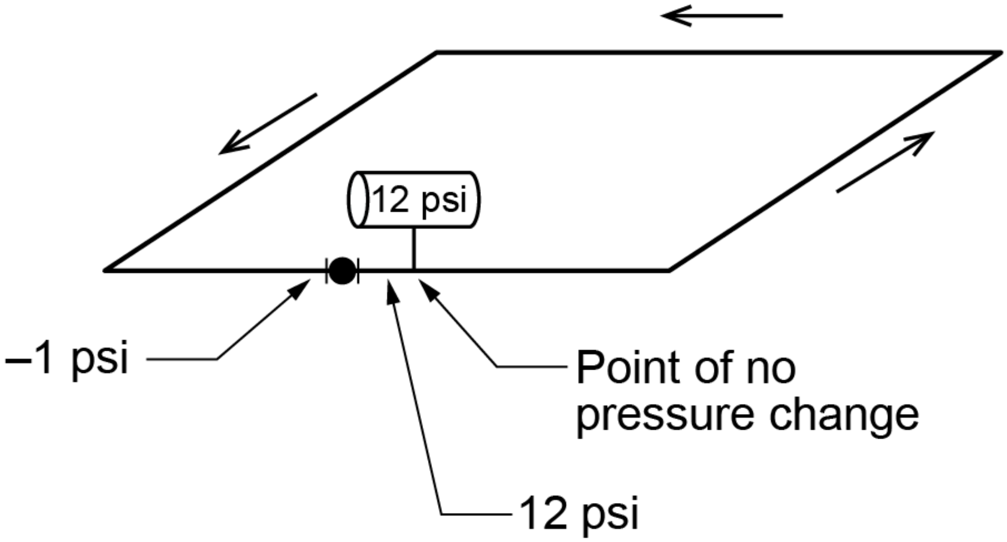

Figure 5 *Pump installed upstream of the point of no pressure change. (Skilled Trades BC, 2021) Used with permission.*

If the same pump is installed halfway around the system from the point of no pressure change, it will show half of its pressure differential ($6\frac{1}{2}$ psi or 45.5 kPa) as an increase at its outlet and half of its pressure differential ($6\frac{1}{2}$ psi or 45.5 kPa) as a decrease at its inlet.

The total pressure at the outlet will therefore be:

$$12\text{ psi} + 6\tfrac{1}{2}\text{ psi} = 18\tfrac{1}{2}\text{ psi} \quad \text{or} \quad 84\text{ kPa} + 45.5\text{ kPa} = 129.5\text{ kPa}$$

The total pressure at the inlet will be:

$$12\text{ psi} - 6\tfrac{1}{2}\text{ psi} = 5\tfrac{1}{2}\text{ psi} \quad \text{or} \quad 84\text{ kPa} - 45.5\text{ kPa} = 38.5\text{ kPa}$$

In a residential system, the pump will not normally be powerful enough to develop more pressure than the static fill pressure. As a result, even if the pump is installed immediately upstream of the point of no pressure change, it will not be capable of reducing the pressure to a sub-atmospheric level.

For example, if the pump can develop 5 psi (35 kPa) and the static fill pressure is 12 psi (84 kPa), then the pressure at the pump's inlet will be:

$$12\text{ psi} - 5\tfrac{1}{2}\text{ psi} = 7\text{ psi} \quad \text{or} \quad 84\text{ kPa} - 35\text{ kPa} = 49\text{ kPa}$$

There is little danger of air being pulled into the system, but there are other negative consequences.

Older packaged boilers often come complete with a pump installed on the return main connection to the boiler. This location was not ideal at the time; it merely allowed the manufacturer to ship it installed and pre-wired. If the water makeup is installed upstream of a pump located upstream of the point of no pressure change, then the pressure-reducing valve may open when the system starts because it senses a reduction of the system's static fill pressure.

In this example, the fill valve will open and increase the pressure by 5 psi (35 kPa). As a result, the actual fill pressure increases to:

$$12\ \text{psi} + 5\ \text{psi} = 17\ \text{psi} \quad \text{or} \quad 84\ \text{kPa} + 35\ \text{kPa} = 119\ \text{kPa}$$

If the compression tank was sized and set for a static fill pressure of 12 psi, it is now too small.

On larger non-residential applications, the pump will often be strong enough to develop a pressure differential that is greater than the static fill pressure. In these cases, it is critical that the pump not be installed immediately upstream of the point of no pressure change. Figure 6a shows a good way to install one pump in relation to other components. Figure 6b shows how to modify this design for two pumps.

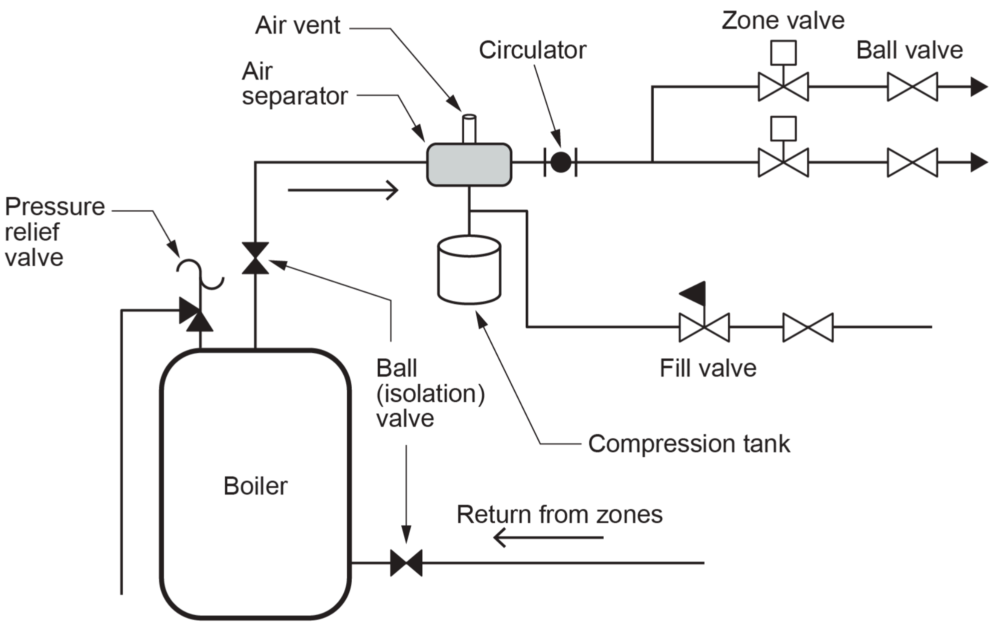

Figure 6a *Installation of one pump with respect to other components. (Skilled Trades BC, 2021) Used with permission.*

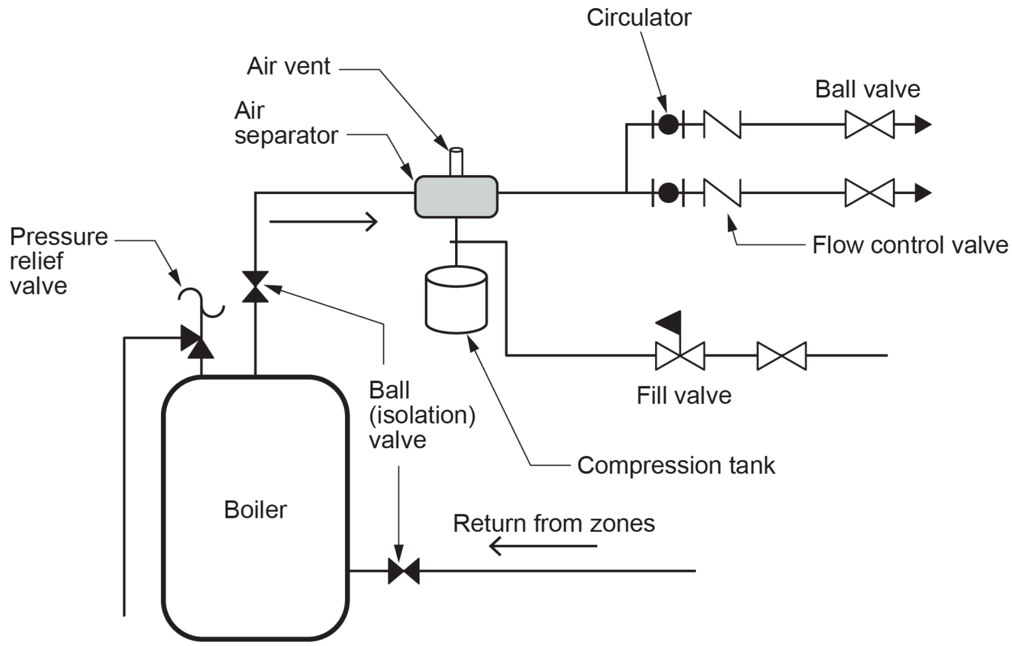

Figure 6b *Installation of two pumps with respect to other components. (Skilled Trades BC, 2021) Used with permission.*

The actual installation of pumps will depend on building and system design. Pumps should also be installed as low in the system as possible. Pumps are less likely to cavitate if there is always enough positive pressure at the pump inlet. Most modern systems will have at least one system pump and a separate boiler pump to ensure the correct flow rate throughout the boiler, regardless of the system flow requirements. Modern condensing boilers will require the boiler pump to be located where it pumps into the boiler return (Figure 7). This is required due to the higher pressure drop created by the condensing boiler's heat exchangers.

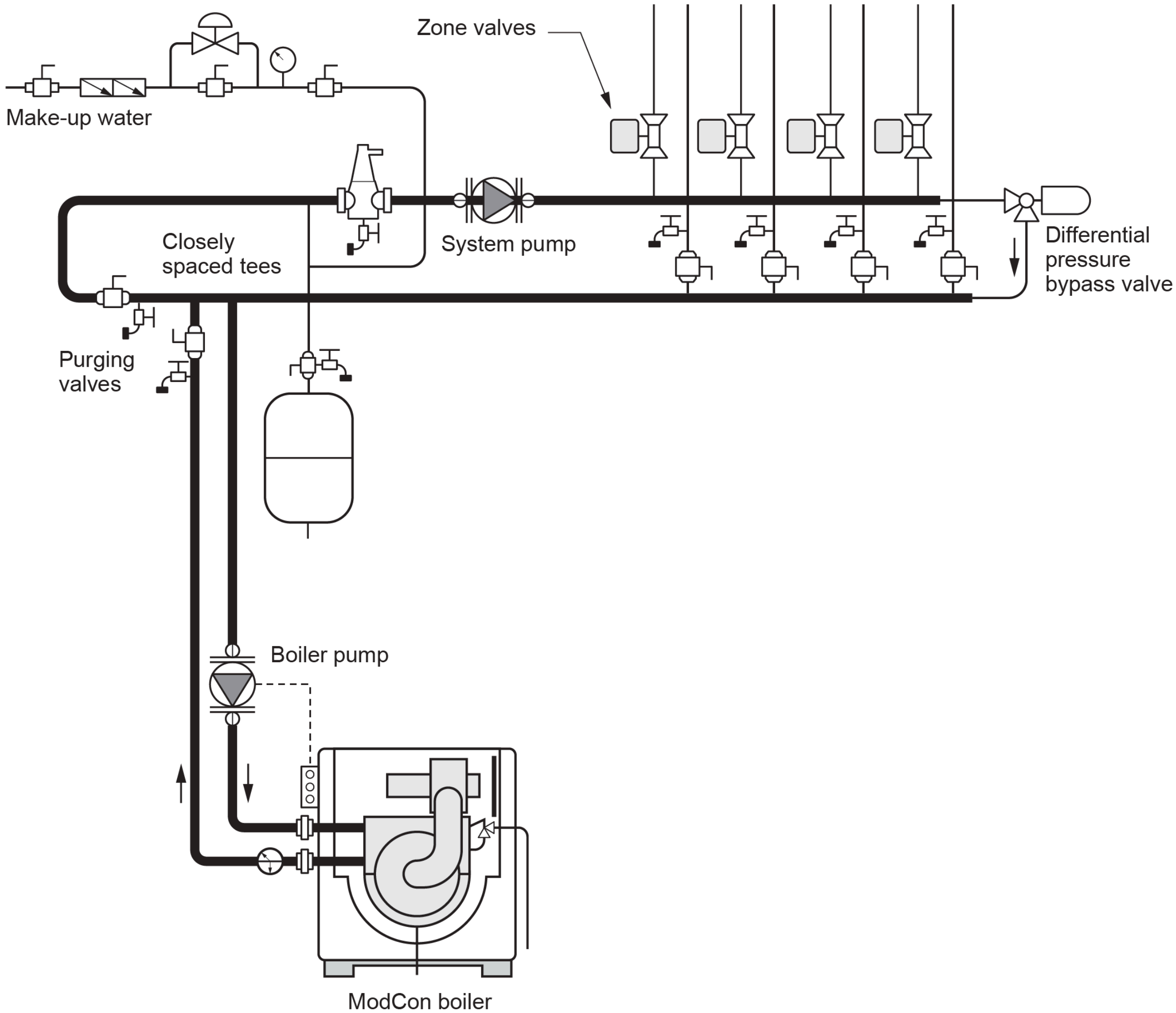

Figure 7 *Condensing boiler pump arrangement. (Skilled Trades BC, 2021) Used with permission.*

Pump Installation

Circulating pumps will have their inlets and outlets identified; if they are not immediately visible, remember that the inlet water is directed to the eye of the impeller. Circulators can be installed on horizontal or vertical piping, but it is important to check the manufacturer's specifications to see which orientation is preferred for a particular pump.

A circulator must be properly supported. For systems up to 50 mm (2 in.) in size, the piping itself is able to support the circulators(s). Larger flanged pumps are normally mounted on a base on a concrete pad on the floor, and piping must be brought down from overhead and run back up again. "Base-mounted" pumps (Figure 8) require special considerations when designing the supply piping and components to avoid creating a swirling action or turbulent flow within the fluid just before it enters the eye of the impeller. Laminar flow is desirable upstream of the impeller.

Figure 8 *Base-mounted pump. (Skilled Trades BC, 2021) Used with permission.*

The swirling action creates a “hole” in the water, which causes cavitation of the impeller. **Cavitation** is the phenomenon where water boils, even at low temperatures, because the air in the solution is being pulled out of the liquid. The impeller can be destroyed fairly quickly due to the air bubbles being compressed and re-absorbed into the water at the impeller’s tips. This can also cause a great deal of noise, ranging from churning and popping sounds to the sound of hammers and bolts being thrown around inside the pump casing. Cavitation can best be avoided by correctly sizing the circulator, not restricting the flow into the impeller, “straightening” the water that enters the circulator, and installing the circulator where the static pressure in the system is highest. If the layout requires elbows close to the pump, special fittings with straightening vanes can be installed on the inlet to straighten out the flow pattern of the water (Figure 9).

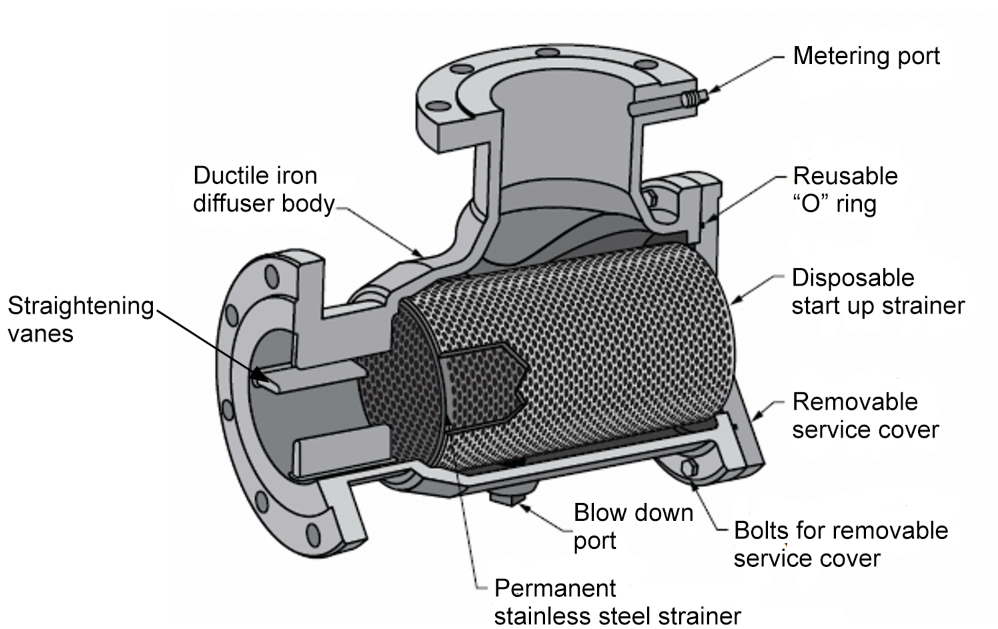

Figure 9 *Suction guide for base-mounted pump. (Skilled Trades BC, 2021) Used with permission.*

The motor of a three-piece circulator can be quite heavy and cause damage and misalignment if installed incorrectly. When mounting larger pumps, always use vibration mounting brackets (Figure 10). Pumps can sometimes vibrate when operating and, over time, mounting brackets can shift and move if no allowance is made for vibration.

Figure 10 *Vibration mounting brackets. (Skilled Trades BC, 2021) Used with permission.*

Circulators in a hydronic system may need to be serviced, repaired, or replaced. For these reasons, the ability to both isolate and remove a circulator from a hydronic system is necessary. Isolation is usually done using ball valves, whereas flanges are used to easily remove the pump from the system. Figure 11 shows a small circulator flange kit.

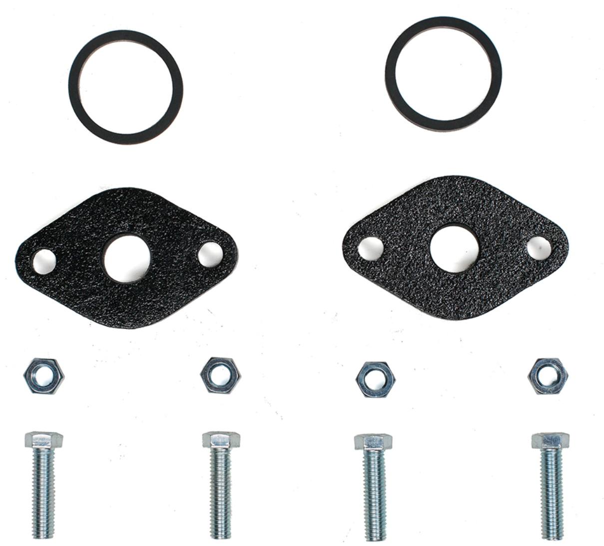

Figure 11 *Flange kit. (Skilled Trades BC, 2021) Used with permission.*

Often, a flange and ball valve can be supplied as one unit, referred to as an isolation flange (Figure 12).

Figure 12 *Isolation pump flanges. (Skilled Trades BC, 2021) Used with permission.*

A flange has three parts. One side of the flange is part of the pump assembly. The other side of the flange is attached to the system piping. Between the two flanges is an O-ring or gasket that is compressed to form a seal. The flange parts are tightened together using two or more bolts, depending on the pump size and flange configuration.

Figure 13 *Strainers. (Skilled Trades BC, 2021) Used with permission.*

System Pumps in Parallel and Series

It is possible to obtain more flow or higher head pressure by using two pumps. Two circulators of the same size installed in series will approximately double the pressure, whereas two circulators of the same size installed in parallel will approximately double the water flow (Figure 14).

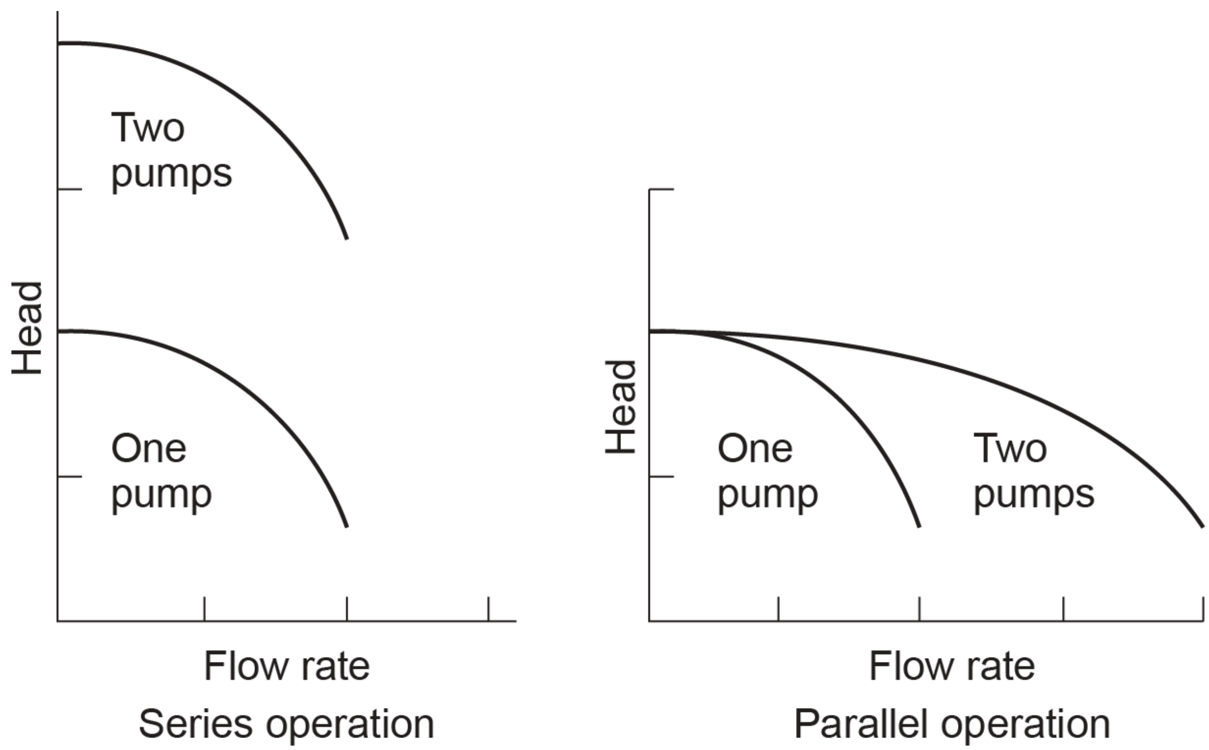

Figure 14 *Two pumps in series and in parallel. (Skilled Trades BC, 2021) Used with permission.*

Selecting the Pump

There are two factors that determine the selection of any centrifugal pump: flow rate and head pressure.

The flow rate dictates the amount of heat delivered to the system. The pump must be capable of sending enough heat out to offset the heat losses from design conditions. The amount of water needed to achieve this depends on the system's temperature drop (ΔT or Delta T). Temperature drop refers to the difference in the temperature of supply water leaving the heating source and return water re-entering the source.

The second factor, head pressure, is the pressure that is needed to overcome the friction within the piping system. The pump must be able to supply a head pressure at least equal to the pressure loss of the circuit that has the most friction. When pressure is referenced, the language of pumps is in feet of head, which can also be expressed as pounds per square inch or psi. One foot of head equals 0.433 psi; inversely, 1 psi. equals 2.31 ft of head.

With the flow rate and head pressure established, the proper circulator can be chosen using the manufacturer's performance curves, which show the interaction of these two variables. The goal is to choose the smallest pump that can supply the required flow and head pressure.

Determine Temperature Drop and Flow Requirements

Temperature drop refers to the difference in the temperature of water between when it leaves the boiler and when it returns to the boiler. The temperature of the water drops because heat is transferred from the water to the room or zone through heat transfer units. Heat transfer units will have a designed heat output at a particular temperature.

Flow is the rate of water movement through a heat transfer unit, circuit, zone, or system. It is normally measured in US gallons per minute (USGPM). Temperature drop, flow, and BTU/h are closely related. The goal is to choose a flow rate that is neither too slow, causing a greater temperature drop in the water, nor too fast, requiring larger pumps and increased pipe sizes.

A temperature drop of 20°F (11°C) is most commonly used in the heating industry; however, for radiant in floor systems, a temperature drop of 10°F (5°C) is becoming common to achieve a more even surface temperature. It was initially chosen by the Institute of Boiler and Radiator Manufacturers (IBR) so that non-condensing boilers operating at 180°F would not have water returning to the boiler below dew point, which causes condensation and corrosion on the boiler's heat exchanger surfaces. Dewpoint temperature at atmospheric pressure is approximately 127°F (53°C). Return water temperature to a non-condensing boiler should never be lower than 140°F (60°C).

Calculate USGPM Flow Rate

The formula to calculate USGPM when the BTU/h heat requirement is:

$$\text{USGPM} = \Delta T \times 60 \times 8.33$$

Where:

- ΔT is the temperature drop desired, usually 20°F.
- 60 is the number of minutes in an hour.
- 8.33 is the mass in pounds of a US gallon of water.

With this formula, the standard for the heating industry is 1 USGPM = 10,000 BTU/h. (The exact calculation comes to 1 USGPM = 9,996 BTU/h.)

If the flow is too slow, there will be too much temperature drop, causing the heat transfer unit to operate at a lower temperature than the system design, and the building may not be adequately heated. If the flow is too fast, there will not be as much temperature drop, causing the heat transfer unit to operate at a higher temperature than the system design. This can cause the system to overreact to a call for heat, possibly overshooting the room temperature setpoint.

Designers can allow for more or less temperature (ΔT) being transferred out of the water, but the number 10,000 is quite convenient for determining flow rates, and designers typically stay with that number.

So, as an example, a building with a heat loss of 66,000 BTU/h will require a flow rate of 6.6 USGPM.

$$66\,000 \div 10\,000 = 6.6 \text{ gpm}$$

Determine Head Pressure

The amount of flow that a pump can supply is inversely proportional to the amount of head pressure it can overcome. In other words, if the amount of system head pressure increases, the amount of flow that the pump can deliver decreases.

Manufacturers publish charts called curves that show the capabilities of their products. For each size of a pump, the chart shows a curve that represents the capacity of the pump. Figure 15 shows a typical pump sizing chart for three small pumps. Once the designer has calculated the system head loss that will be created at the flow rate needed, known as the pump's "operating point," it is plotted onto the pump graph. For a pump to be able to deliver the necessary flow, the operating point plotted onto the graph must be below the curve of a chosen pump.

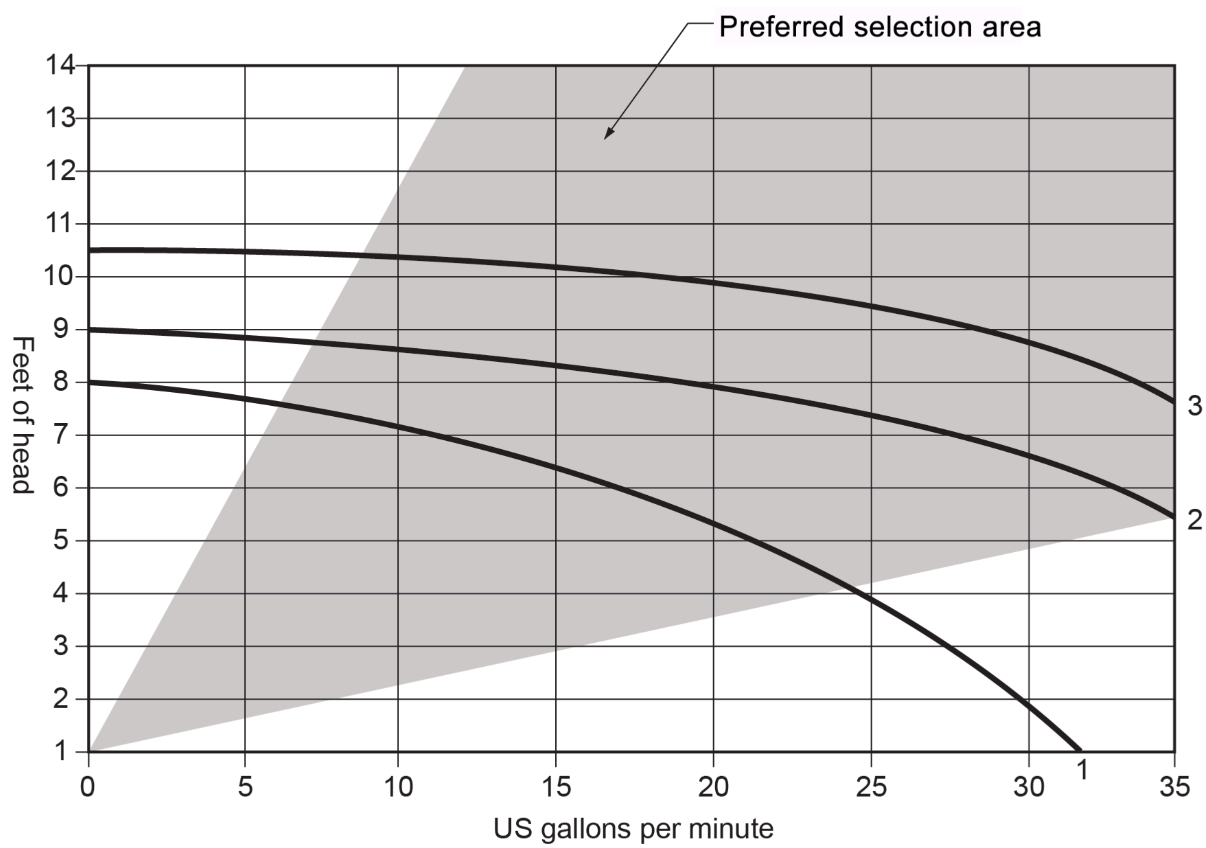

***Figure 15** Pump sizing chart. (Skilled Trades BC, 2021) Used with permission.*

The best overall efficiency of a centrifugal circulator occurs at a flow rate that is close to the center of the **pump curve**. The two diagonal lines on the chart define the preferred selection area (the shaded part) as determined by this manufacturer. Notice that the flatter pump curves have a wider efficiency flow range.

High-Head and Low-Head Pumps

Some circulators are designed to produce relatively high heads at lower flow rates while others produce lower stable heads over a wide range of flow rates. These differences are fixed by the circulator design, particularly the diameter and width of the impeller. The larger the diameter or length of the blades, the higher the pressure; the wider the impeller, the greater the volume. Impeller speed, measured in revolutions per minute (rpm), is the third factor in determining the capacity and pressure of a circulator.

Notice the two pump curves shown in Figure 16. The high-head pump has a steep curve, and the other pump has a flat curve. Interestingly, both of these pumps have the same horsepower motor rating and operate at the same rpm, so the difference between them would be the result of differing impeller designs.

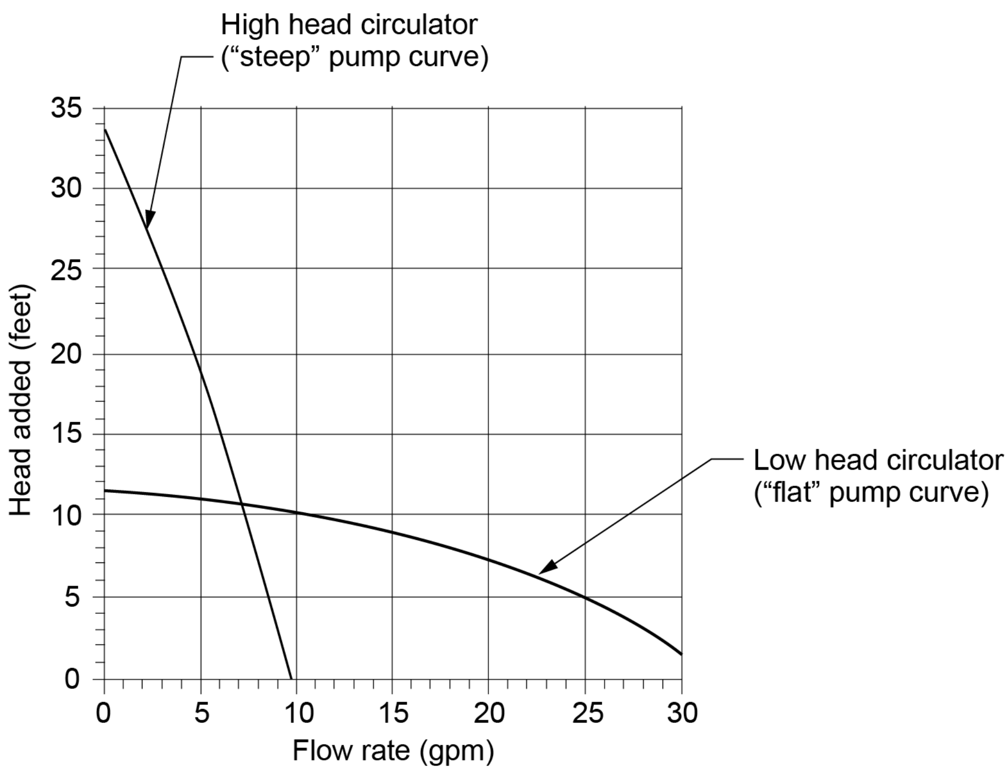

Figure 16 *Pump chart. (Skilled Trades BC, 2021) Used with permission.*

Pump curves (Figure 17) are a very good tool for matching the performance of a circulator to the flow requirements of a piping system. In many cases, the pump manufactures will plot the pump curves for an entire series or family of their circulators on the same set of axes so that performance comparisons can be made (Figure 18). Whenever a hydronic system is zoned using valves, it is best to choose a pump that has a relatively flat curve to limit the increase in differential system pressure as zone circuits are closed.

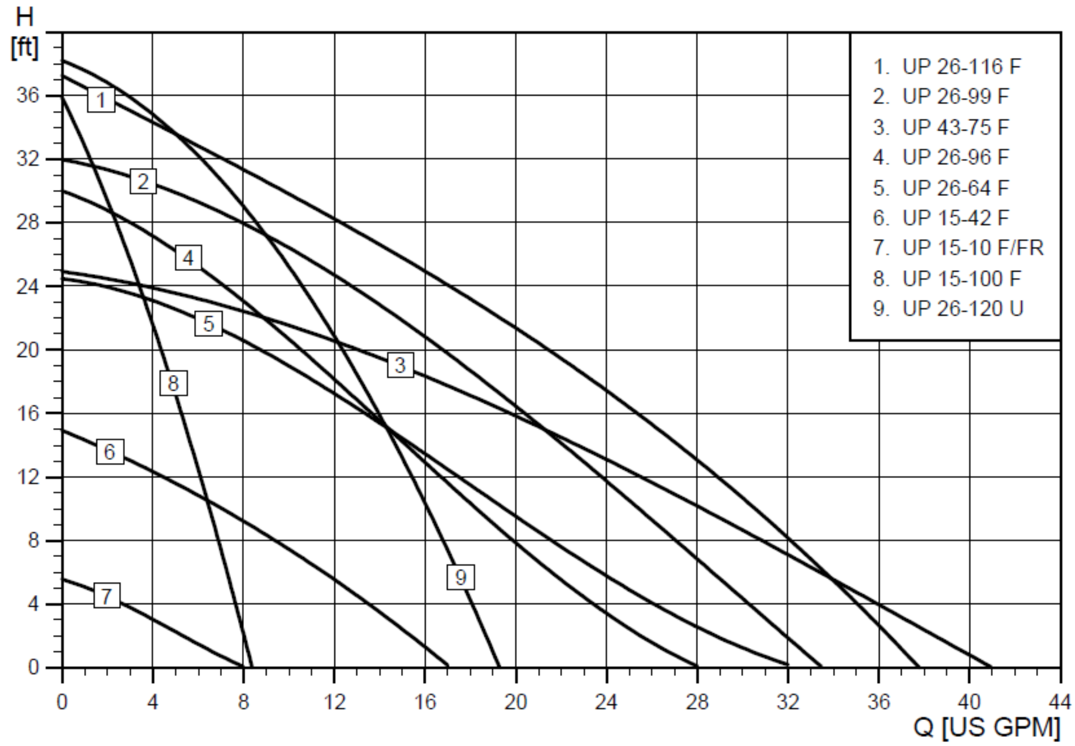

Figure 17 *Grundfos UP series cross-reference performance curves. (Grundfos, n.d.) Fair Dealing (https://laws-lois.justice.gc.ca/eng/acts/c-42/page-6.html#docCont:~:text=Exceptions-,Fair%20Dealing,-Marginal%20note%3A)*

Multi Speed Pumps

Most pump manufacturers also produce multi-speed pumps (Figure 18) in addition to their single-speed varieties. They have a switch that can be set to one of usually three speed positions (Figure 18). Once again, the flow rates and head output of a three-speed pump would be represented on a pump graph for that particular pump. For example, the previously shown Figure 15 chart could represent the curves of the three different pump speed settings of the same circulator. One may think it safest to operate the pump at the highest speed to ensure the system flow required but this would be less efficient than operating at a pump curve that is closest to the required system head.

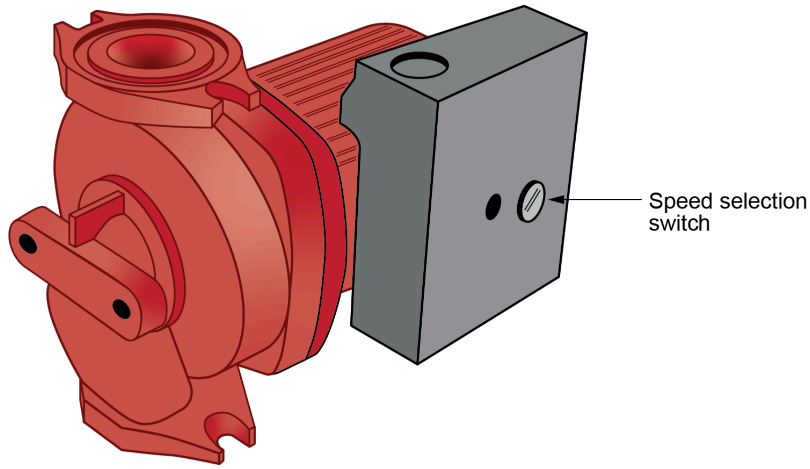

Figure 18 *3-Speed circulator. (Skilled Trades BC, 2021) Used with permission.*

The use of small variable speed circulators has become common, as they help match the changing flow rate requirements of multi-zone valved systems. These variable speed/variable voltage circulators use an input control signal to operate the pump at different speeds and maintain a system pressure differential or setpoint temperature. For example, the pump curve shown in (Figure 20) shows the pump maintaining a set head pressure on a multi-zone valve hydronic system by decreasing its speed and reducing the flow as zone valves within the system are closed. In this situation, the pump's pressure sensor interprets the increased system resistance head as a sign that less flow is needed in the system.

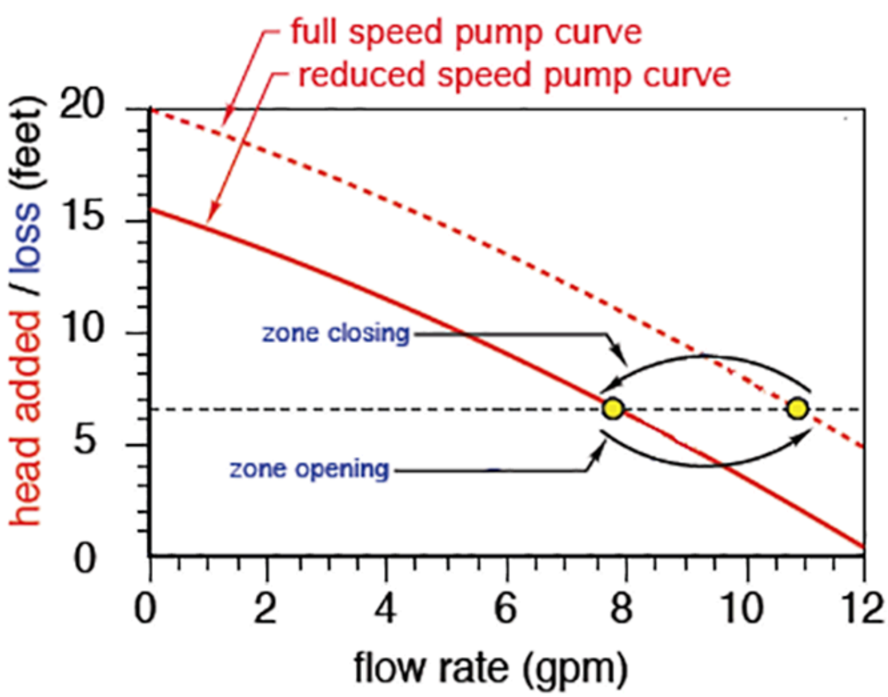

Figure 19 *Variable speed circulator maintaining constant pressure. (Image [modified] from Caleffi, idronics™, 2015). Caleffi S.p.A. All rights reserved. Used with permission.*

In addition to pressure regulation, these variable-speed circulators with electronically commutated motors use significantly less electricity when operating at reduced speeds.

This application of variable speed motors is the opposite of the strategy described in Section B-1 for a variable speed forced air fan, where the blower will ramp up its speed to overcome the air flow restriction created as the filter starts to collect dust.

Expansion Tanks

As water is heated, it expands. This expansion must be allowed to prevent an increase in pressure inside a closed-loop piping system. A properly sized and placed expansion tank (Figure 21) allows room for the water to expand and contract.

Figure 20 *Hydronic expansion tank. (TRU Open Press)* CC BY NC SA *(https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en)*

Calculating Volumetric Thermal Expansion

Most tradespeople have come to know that water expands when it is heated. Just how or why that occurs may be of interest to some, but at the end of the day, most people only want to know what the results of the heating of water are and how to cope with them. Many issues in hydronic heating systems, as well as in domestic potable hot-water systems, are caused by not acknowledging and dealing with the thermal expansion of water before it occurs. The following section will explain how the thermal expansion of water's volume works.

All forms of matter are affected by heat. Expansion of matter occurs in all directions, but, due to the shape of some objects (e.g., pipe), expansion is more profound in its length rather than in its area or volume. The area of a material, when heated, can increase. The increase in the area of a sheet of aluminum, before being welded, can be calculated and adjustments can be made to minimize warping.

Water is an unusual liquid with unique properties. For most temperatures, water does indeed expand when it warms and contract when it cools. Molecules of water are always in contact with each other. When heat is added to water, the molecules gain energy and move more rapidly, creating more space between them. This translates to the water taking up more space than when it was cooler. There are no more molecules of water than there were before; they simply take up more space, so the water is said to be less dense.

On the other hand, if the temperature of that same amount of water is lowered, the molecules' vibrations slow down and they occupy less space, so the water's volume decreases, while its density increases over what it was at the higher temperature. This trend continues down to 4°C (39°F), where the density begins to decrease again. The volume starts to increase because the water molecule (H_2O) is starting to crystallize into ice.

In crystallizing, the hydrogen atoms bonding to the oxygen atoms take up more space than they do as a liquid. This expansion can be quite significant, increasing by approximately 9% of its original volume and be powerful enough to split pipe, tanks, and fittings.

The expansion rate of water is considered "non-linear," meaning that the ratio used to calculate expansion will vary with pressure and salinity (saltiness) as well as with the starting temperature of the water. The amount of this variance is so minimal that, for all intents and purposes, these ratios can be assumed to be constant.

For water, the volumetric expansion ratio to use is 0.00021/°C (0.00012/°F).

What this means is that, for every 1°C (1°F) increase in temperature of a volume of water, measured in whatever units of volume preferred (m^3, ft^3, in^3, cm^3, USG, Imp gal, etc.), the volume will increase by a factor of that unit.

For example, if a hot-water heating system is filled with fresh water at 10°C (50°F) and heated to 82°C (180°F), the water's expansion can be calculated using the following formula:

$$\text{Expansion} = \Delta\text{T} \times 0.00021 \text{ (for } ^\circ\text{C)} \quad \text{or} \quad \text{Expansion} = \Delta\text{T} \times 0.00012 \text{ (for } ^\circ\text{F)}$$

So, from the information above, for whatever the starting volume, the water would expand:

For Celsius or Kelvin:

$$72^\circ\text{C} \times 0.00021 = 0.015 \text{ times or } 1.5\% \text{ its original volume}$$

For Fahrenheit or Rankine:

$$130^\circ\text{F} \times 0.00012 = 0.015 \text{ times or } 1.5\% \text{ its original volume}$$

Note that it does not matter which expression of temperature is used (Celsius/Kelvin or Fahrenheit/Rankine), only that the expansion ratio chosen marries up with its proper corresponding units of temperature.

Therefore, using the example calculation above, if the starting volume of the water is 20 gallons, the water would end up occupying:

$$20 \times 0.015 = 20.3 \text{ gallons of space}$$

If the starting volume of the water was 20 m^3, it would occupy 20.3 m^3 of space, and so on.

Why the Need for Expansion Tanks?

Hydronic heating systems work because they are completely filled with water with no air pockets. Air causes blockage of flow because a pump (circulator) is incapable of moving anything but a liquid. Thermal expansion of the system fluid as it heats up causes an increase in the space that the system water needs to occupy. If the extra volume in the system's water is not given a place to push into, the pressure in the system will rise sharply and likely trip the pressure **relief valve** mounted on the boiler.

When some hot-water heating systems are not providing heat, the entire system may cool from an operating temperature of about 82°C (180°F) to the temperature of the surroundings. The result is an approximate 1.5% decrease in the volume of the water and a slight decrease in the volume of all the components (boiler, heat transfer units, valves, and piping). Similarly, when the system heats up again, the water and the components increase in volume by roughly 1.5%.

A properly sized and placed expansion tank allows room for the water to expand and contract without causing a significant change in system pressure.

The water expands and contracts much more than the components that contain it. As stated earlier, when the system heats up to operating temperature, enough pressure is created to cause the pressure relief valve, which is installed directly into the boiler, to do its job. The relief valve opens enough to keep the pressure in the boiler to no more than 30 psig, which is the maximum pressure that any cast-iron boiler is allowed to be subjected to.

Once the call for heat ends and the boiler energy source shuts off, the water in the system cools. Its volume shrinks and the system pressure drops, sometimes to a value below the initial fill valve setting, which is typically 12 psig for most residential houses. Once this occurs, the automatic fill valve does its job. It opens and adds water to the system to re-establish the 12 psig setpoint pressure. When the thermostat calls for heat, this cycle of discharge/fill is repeated.

The net effect of the relief valve discharge/fill valve open sequence is that there is a constant introduction of fresh water into the system. Fresh water contains oxygen in solution, and the oxygen, while being beneficial to most living things, will kill a hydronic system that has ferrous components in contact with the system water.

When a system is initially filled, the dissolved oxygen migrates right away to any system equipment that contains iron and forms rust. The ferrous components, however, are not usually affected by this small bit of oxidation because it is not constant. Once the oxygen level in the water drops because it has combined with iron, it is no longer a rust-causing threat. This is why commercial fire protection systems made of steel pipe will last decades without rusting and falling apart. Aside from periodic tests every three to five years, no fresh water enters these systems, and rust is not an issue.

Any hydronic heating system that has water added to it on a continual basis is a prime candidate for rusting from the inside out. The ferrous components are circulators, boilers, and any other iron-bearing parts that are in contact with system water. This is the reason for the expansion tank.

Conventional Expansion Tanks

The earliest hydronic systems had an expansion tank mounted in the attic. The tank was the highest point in the system and was open to the atmosphere. The water level in the tank created the head pressure for the system's operation. Because it was connected to the piping off the top of the supply main, any air liberated from the boiler water by the heating process travelled easily upward and was released into the tank and subsequently dumped into the atmosphere through the vent.

As the system water heated up and expanded, the extra volume pushed upward into the expansion tank, sometimes overflowing out onto the roof. Over time, the attic location proved to be problematic, so the expansion tank was relocated into the basement and mounted just above the boiler. It also had to be a closed tank because it was no longer the system's high point (Figure 22).

The early tanks were of either galvanized or copper construction. They were installed horizontally and had a vertical glass tube mounted on one end between two valved fittings threaded into the tank. This "sight tube" was a visual indicator of the water level in the tank. When the tank was mounted in the attic, seeing the water level was not really necessary because the system was filled until water spilled through the overflow onto the roof. As long as water was present at some level in the tank, the system operated as it should.

When the tank was relocated to above the boiler in the same room, the sight tube became a much more important component.

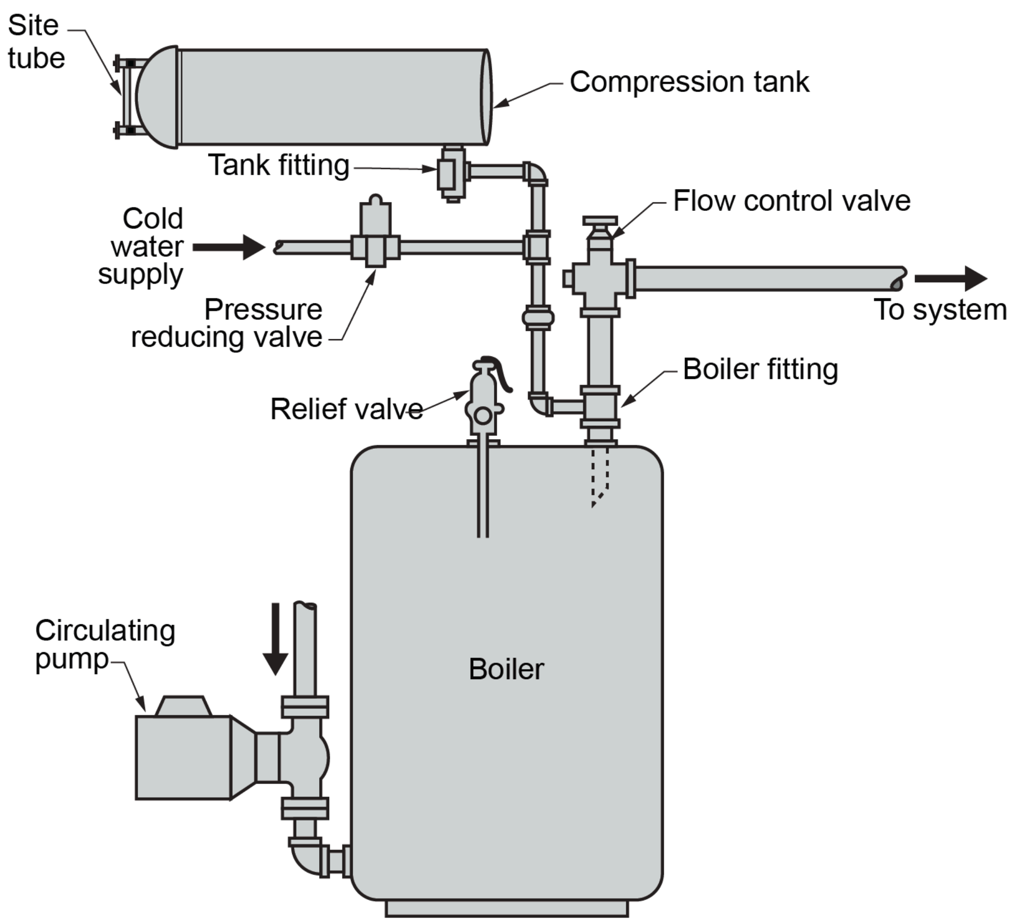

Figure 21 *Old-style steel boiler expansion tank. (Skilled Trades BC, 2021) Used with permission.*

When filling the system initially, water was introduced through the cold-water makeup line to fill the system to approximately 12 psig (for most systems). Any trapped air migrated to the system's high points, where it had to be bled by opening properly located air vent valves or, as an alternative to that, by "power purging," which will be discussed later.

Water also pushed into the expansion tank, a high point on its own, and filled it to approximately $\frac{2}{3}$ to $\frac{3}{4}$ its volume. The air trapped above the water was compressed to the same pressure. This air was not bled off; it became the "cushion" that accommodated the expanded water volume from the system.

These rather large tanks easily accommodated the extra volume of heated water. The air cushion acted like a spring that pushed the water back into the system piping when the boiler was not firing, and the water cooled and contracted. The system's volume was able to expand and contract without appreciably affecting the pressure in the system. The relief valve stayed un-tripped, and the cold water makeup valve stayed closed. Hydronic systems were not subjected to the forces of oxidation, and life was good — for a while.

It was soon discovered that air, once bled from a body of water, has the ability to be re-absorbed over time. Checking the sight tube periodically led to the discovery that the volume of air trapped above the water became less and, at some point, its volume became so low that when the boiler fired, the pressure created was once again enough to trip the boiler's pressure relief vale. This was due to a lack of air space in the tank. This phenomenon is known as "waterlogging." A waterlogged tank will not have enough volume to accommodate or accept the extra volume of water, so the pressure rises to levels that it should not reach.

The solution then is to drain the tank and refill it to re-establish the proper water-to-air ratio. When these conventional tanks were in use, two special fittings were commonly installed along with it.

One was a tee with an internal dip tube meant to be installed on a top-outlet boiler. Air liberated from the water through the heating process tended to collect at the top of the boiler. Once there, it would exit the boiler into the system supply piping and end up somewhere in the system, possibly causing circulation issues. The dip tube in the aptly named "boiler fitting" allowed system water to leave at a slightly lower point than where the air collected. The air then left the boiler through the same fitting but through a space around the dip tube and out the branch of the tee, where it was directed to the expansion tank through another special fitting, the "tank fitting." The tank fitting also had a tube located within it that allowed air or water to be bled from the tank without having to shut off or disconnect the tank from the system piping. The "conventional" tank, with its specialized fittings, is now considered old school and is not used much anymore, other than possibly in larger commercial systems, where an operator is available to monitor the water level in the tank.

Bladder or Diaphragm Tanks

Conventional expansion tanks were typically large because they had to allow a reasonable length of time between replenishment of air due to waterlogging. For a number of decades now, manufacturers have been producing tanks with a rubber diaphragm within them (Figure 23) that physically prevents water and air from being in contact. This style of tank eliminates the possibility of waterlogging unless the diaphragm material tears or the Schrader valve leaks and allows the air pressure to escape. They are pre-charged with air, which surrounds the diaphragm, with the system water filling the diaphragm's interior space. Besides a lower cost factor to purchase and install, some of the other benefits of this newer style of tank are:

- The tank is now normally installed under the system piping, eliminating the need to support it above the boiler. It now "hangs" from the piping.
- The pre-charged tanks are typically much smaller than their old counterpart now that extra space to accommodate waterlogging is not required.
- With air surrounding the diaphragm, there is no contact between system water and the steel of the tank, so tank corrosion is essentially negated.

Figure 22 *Diaphragm-type expansion tank. (Skilled Trades BC, 2021) Used with permission.*

Point of No Pressure Change

The location in the system piping where the expansion tank connects to the system is known as the point of no pressure change, which was covered earlier in the "Pump Location" section. Make sure to read the information there thoroughly, as it has a great effect on pump placement in every hydronic system.

Selecting Expansion Tanks

Certain variables must be considered to properly calculate the amount of expansion that will take place and to ensure that the tank will operate correctly for that system, including the following:

- Total volume of water in the system
- Minimum system temperature
- Maximum system temperature
- Minimum operating pressure
- Maximum operating pressure
- Presence of glycol in the system

This information is compared with manufacturers' information and tank specifications to size the expansion tank. Figure 24 is an example of one such graph used to calculate the amount of expansion that takes place for different system temperature changes.

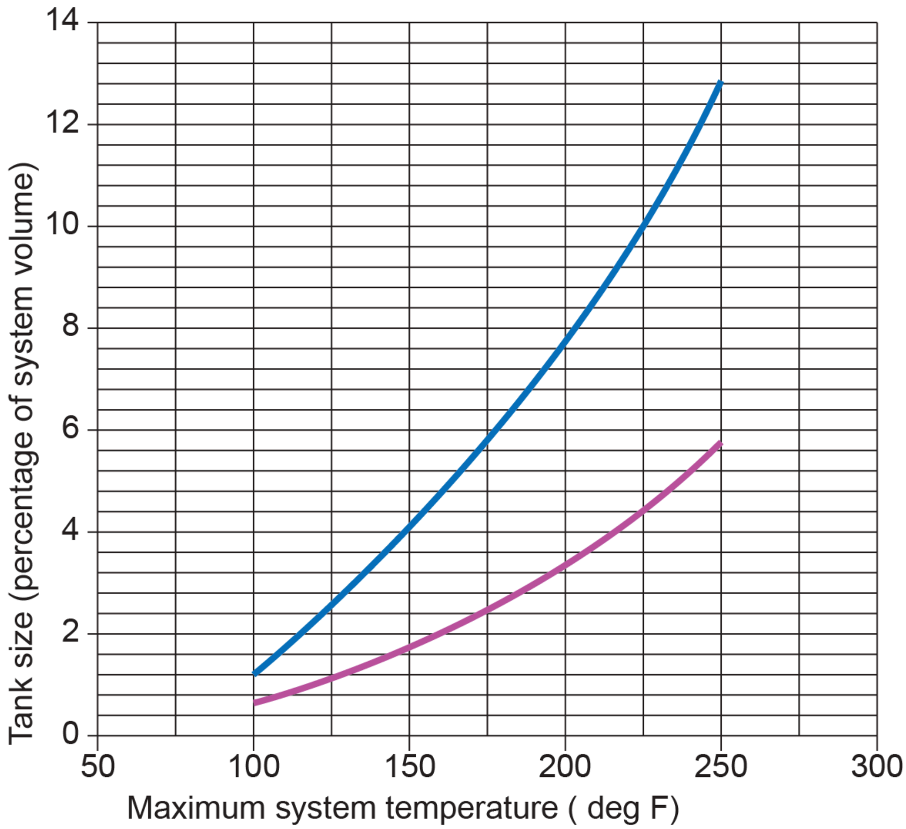

Figure 23 *Expansion tank sizing graph. (Skilled Trades BC, 2021) Used with permission.*

Expansion tank sizing will be covered in more detail in Level 3 Plumbing Apprenticeship.

Air Removal

Every hydronics installer will eventually come across the issue of no or very little flow through the system. Although there can be many reasons for this, one of the most common is air trapped within the system. All water contains air in solution, and when that water is heated up, the air slowly separates and collects at high points. These air bubbles move around the system, creating all types of problems. The job of designers and installers is to create a system that is able to remove the air before it becomes a problem.

Problems Created by Entrapped Air

There are several problems that can be traced to excessive air within hydronic heating systems:

- Noisy flow
- Increased corrosion
- Poor or possibly no flow
- Poor heat transfer

- Cavitation leading to circulator damage

For these reasons, air removal must be a priority in system design.

Air Removal Devices

Air removal devices can be categorized by where they are placed in a system.

Because heated air tends to rise, it makes sense to place some type of air vent at the high points in a system. For this reason, these vents are referred to as “high-point vents” or simply “air vents.” Typical locations for such vents are at the top of each heat emitter, at the top of distribution **risers**, or wherever piping turns downward following an upward or horizontal run. High-point vents are particularly useful for removing air immediately after the system has been filled with liquid.

The second type of air removal device is the central air separator. When water passes through a boiler, it is heated, which releases air as bubbles. These air bubbles will then work their way around the piping system until they find somewhere to collect and create issues. A central air separator is located on the supply piping leaving the boiler because air is most easily removed from water wherever it is hottest and slowest.

Manual Air Vents

The simplest type of high-point vent is a manual air vent (Figure 25). As the name implies, the manual air vent requires an operator to both open and close the vent. These vents can sometimes be referred to as coin vents or bleeders. Manual air vents are installed at locations where small amounts of air will have to be eliminated during startup and maintenance, but not where large amounts of air are likely to accumulate during normal operation. The most common location for manual air vents is at the downstream (return) end of heat transfer units. Manual air vents have a needle-type stem with either an insulated hand wheel or simply a slot in the end for a screwdriver or a coin.

Great care must be taken to ensure that these types of vents do not leak after being used because they have been known to leak small, unnoticed amounts of water over long periods; this can cause widespread water damage in wooden buildings.

Figure 24 *Manual air vent.(Skilled Trades BC, 2021) Used with permission.*

Automatic Air Vents

Automatic air vents open automatically in the presence of air and close automatically in the presence of water. There are automatic disk and automatic float air vents. Automatic air vents should be installed together with isolating valves so that repairs or replacement can occur as required.

An automatic disk air vent (vent valve) contains one or more water-sensitive disks (Figure 26). These disks swell up in the presence of water and shrink in the presence of air. This effect is used to open and close a small valve that automatically releases any enclosed air. Automatic disk air vents are very slow devices, but they do not drip when operating. They can be manually opened to let more air out when you fill the system, and they can readily cope with the small amount of air that is released when water is heated. They can come equipped with a ball check to enable removal and replacement of the air vent while maintaining the liquid within the system.

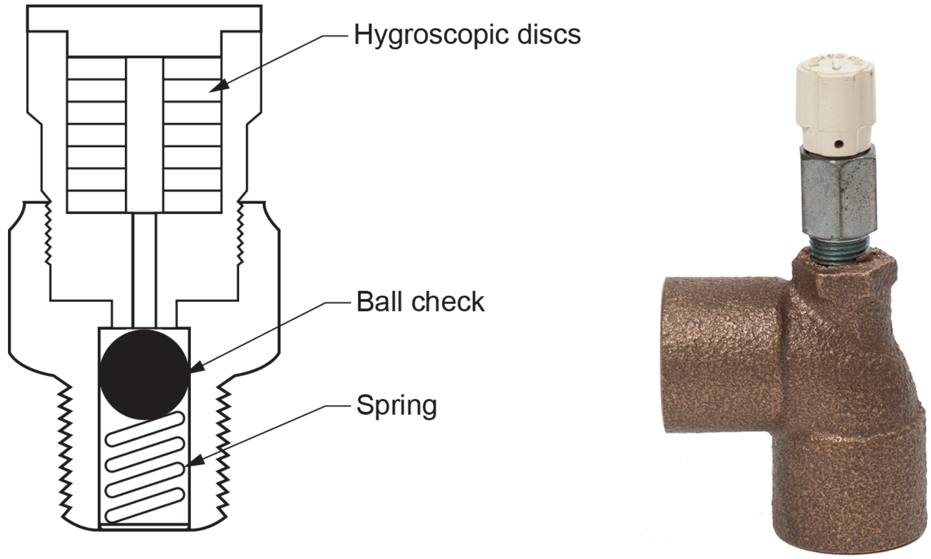

Figure 25 *Automatic disk vent. (Skilled Trades BC, 2021) Used with permission.*

An automatic float vent (Figure 27) works on the principle of buoyancy. The device contains an air chamber, float, and air valve. The float moves up and down based on the presence of water in the chamber. If there is no water in the chamber, the float will drop down, opening the air valve. This allows the air in the chamber to escape. As the air escapes, water from the hydronic system begins to fill the chamber and lift the float up. This causes the air valve to close. There are times during this process when a small amount of water also escapes, but generally, this is not an issue.

Figure 26 *Automatic float vent. (Skilled Trades BC, 2021) Used with permission.*

Automatic air vents have a $\frac{1}{8}$ in. threaded connection on the Shrader valve, similar to that found on a car's tire. An adapter and overflow tubing can be connected to the air vent, and any discharge of water during its operation will be directed to a safe location. This is especially helpful in situations where the automatic vent is located high overhead or where it may not be readily visible. The threaded vent connection comes equipped with a threaded cap. It is important to leave the cap partially unscrewed or the air outlet will be sealed. Install these vents in the vertical position, with the vent connection pointing up.

Air Purgers or Air Scoops

Air purgers (also called air separators or air scoops) remove the air in water by separating it from the water and venting it outside the system. An air scoop consists of a one-piece, cast-iron chamber with two passages containing contours and baffles (Figure 28).

As a mixture of water and air flows through these passages, the air is separated and then vented to the atmosphere through an automatic float air vent. Air scoops are installed horizontally on the main as close to the boiler as possible. However, to optimize effectiveness, 18 in. of straight horizontal piping is required on the inlet side to achieve the desired laminar flow. The enlarged cross-sectional area causes a velocity drop through the air scoop that allows more time for entrained air bubbles to float up to the air vent. If a diaphragm compression tank is installed, it may be connected to the bottom of the air scoop.

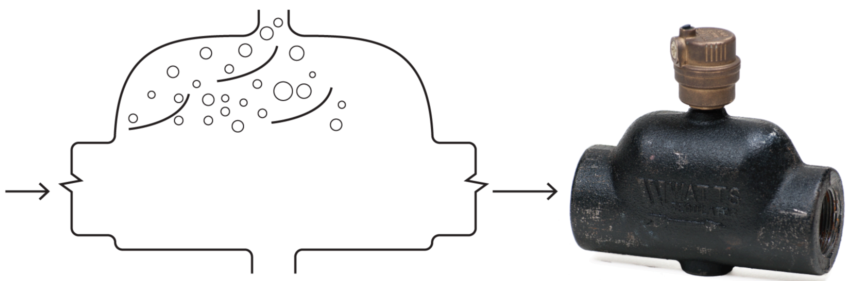

Figure 27 *Air scoop and cutaway showing baffles for directing air. (Skilled Trades BC, 2021) Used with permission.*

Microbubble Resorbers

Another device similar to an air scoop and serving the same purpose is a **microbubble resorber** (Figure 29). Microbubble resorbers are very effective in removing all types of air from the system. They have many small vertical wires or screens inside that create areas of reduced pressure on their downstream side. The low pressures encourage dissolved air to come out of the solution as microbubbles coalescing and rising along the wires. The microbubbles accumulate in the upper auto air vent and are released from the system. Microbubble resorbers are the preferred choice for air removal devices, especially in situations where there is not enough room to install 18 in. of straight horizontal piping on the inlet side.

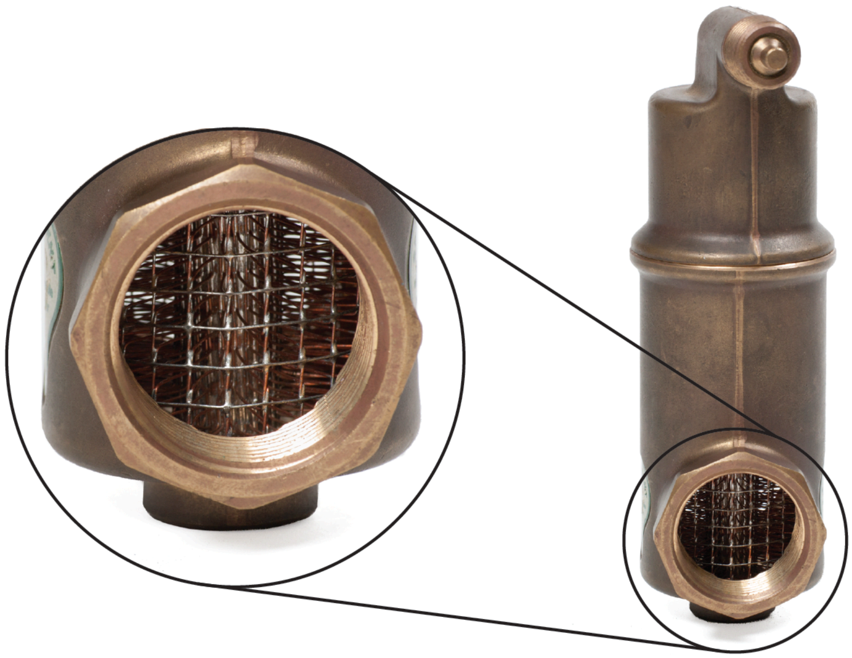

Figure 28 *Microbubble resorber. (Trades Training BC, 2021) Used with permission.*

Either an air purger or microbubble resorber will be located on the supply piping as it leaves the boiler, where the water is hottest and most easily released from the solution. Figure 30 shows a typical location of an air separator within a system.

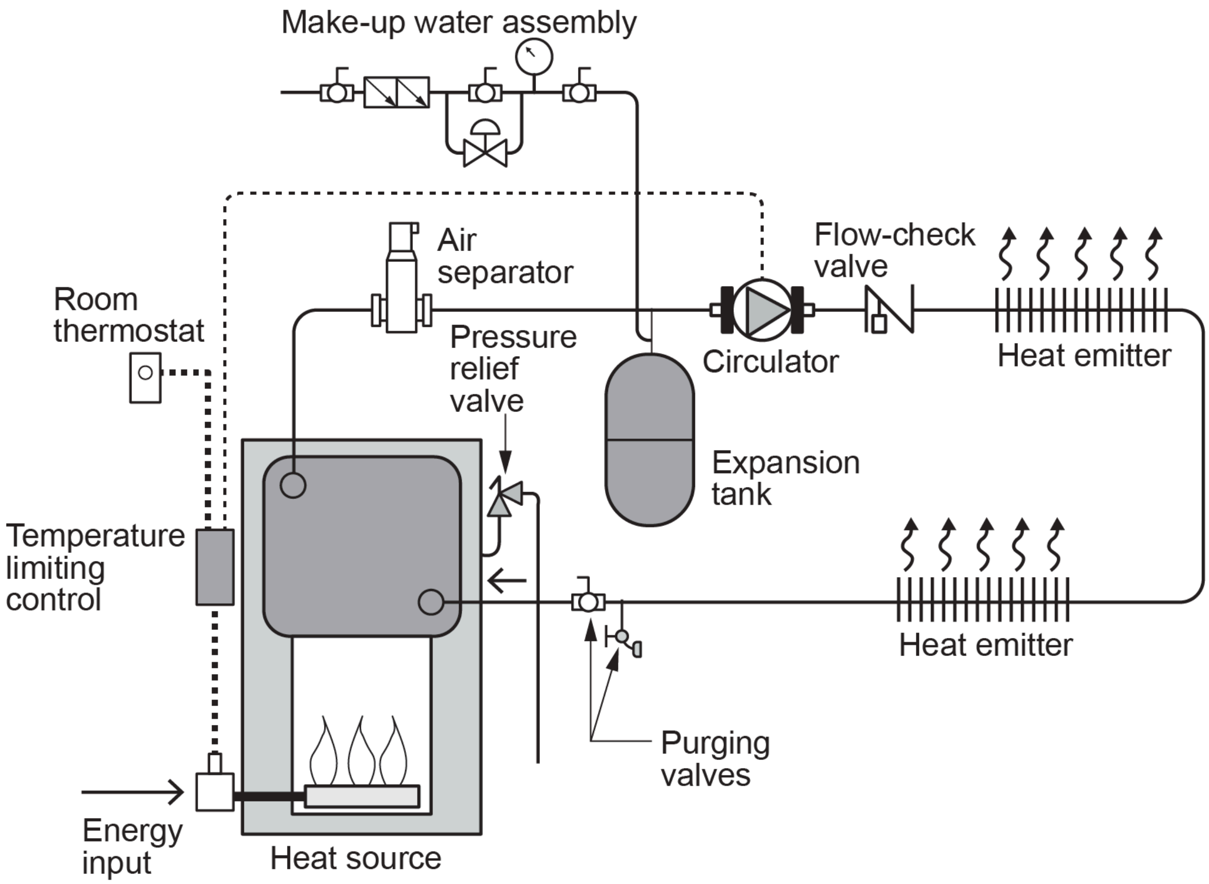

Figure 29 *Components of a hydronic heating system. (Skilled Trades BC, 2021) Used with permission.*

Water Quality

The ideal water for use in hydronics systems would contain very little physical or chemical contaminants. Treatment for water quality can be divided into two categories:

- Physical water quality
- Chemical water quality

Physical water quality treatment captures and eliminates air and dirt from the system. Chemical water quality modifies or eliminates harmful chemical substances in the system water.

Dirt Removal

The ideal heating or cooling system would be dirt-free. But, in reality, there are many ways that dirt and sediment can get into a hydronic system. The presence of dirt can cause serious problems including:

- Circulator damage

- Reduced heat transfer due to fouled surfaces in heat exchangers
- Increased internal flow erosion
- Blocked sight glasses on flow meters
- Clogging and malfunction of flow meters, zone valves, balancing valves, check valves, vents, and thermostatic **radiator valves**

There are three common methods of removing dirt and debris from hydronic systems:

- Initial flushing and cleaning
- Basket strainers
- Dirt separators

System Flushing and Chemical Cleaning

An assembled system must be flushed to remove debris, such as solder balls, metal chips and shavings, casting sand, sawdust, drywall dust, insects, paper labels, and dirt, that entered the piping during transportation, storage, or handling on the installation site. Chemical cleaning removes oils and greases from thread cutting oil, soldering flux, or small amounts of machining oil remaining inside system components.

The preferred method for the initial chemical cleaning of the inside of a hydronic system is by circulating a hydronic detergent mixed with hot water through the system. When the cleaning solution has been sufficiently circulated, it is drained from the system, carrying the dissolved oil and grease residue with it.

To perform either initial flushing or chemical cleaning procedures, the system must be equipped with the appropriate valves (Figure 31) to add fluid and remove both air and dirty fluid.

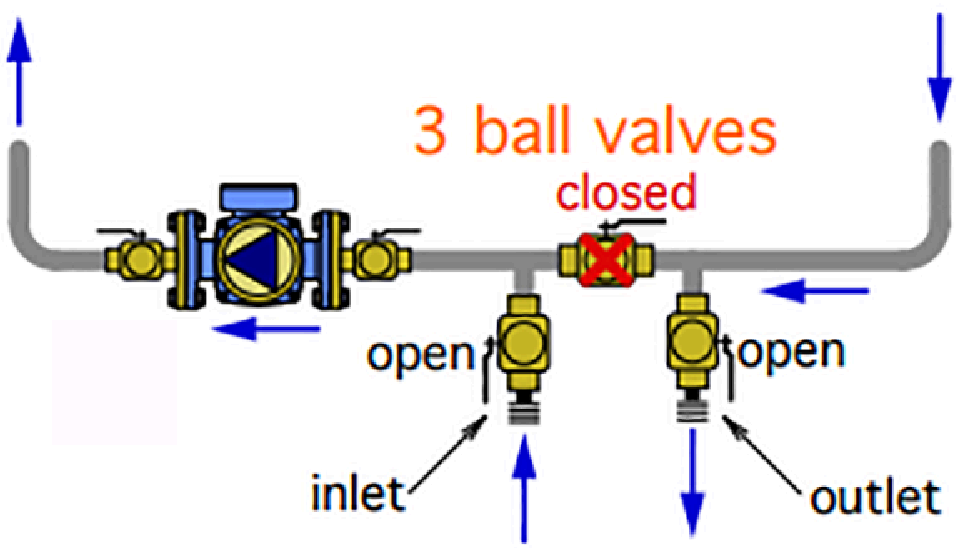

Figure 30 *System flushing valve arrangement. (Caleffi, idronics™, 2016). Caleffi S.p.A. All rights reserved. Used with permission.*

When possible, purging valves should be located upstream of components such as circulators and heat exchangers.

This minimizes the chance of flushing debris in the piping through these components. After the initial debris flushing, a chemical cleaning solution can be added to systems by use of a flush pump cart connected to the purge valves (Figure 32).

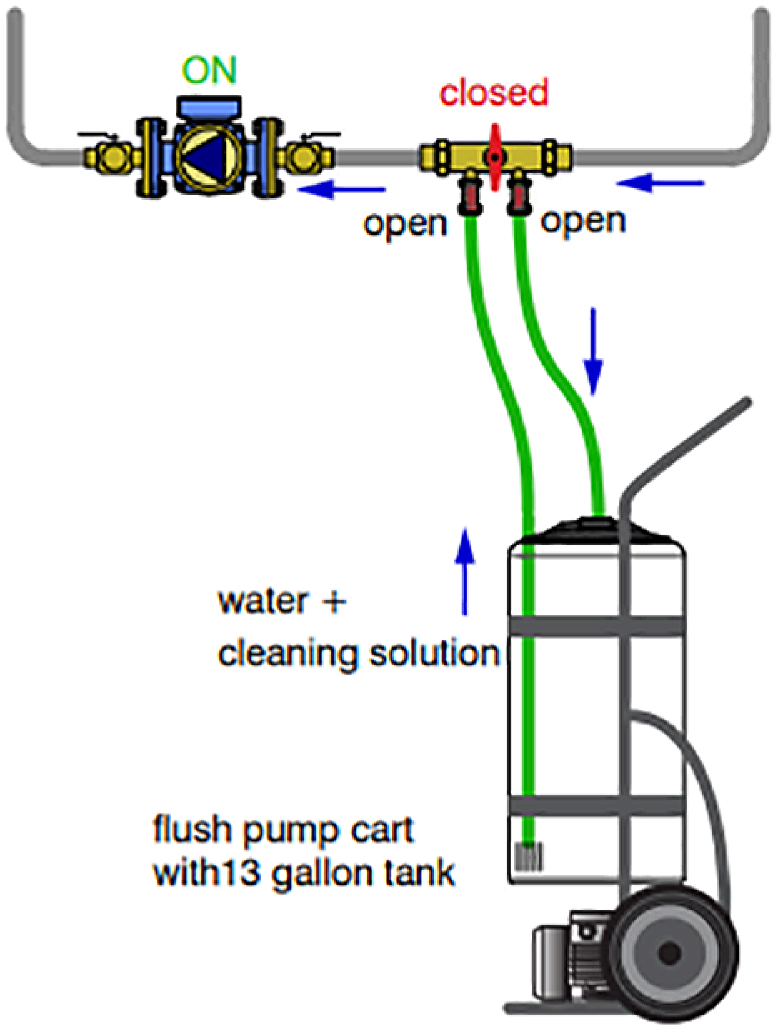

Figure 31 *Flush pump cart. (Caleffi, idronics™, 2016). Caleffi S.p.A. All rights reserved. Used with permission.*

Other methods for performing the initial system purging using the makeup water connection will also be discussed in B-4.2 Hydronic System Valves (#chapter-b-4-2-valves).

Strainers

Basket strainers, also known as Y-strainers (Figure 33), trap dirt within a mesh basket made of stainless steel or brass. A strainer should be installed just upstream of the pump in order to protect the pump. It is important to maintain the strainer so there is not an excessive accumulation of debris on the inside the strainers basket, which will restrict flow. The strainer normally has a tapping with a plug, or a blow-down valve can be installed to allow for easier cleaning. A blowdown is a drain point used to flush out sediment captured in the strainer.

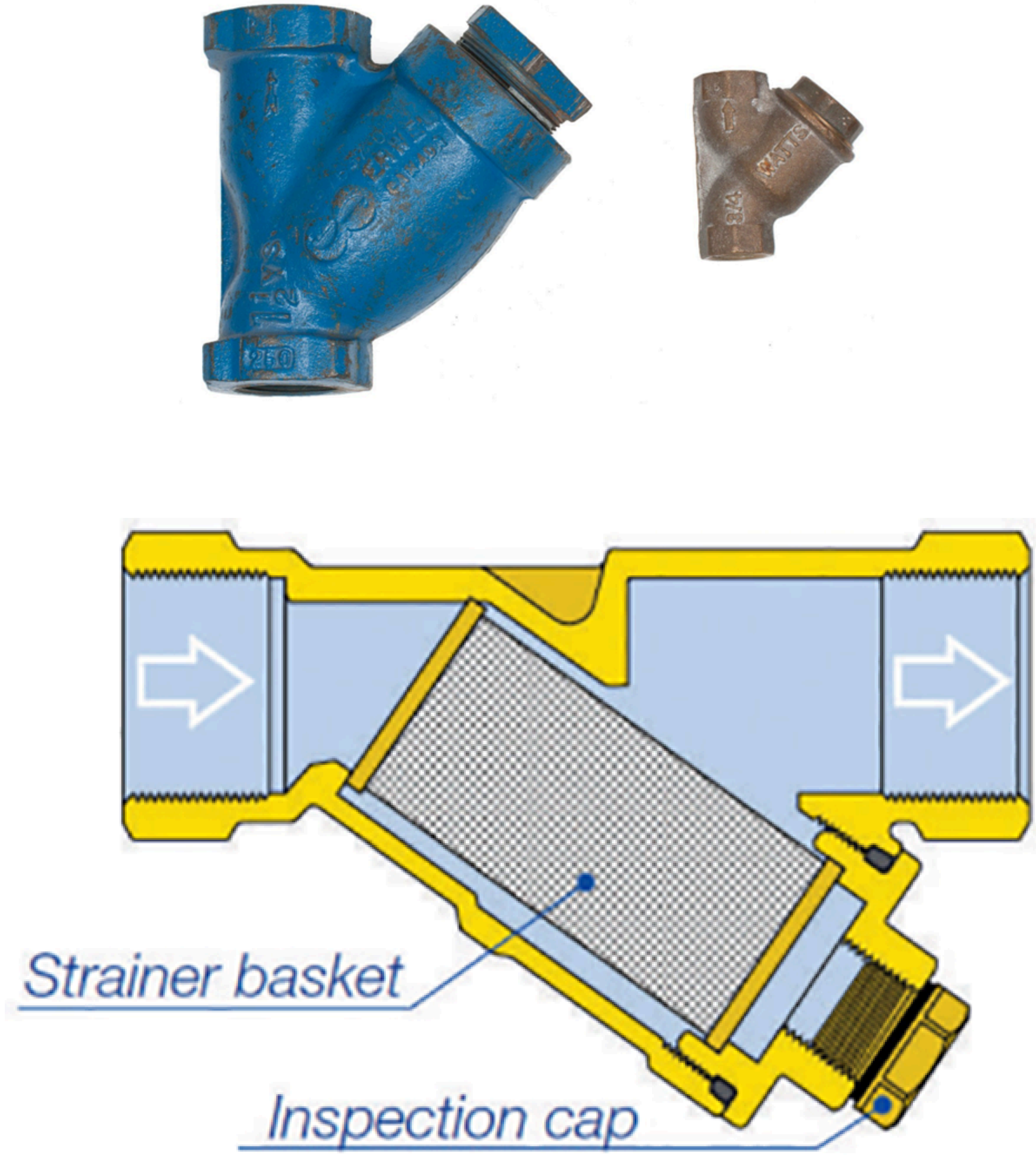

Figure 32 *Y-strainer (top: Skilled Trades BC, 2021; bottom: Caleffi, idronicsTM, 2014). Caleffi S.p.A. All rights reserved. Used with permission.*

On commercial systems, pressure gauges may be installed to monitor the pressure drop across a basket strainer (Figure 34) and determine when cleaning is needed.

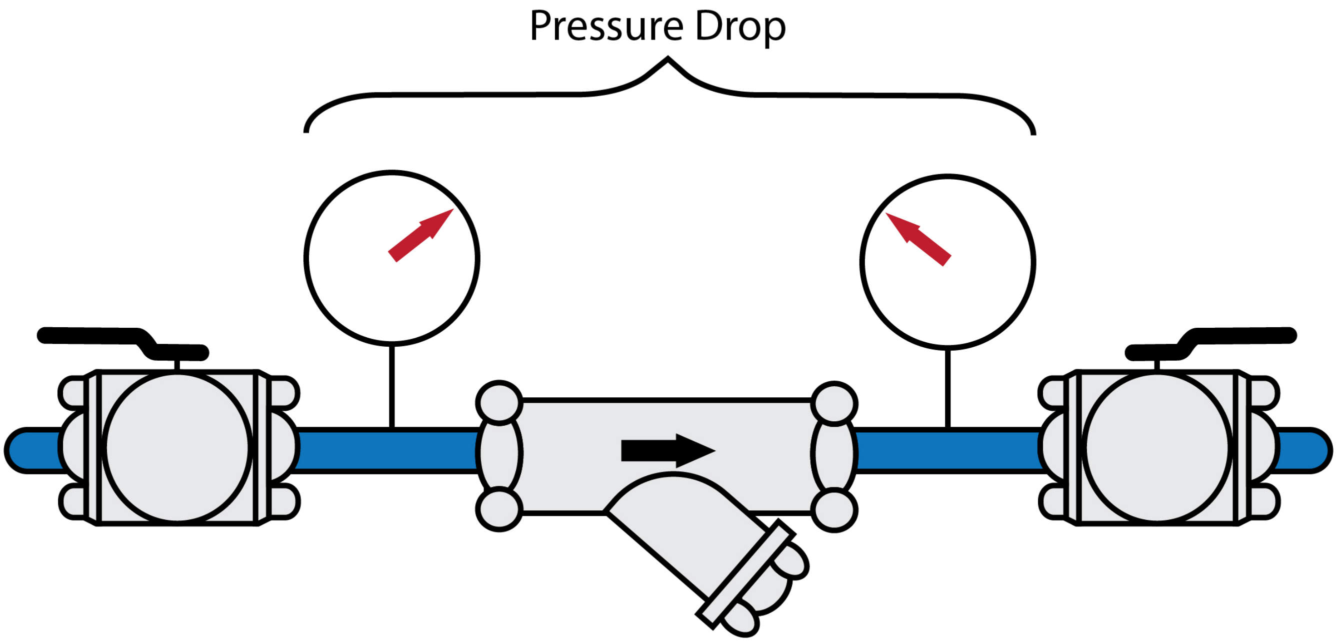

Figure 33 *Monitored strainer pressure drop. (Caleffi, idronicsTM, 2014 [modified]). Caleffi S.p.A. All rights reserved. Used with permission.*

Dirt Separators

Many dirt separators are also air vents, as they use the same principle as microbubble resorbers. As the water passes through the low velocity chamber, dirt particles collide with the coalescing media and settle to the bottom chamber. A valve at the bottom of the chamber is used to periodically flush out accumulated particles. Notice that the unit shown in Figure 35 has four pipe connections as it is also a hydraulic separator. The concept of hydraulic separation will be discussed in B-4.3.

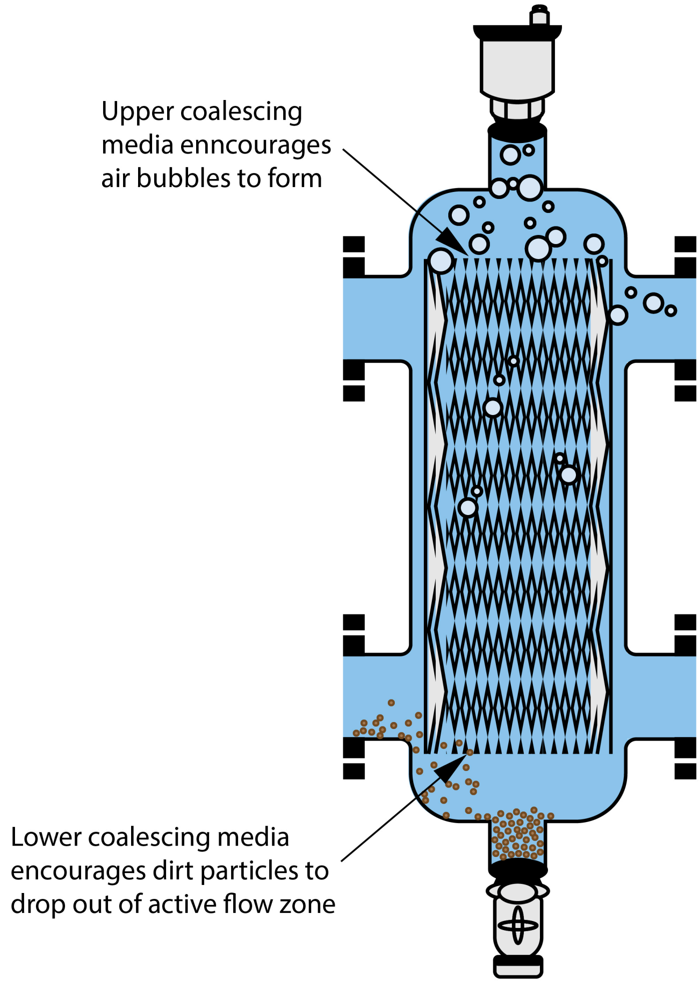

Figure 34 *Combined air and dirt separator. (modified from Caleffi, idronics™, 2014).*

Because the screens and wires do not accumulate sediment, like a Y-strainer, they do not create an increased resistance within the piping system. Many hydronic systems contain cast iron or steel components, which form iron oxides. As iron oxide particles are attracted to magnetic fields, they tend to accumulate in the circulator due to the motor's magnetic fields. The ability of a dirt separator to capture iron oxide particles is enhanced by adding a powerful magnet on or within 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.

Chemical Treatment

Residential hot-water heating systems do not normally require the periodic addition of chemicals, but commercial and industrial hot-water heating systems may require chemicals to:

- Degrease the system
- Inhibit corrosion
- Lubricate components

- Prevent freezing

Degreasing agents are used to clean the system. Corrosion inhibitors prevent rust from forming on interior surfaces. Lubricants help valves and other components function smoothly. Glycol prevents freezing.

Degreasing agents, corrosion inhibitors, and lubricants are added to the system through a pot feeder (Figure 37). The pot feeder is made of cast iron or steel and can hold several litres or gallons of chemical solution. The pot feeder is installed at a convenient location on one of the mains, typically in the boiler room. The pot feeder is installed on a short bypass to the main with an isolating valve at either end.

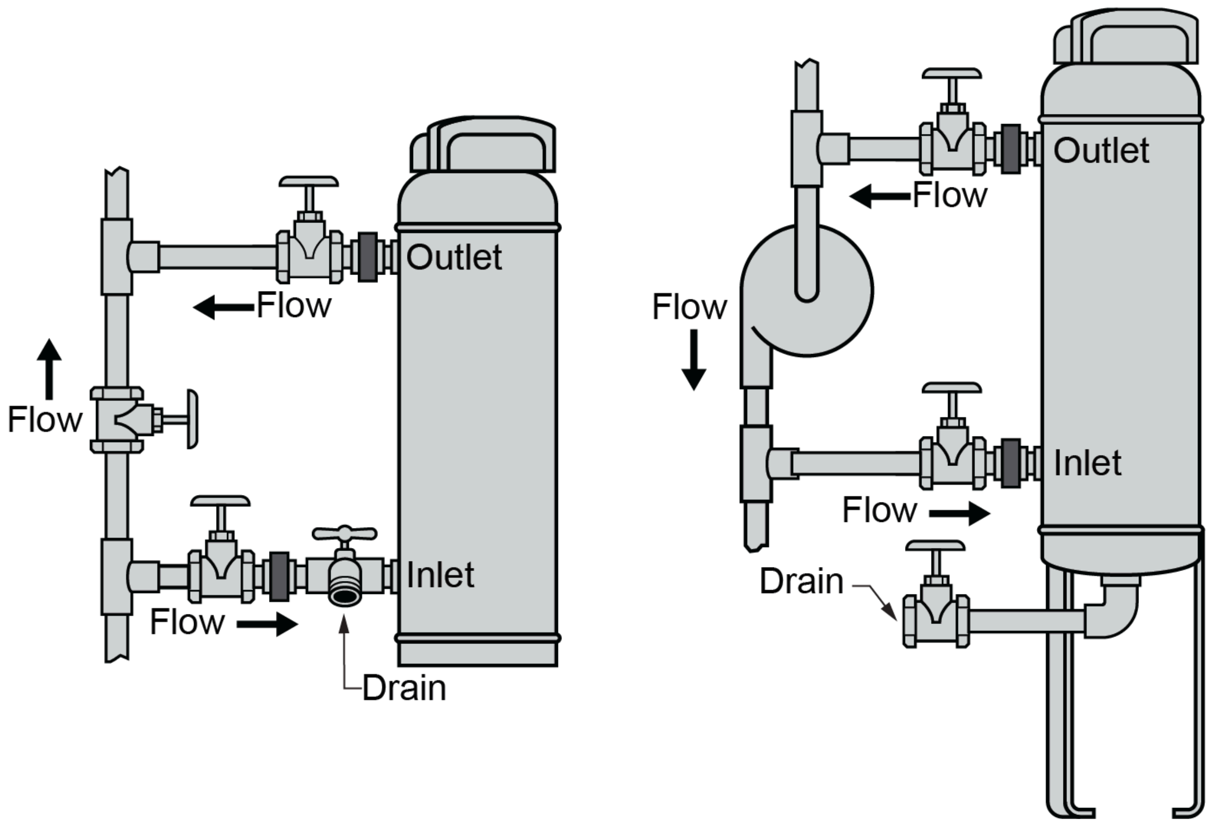

Figure 35 *Pot feeder. (Skilled Trades BC, 2021) Used with permission.*

When a chemical solution needs to be added to the system, do the following:

1. Isolate the pot feeder by shutting off the inlet and outlet valves.
2. Drain the pot feeder of residual fluid.
3. Open the pot feeder lid.
4. Clean the pot feeder tank.
5. Close the drain valve.
6. Add the required solution.
7. Vent excess air from the pot feeder.
8. Open the isolation valves.

Give the added chemicals a few minutes to circulate and mix with the system water, then repeat the process until the required amount of chemical has been introduced into the system. Test kits are available for any water characteristics being adjusted.

Degreasing agents must be flushed from the system after they have served their function, whereas corrosion inhibitors and lubricants are allowed to remain in the system.

Glycol solutions are added to an empty system, although not through the pot feeder. A premixed glycol solution can be added to a system with the use of a pump cart, as previously shown. Systems that use glycol solutions rather than water will require a larger compression tank suitable for glycol, a stronger circulating pump, and a higher level of backflow protection.

Low-Water Cutoffs

Another safety device required on some hot-water boilers and all steam boilers is a low-water cutoff (LWCO). A low-water cutoff is installed as a safety guard against a low-water condition in the boiler. If the water in the boiler gets to a dangerously low level, an electrical circuit to the energy source (typically the gas valve) is interrupted and the burner is shut off. LWCOs can either be of a float type (Figure 38) or a probe type. The float type uses a float ball connected to a switch, and the probe type is inserted into the boiler through a tapping at the lowest safe water level. It uses the conductivity of water to complete or break an electrical circuit, which allows the burner to keep firing or shuts it down.

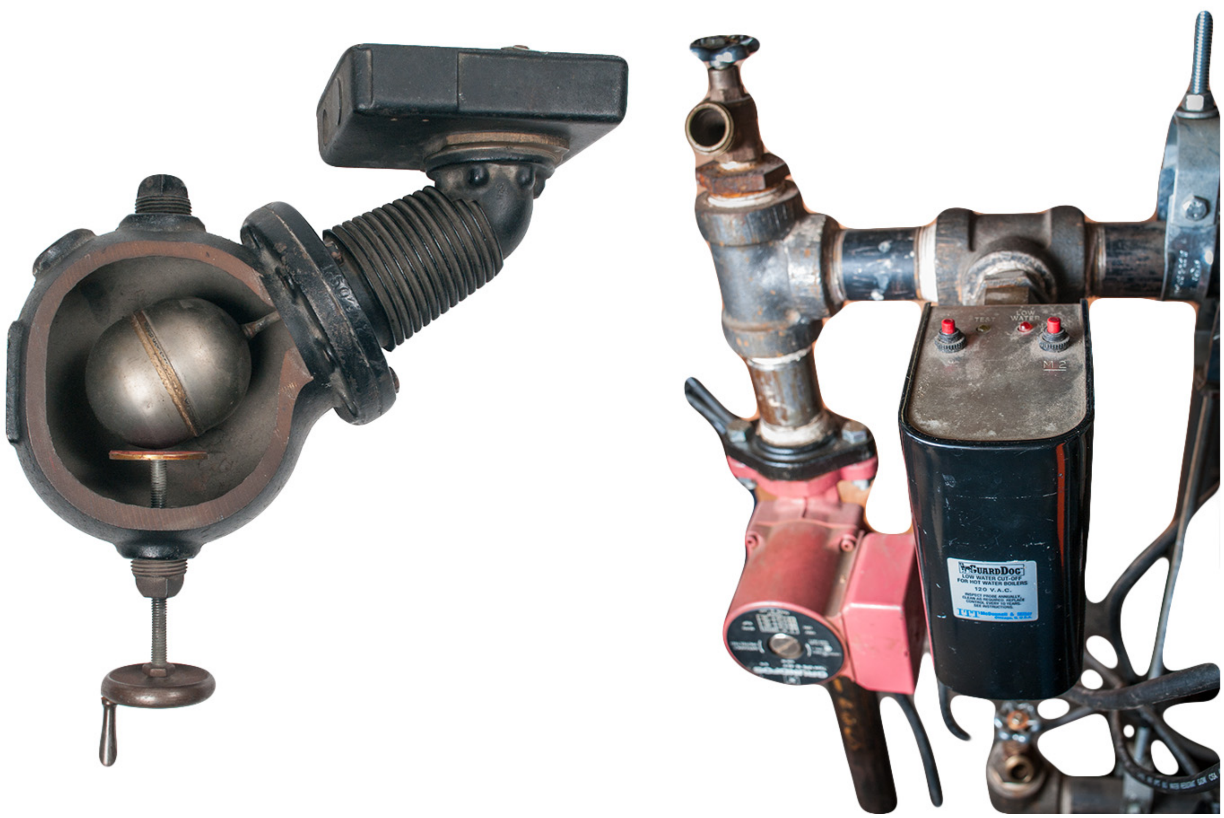

Figure 36 *Float type low-water cutoff (left) & probe-type low-water cutoff (right). (Skilled Trades BC, 2021) Used with permission.*

Self-Test B-4.1: Hydronic Distribution System Components

Complete the chapter Self-Test B-4.1 and check your answers.

If you are using a printed copy, please find Self-Test B-4.1 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=58#h5p-9 (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=58#h5p-9)

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- **Figure 17** Grundfos UP series cross-reference performance curves (https://api.grundfos.com/literature/Grundfosliterature-5235400.pdf) is from Grundfos (https://www.grundfos.com/ca/) and is used for educational purposes under Fair Dealing (https://laws-lois.justice.gc.ca/eng/acts/c-42/page-6.html#docCont:~:text=Exceptions-,Fair%20Dealing,-Marginal%20note%3A) guidelines.
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- **Figure 33** Monitored strainer pressure drop [Figure 3-14, modified] is by Caleffi Hydronic Solutions (2014, p. 20) in idronics™ and is used with permission.
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B-4.2 Hydronic System Valves

There are many types of valves used in hydronic systems. Most of these valves are common to other piping trades and can be found in plumbing, sprinkler fitting, and steam fitting systems. Others are designed for a very specific function in a hydronic heating system. The proper use of valves can make the difference between an efficient, quiet, and easily serviced hydronic system, and one that wastes energy, creates objectionable noise, or even poses a major safety threat.

Common Valves

Most common valves are designed for either component isolation or flow regulation.

Component isolation refers to the use of a valve to stop fluid flow in piping connected to a device that may have to be removed or opened for servicing. Examples include circulators, boilers, heat exchangers, pumps, and strainers. By placing valves on either side of such components, only minimal amounts of system fluid need to be drained or spilled during servicing. In many cases, other portions of the piping system can remain in operation during such servicing.

Flow regulation requires a valve to set and maintain a given flow rate within a piping system or portion thereof. An example is adjusting the flow rates in parallel piping branches to heat emitters.

Valves used for flow regulation are specifically designed to remove mechanical energy from the fluid. This causes the fluid's pressure to drop as it passes through the valve. The greater the pressure drop, the slower the flow rate through the valve.

Valves commonly used in hydronic piping systems (Figure 1) include the following:

- **Gate valves**
- **Globe valves**
- **Ball valves**
- **Check valves**

Gate, globe, and ball valves are all examples of manual valves that can be used for isolation. Air will flow easily through an open gate or ball valve. Because of their restrictive interior design, globe valves are limited to being used to provide throttling or isolation on feedwater lines. The globe valves are also modified into a specialty valve called a balancing valve. These are used for throttling flows in a hydronic system. Check valves can be used wherever reverse flow is unwanted.

Figure 1 *Commonly used valves. (Skilled Trades BC, 2021) Used with permission.*

Specialty Valves

Several valves have very specific functions in hydronic systems. Some provide safety protection, some are required by code, and others automatically regulate the temperature and pressure at various points in the system. All these valves will be incorporated into systems discussed in later phases of training.

Pressure Relief Valves

All closed-loop hydronic systems must be protected by a pressure relief valve. Its function is to provide a relatively controlled and safe release of water in the event of excessive pressure in the system.

Pressure **relief valves** are designed and labelled to open at a specific pressure. In systems with boilers, the relief valve is threaded directly onto the boiler or a nearby supply pipe.

Pressure within a hot-water heating system could reach dangerous levels through the failure of a component to shut off the burner or a failure within the **water makeup** system. Installing the correct pressure relief valve will prevent pressure from building up to an unsafe or dangerous level.

The pressure relief valve for a hot-water heating boiler is spring-loaded and opens at a pressure that is preset at the factory. The valve must not have a discharge pressure setting greater than the maximum rated pressure of the boiler. The pressure relief valve must be capable of discharging as much heat as the boiler can produce. This means that the relieving capacity must match or exceed the output rating of the boiler. An extra margin of safety is given if the boiler's input, rather than its output, is used in selecting the relief valve capacity.

Every pressure relief valve has an information or rating plate (Figure 2) that identifies the following:

- The relief pressure setting; for example, 210 kPa (30 psi)
- The relieving capacity; for example, 44 kW (150,000 BTU)
- The size of the valve; for example, $\frac{3}{4}$ NPS

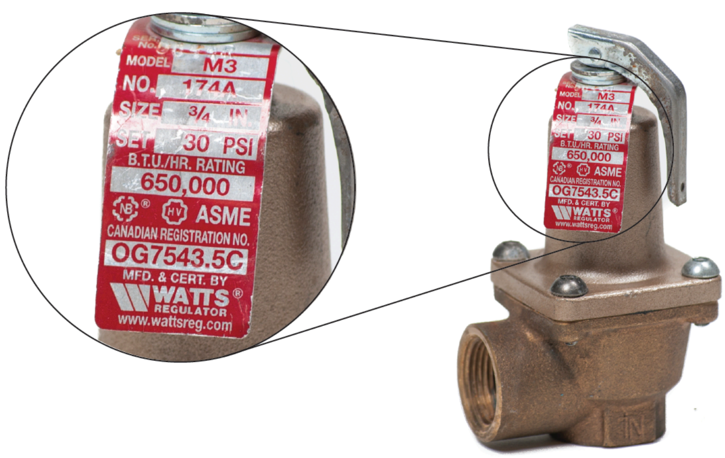

Figure 2 *Pressure relief valve and rating tag. (Skilled Trades BC, 2021) Used with permission.*

The pressure relief valve must be installed directly on the boiler, and there may not be any other valve between the pressure relief valve and the boiler. The spring-loaded valve of the pressure relief valve opens when the preset pressure is reached. When the pressure within the boiler drops sufficiently, the valve closes.

The pressure is relieved by discharging water through a pipe to a drain or safe location. The piping used for the outlet must be:

- The same size as the pressure relief valve
- As short as possible

- Sloped down and away from the valve to prevent a buildup of back pressure

If the pressure relief valve drips water from its discharge opening, and the pressure indicated is not close to the opening pressure of the valve, there may be some debris in the valve seat. To flush the valve, stand in a position clear of the valve's discharge opening. If the boiler temperature is high, scalding water or steam will be discharged. Open the valve fully for a moment to flush out the valve seat and let a finger slide off the end of the trip lever so that it slams shut to prevent nuisance dripping.

> If this does not stop the dripping, the valve has failed and must be replaced. Make sure the replacement valve is of the same type and has the same opening pressure and heat relief capacity. Never plug, cap or install a valve on the discharge side of the pressure relief valve.
>
> If the valve drips because the pressure in the system is at its maximum, the valve is doing its job, and the cause of the excess pressure must be found and fixed.
>
> If the information tag is missing from the pressure relief valve, the valve must be replaced because the correct safe discharge pressure setting cannot be determined.

Boiler Water Makeup

Water makeup refers to the piping and accessories connected to the system that not only fill it, but maintain a constant pressure within it. It's important to carefully select the connection to the system piping. Cold water should never be added directly to a hot boiler, as this can cause thermal shock and crack the metal. Instead, the water makeup is normally introduced into the hot supply main from the boiler through the same fitting used to connect the expansion tank, which is the point where pressure remains stable.

The water makeup to a boiler has four components:

- **Main stop valve**
- **Backflow preventer**
- **Feedwater valve (pressure-reducing valve)**
- **Bypass valve (quick fill)**

Main Stop Valve

The main stop valve is normally a ball or gate valve; in other words, a valve that, in operation, is either open or closed. Although almost any manual valve will perform the intended function, **ball valves** are used most often because they are readily available and easily seen as either open or closed. The position of a valve with a rotary handle, such as a gate or globe valve, cannot be seen at a glance as being open or closed and so they are less commonly used.

Backflow Preventer

As seen above, water is introduced into the hydronic system through the feedwater or pressure-reducing valve. Once in the hydronic system, this water is no longer considered part of the domestic system, and there must be some mechanism that ensures boiler water does not return to the domestic system and contaminate it.

A **backflow preventer** performs this function. A backflow preventer does exactly as the name implies: it prevents the flow of liquid back to where it originated. All boiler systems require a backflow preventer. The type and style of backflow preventer are determined by the presence or absence of additives in the boiler water and whether it is a residential or commercial installation. A typical backflow preventer on a residential hydronic system is a dual check with an atmospheric port (Figure 3).

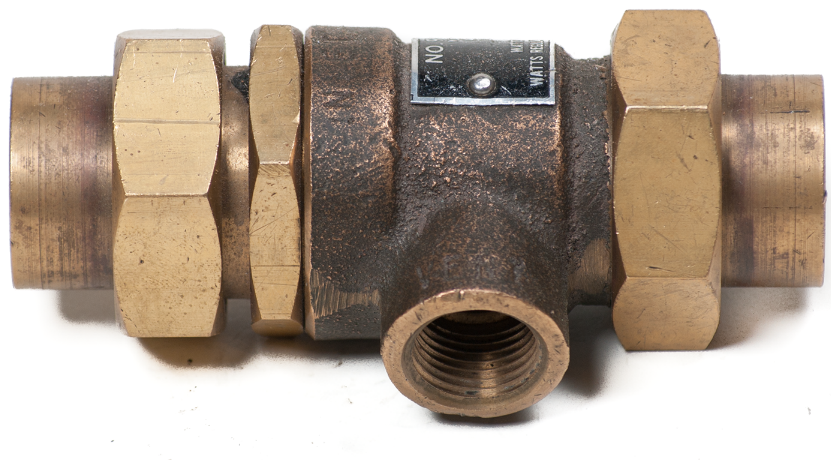

Figure 3 *DCAP backflow preventer. (Skilled Trades BC, 2021) Used with permission.*

This device has two check valves in series, with a port open to atmosphere located between the two check valves. If water flows in the opposite direction than intended, it will be discharged through the atmospheric port to the atmosphere.

If chemicals have been added to the boiler system, in many jurisdictions, a more reliable backflow preventer must be installed. An example is the reduced pressure backflow assembly (Figure 4), which functions similarly to a dual check with an atmospheric port but with the added advantage of being in-line testable. Testing the assembly regularly ensures its proper operation.

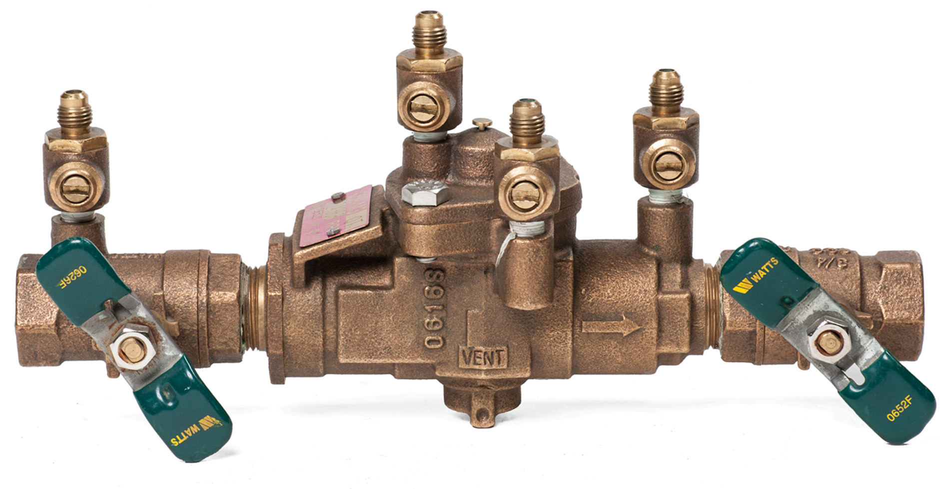

Figure 4 *Reduced pressure backflow assembly. (Skilled Trades BC, 2021) Used with permission.*

Feedwater Valves

All hydronic systems referred to in this section are known as closed-loop systems. Even though they are closed loop, they still require the ability to fill the system and have water added when necessary. This is done automatically through a **feedwater valve**, also known as a pressure-reducing valve (Figure 5).

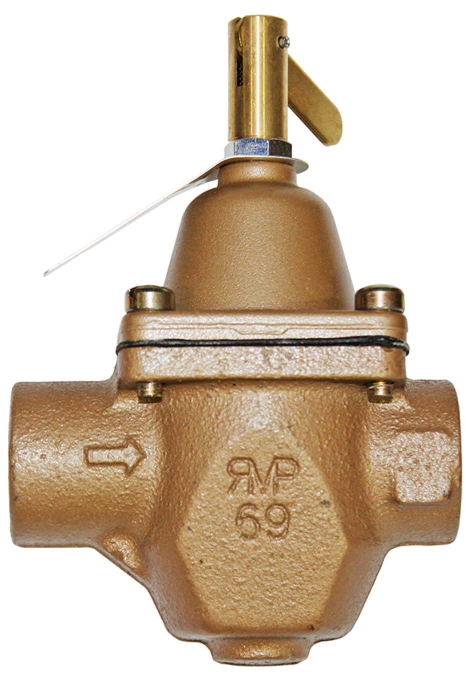

Figure 5 *Boiler feedwater valve. (Skilled Trades BC, 2021) Used with permission.*

A feedwater valve takes the domestic water from the building and lowers the pressure to the working pressure of a hydronic heating system before it enters the system. For a residential system, this pressure is normally between 12 psig (84 kPa) to 20 psig (140 kPa). A hydronic system will typically lose a little water due to air being eliminated as the system goes through its cycles. Potable water is brought in through the feedwater valve when the valve senses the pressure in the system has dropped below its pre-set level. Once enough water has been introduced into the system to bring it to its operating pressure, the feedwater valve automatically closes and no more water is added.

Bypass (Quick-Fill)

Some feedwater valves, like the one shown in Figure 5, have a lever at the top that allows the valve to be manually opened to quickly fill the system during startup. When lifted, this lever temporarily disables the pressure-regulating function of the valve and is known as a bypass. The lever must be manually returned to its normal position after the system is filled and purged (bled of air).

The bypass feature supplies the system with full building pressure to rapidly fill the system. Furthermore, the velocity of water entering the piping helps push air out of purge valves for better initial air removal (see "purge valve" description below).

The flow speed through the feed water valve when in quick-fill mode is usually sufficient to purge a typical residential system. On larger systems, it is common practice to install a bypass valve (usually a full port ball valve) to provide even faster filling and purging flow (Figure 6). Notice the bypass ball valve is installed on the piping run to minimize the pressure drop for fastest possible purging. This bypass valve should be closed and marked, so it remains closed during normal system operation.

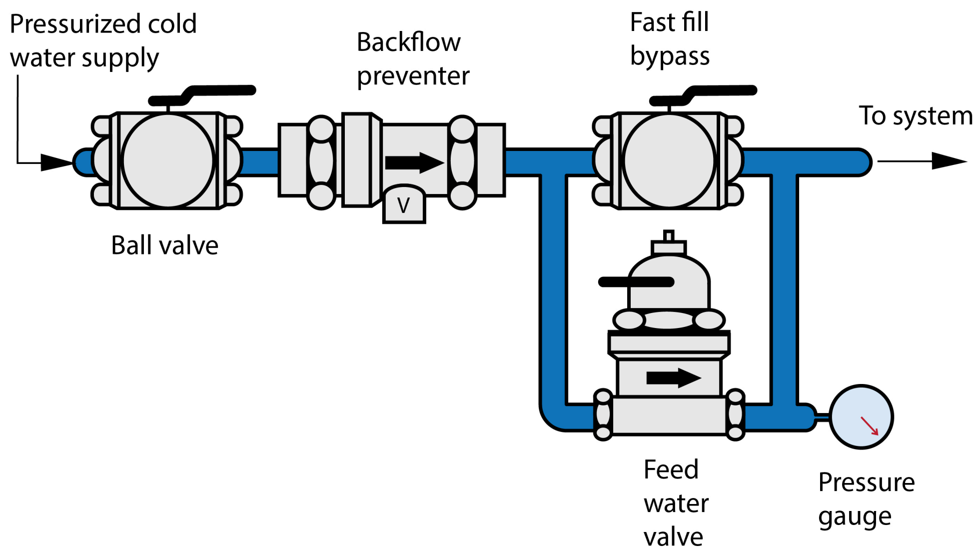

***Figure 6** Quick fill bypass arrangement. (TRU Open Press,)* CC BY-NC-SA *(https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en)*

The backflow preventer is located on the feedwater line in series with the feedwater valve, and in some cases, they are available as a packaged unit (Figure 7). It is important to note that the backflow preventer is always installed upstream of the feedwater valve. This ensures that the pressure drop through the backflow preventer does not affect the final fill pressure setting provided by the feedwater valve. All quick-fill valves must be installed so as to not bypass the backflow preventer.

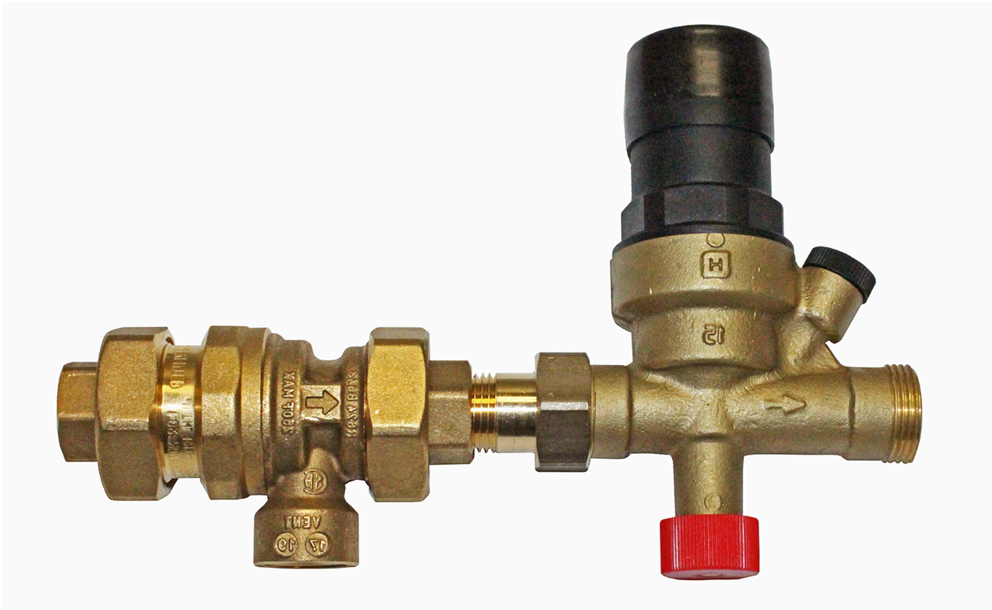

Figure 7 *Backflow preventer/feedwater valve as a unit. (Skilled Trades BC, 2021) Used with permission.*

Purge Valves

During the initial filling of a hydronic system, most of the air that is in the empty system can be effectively pushed out of the system using the pressure and velocity of the water entering through the makeup line. This is sometimes called power purging or gravity purging, and it reduces the time needed to bleed the air through high-point vents.

The purge valve is located on the return piping near the boiler. Modern purging valves consist of two ball valves in one common body. One ball valve is in line with the system, while the other is a side outlet port with a hs connection. Figure 8 shows two types of manufacture purge valve arrangements. Having different configuration options gives the installer location flexibility. The valve on the left has added installation versatility, as it has a three port ball with a reversible handle, which allows it to be set up for draining from either side of the ball.

Figure 8 *Purge valve/drain valve. (TRU Open Press)* CC BY NC SA *(https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en)*

Many wall-hung boilers come supplied with specialty purge valves kits for the supply and return connections (Figure 9).

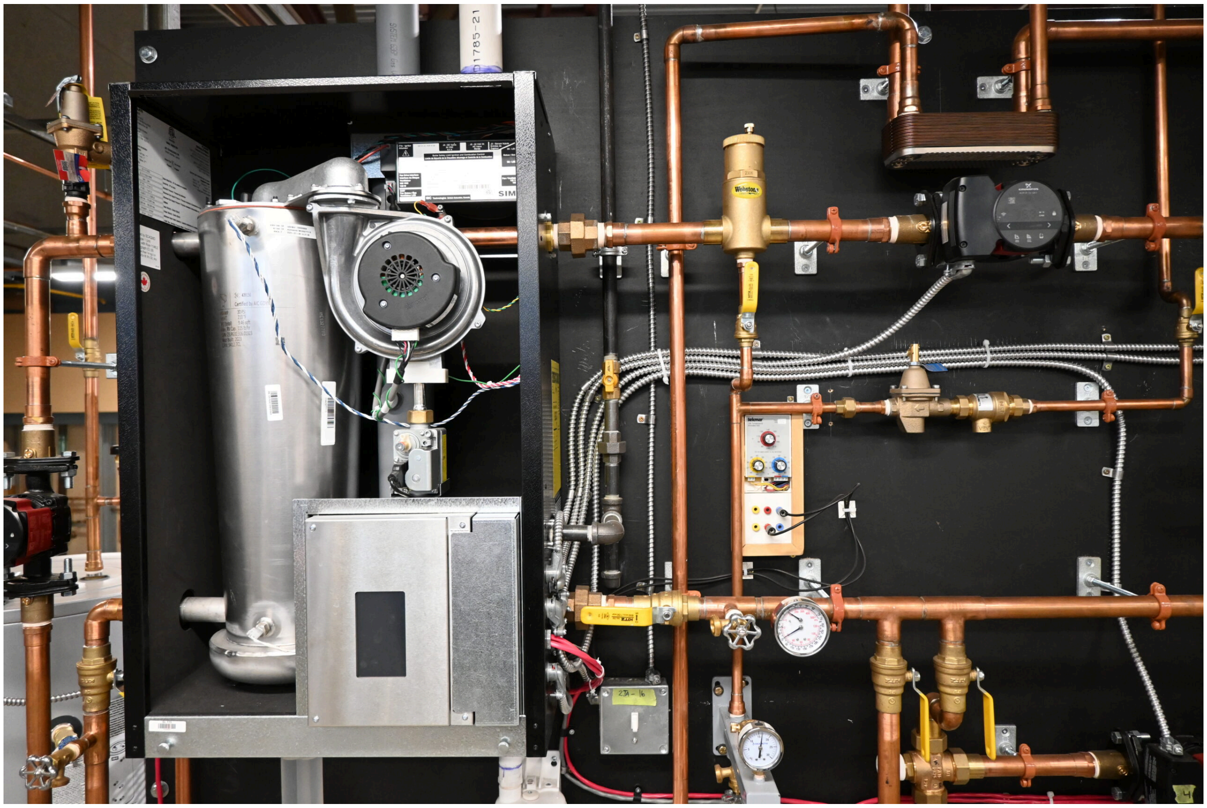

***Figure 9** Wall-hung boiler service valves. (TRU Open Press)* CC BY NC SA *(https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en)*

When purging the system (Figure 10), the inline ball valve is closed and the side outlet ball valve is opened, with a hose attached to it directing the water/air to a drain. The feedwater valve bypass or piped bypass can be fully opened to quickly let water into the system. As water enters the system, the air that previously filled the system is pushed out through the purge valve. Continue to fill the system until the fluid stream exiting the outlet port of the purge valve is free of visible bubbles. The bypass valve or quick-fill lever is then closed, the side outlet valve is closed, and the inline ball valve is opened. With the feedwater valve now set to work automatically, the system should require minimal manual bleeding of air. Pressures within the building piping feeding the quick-fill valve are almost always higher than the boiler relief valve; therefore, the boiler should be isolated, or this power purge will typically trip the relief valve. A cast-iron boiler should never be subjected to pressures over 30 psig.

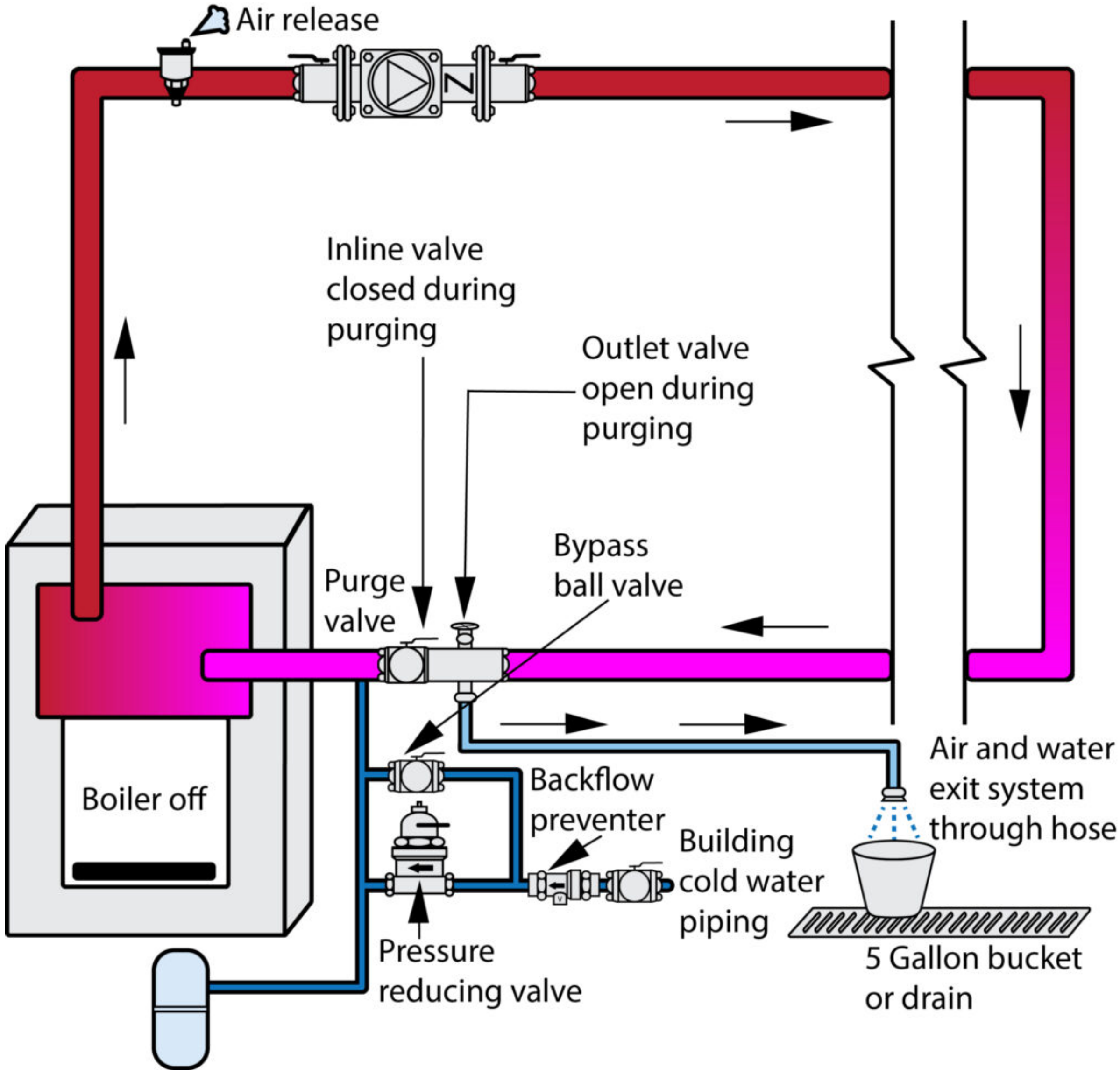

Figure 10 *Purging air from system. (TRU Open Press; [modified from] HPAC Magazine, 2017).*

For a newly constructed building, it is important that the water supply piping has been thoroughly flushed before using the auto fill as a purge supply. If there is any doubt as to the quality of the water supply, or if the potable supply has not been commissioned yet, it may be necessary to connect to an external source or purge cart. In this case, the previously described flushing procedure that used a three-valve arrangement would be used. For ease of installation, there are specialty manufactured double port flushing valve arrangements available (Figure 11).

Figure 11 *Pro-Pal Purge & Fill, Full Port Forged Brass Ball Valve. (Nibco, Inc.) Used with permission.*

Flow Check Valve

When water is heated, it becomes less dense than the cooler water on the return side of the boiler. During the off cycle of a boiler, hot water still has the tendency to rise up through the heating system and provide flow and heat, even when none is needed. This is referred to as thermal siphoning or gravity flow. Flow check valves are designed with a weighted internal plug (Figure 12) or a spring that is heavy enough to stop thermal siphoning or gravity flow of hot water while the system's circulator is off, but light enough not to cause unwanted resistance for the pump. They also act like a basic check valve and will prevent reverse flow in a multizone system.

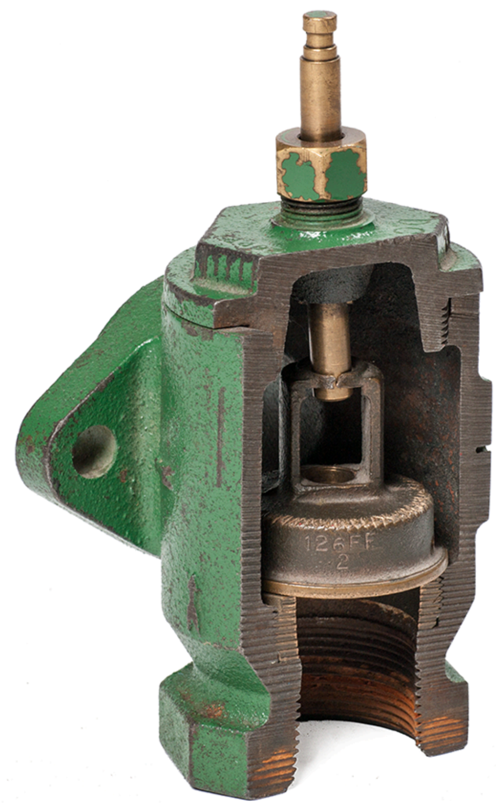

Figure 12 *Cutaway of a cast-iron threaded flow check valve. (Skilled Trades BC, 2021) Used with permission.*

The stem at the top allows the valve to be manually opened if gravity circulation is desired or for draining the system.

Thermostatic Radiator Valve

The thermostatic **radiator valve** (TRV) (Figure 13), is a device installed in the inlet or supply side of a heat transfer unit (HTU) and is normally used on a constant flow system. It contains two parts: the valve body and the thermostatic operator. The thermostatic operator senses the temperature of the room air surrounding the valve and forces the valve to either open or close. The TRV can also be fitted with a capillary tube and bulb mounted near the bottom of the HTU that senses the temperature of the air being pulled into the HTU through convection currents.

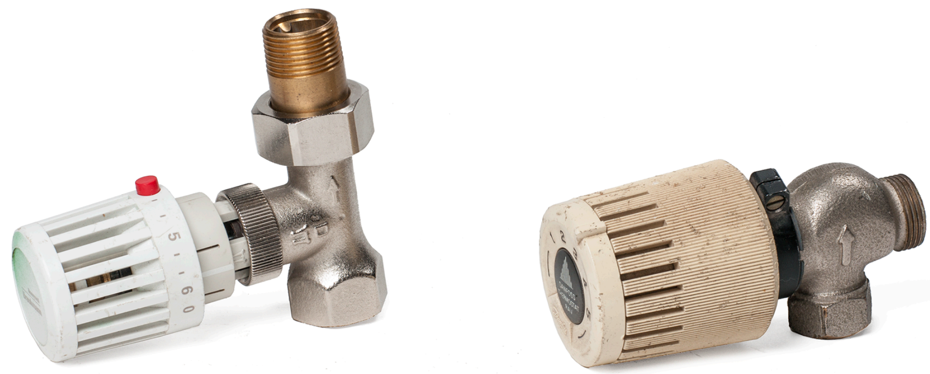

Figure 13 *Thermostatic radiator valve. (Skilled Trades BC, 2021) Used with permission.*

Opening the TRV allows more water to flow through the heat transfer unit, causing an increase in the room temperature; closing the TRV does the opposite. The opening and closing of the TRV is done using a spring, a bellows, and a fluid located inside the bellows (Figure 14).

The spring inside the TRV normally holds the valve open, allowing hot water to flow through the heat transfer unit; it will close to stop water flow when the room temperature rises to its set point. This is accomplished through the use of a fluid inside the bellows, which heats up and expands in reaction to the room temperature increasing. The force of the expansion causes the bellows to act upon the valve plug to overcome the opening force of the spring and eventually close the valve. In the reverse, as the room temperature drops, the liquid cools and contracts, releasing the pressure on the bellows and allowing the spring to push the valve open. This allows water to pass through the heat transfer unit, and the whole process starts again.

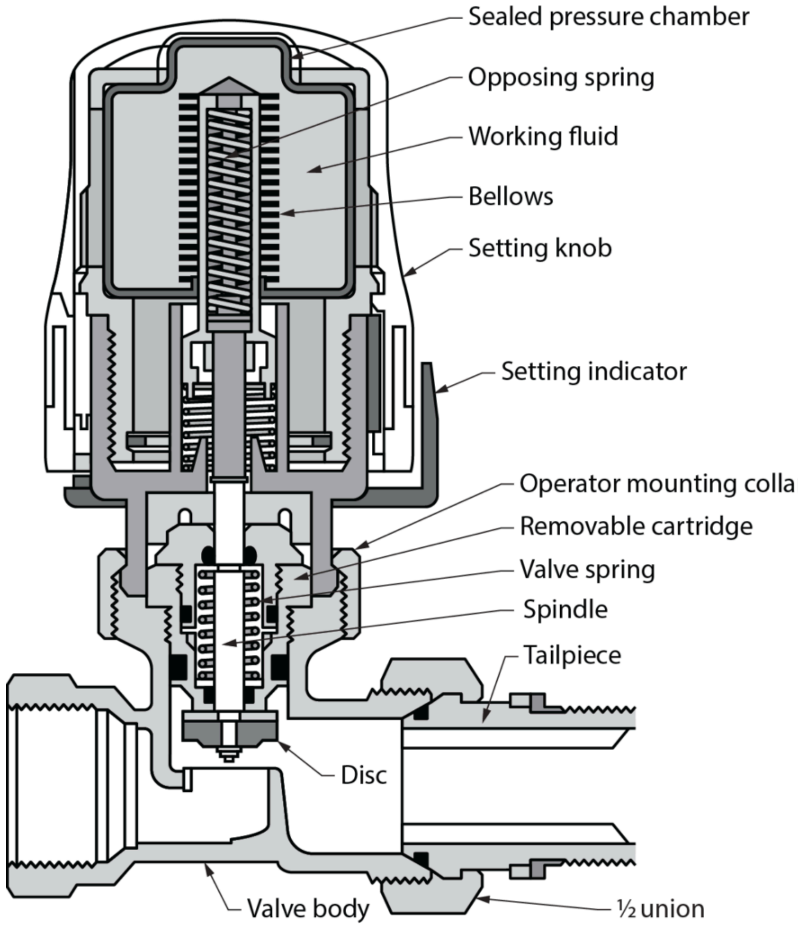

Figure 14 *Thermostatic radiator valve (cutaway). (Skilled Trades BC, 2021) Used with permission.*

Thermostatic radiator valves can also be controlled via a wall-mounted thermostat. The thermostat senses room temperature and has a capillary tube connecting it to an operator mounted onto the valve on the heat transfer unit. The operation is similar to that of the directly mounted thermostatic valve except that the sensor is now remote to the valve itself. The advantage to this setup is that room temperature is controlled at thermostat height; the drawback is that the exposed capillary tube will be surface-mounted and must be covered to be aesthetically acceptable and also protect it from damage.

Zone Valves

One of the main benefits of a hydronic heating system is the ability to independently control different areas of the building or "zones." Zone valves play a big part in this control strategy.

Zone valves permit or prevent the flow of water through the zone they control. When a room thermostat senses the need for heat, it signals the control valve for that zone to open.

There are two types of electrically operated zone valves:

- Motor operated actuator
- Wax filled actuator

Their difference is relative to their operation.

Motor Operated Zone Valves

Motorized zone valves are operated by electric motors activated by a 24-volt signal from the thermostat in that zone. Figure 15 shows a $\frac{3}{4}$-inch motorized zone valve with sweat connections intended for installation on copper tubing.

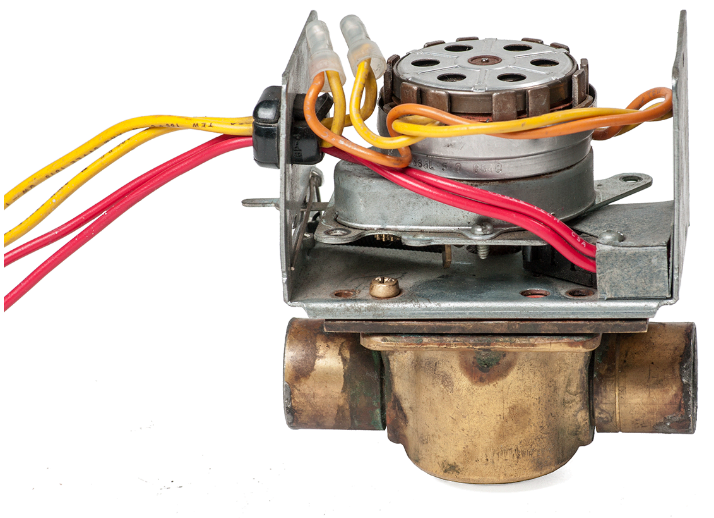

Figure 15 *Zone valve. (Skilled Trades BC, 2021) Used with permission.*

The electrically controlled motor drives an actuator with a rubber ball mounted on it (Figure 16). When a call for heat occurs, 24 volts AC is sent to the zone valve motor through the yellow wires. The motor spins to move the actuator, and the rubber ball moves away from the opening connected to the piping. Water pushed by a circulator is then able to flow through the piping in that zone. When the call for heat is satisfied, the thermostat contacts open and power to the zone valve is interrupted. A spring then pulls the actuator back to its original position, and the valve closes.

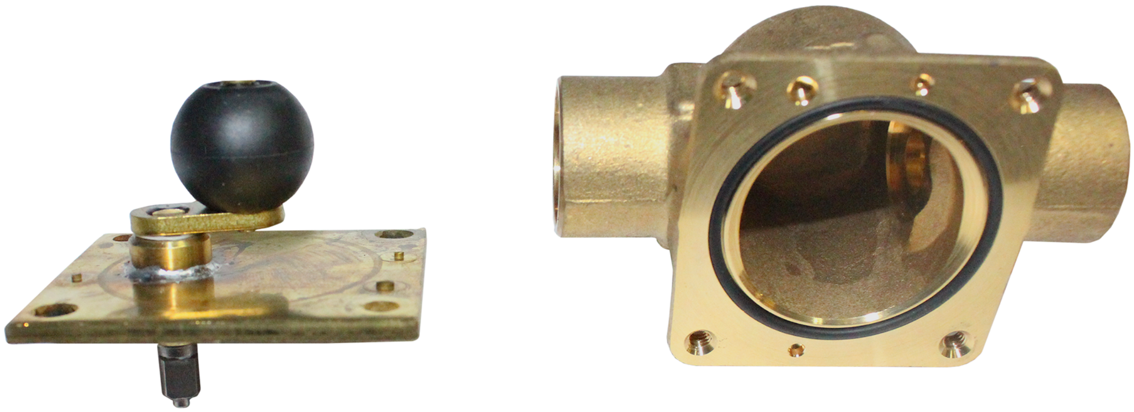

Figure 16 *Zone valve ball. (Skilled Trades BC, 2021) Used with permission.*

Wax Filled Actuators

Zone valves controlled by a wax filled actuator use a similar valve design as the one shown for thermostatic radiator valves. These valves are opened and closed with a simple linear (versus rotational) movement of their shaft. When the unenergized actuator (Figure 17) is mounted onto the valve body, the cool contracted wax and an internal spring push down onto the valve stem and close the valve. On a call for heat, the valve is energized with 24 VAC and a small heating element warms the wax chamber; the expanding wax lifts up a piston assembly and opens the valve.

The total movement of the actuator shaft is only about $\frac{1}{8}$ of an inch. The movement of the shaft is slow. A typical actuator reaches its fully open position two to three minutes after power is first applied, which is preferred on a radiant system to avoid unnecessary opening for a brief room draft that will be picked up by the high mass of the system.

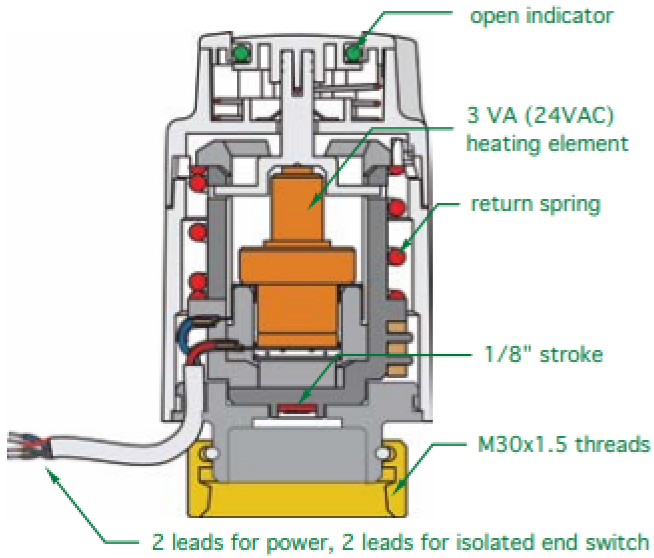

Figure 17 *Wax filled zone valve actuator. (Caleffi, idronicsTM, 2009).*

Zone valves are normally installed on the supply side of each zone circuit. This is done so that heat migration will not occur during the off cycle. If the zone valve is installed on the return from a circuit, the supply to that circuit should have a flow check installed.

Zone valves are available in two-wire and four-wire configurations. In a two-wire configuration, power is only sent to the actuator to open and close the valve. A four-wire configuration is used when a circulating pump is required to turn it on but only if a zone valve is open. In this case, there needs to be some way for the system to recognize that there is somewhere for the water to go. The four-wire configuration has two extra wires that incorporate an end switch to prove that the valve is open.

The end switch is simply a proving switch. As the zone valve actuator arm moves, a small metal plate attached to the arm moves with it. Only when the zone valve is fully open does this metal plate press against a microswitch, closing it and allowing the electricity to travel through the switch's red wires to the pump relay. The relay coil energizes, which closes internal contacts and turns the pump on.

If the zone valve fails to open, the end switch will not close, and the pump will not start. This saves the pump from "deadheading" (spinning the impellor without letting water flow), which will eventually cause the pump to fail.

System Operating Pressure Controls

Figure 18 shows a number of zones being supplied by one fixed-speed circulator. As zone valves are closed, the flow resistance of the system is increased and the zones that remain open "feel" this increased differential pressure, and their flow rates immediately increase. In some systems, the increased pressure differential and flow velocity may be of little consequence. In others, it may be sufficient to create flow noise, pipe erosion, and valve stem lift.

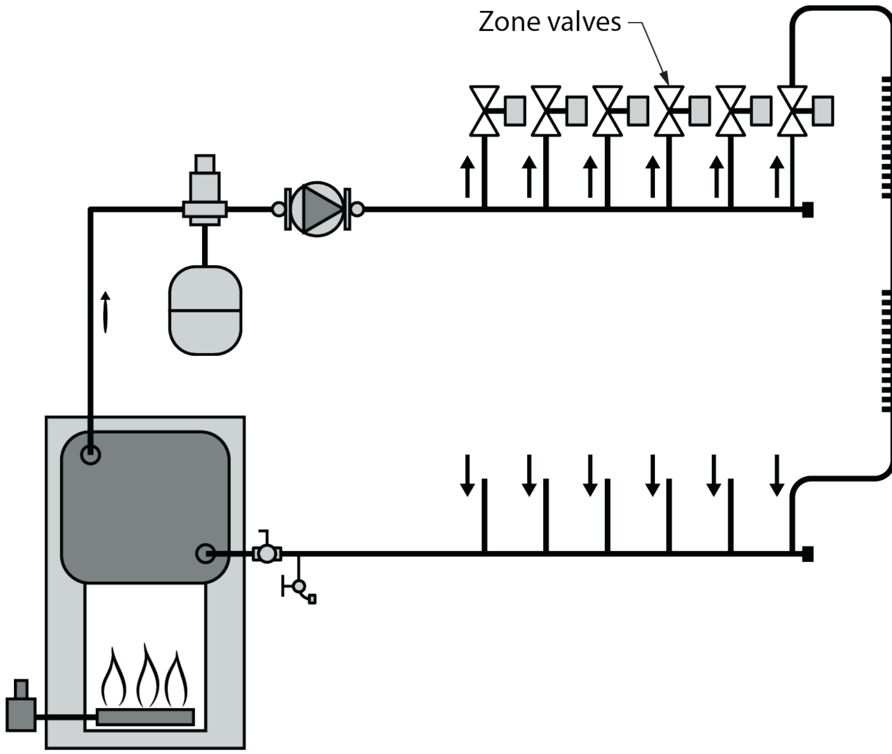

Figure 18 *Multiple zones valve system. ([modified] Skilled Trades BC, 2021) Used with permission.*

Reducing excess system pressure created by zoning can be achieved by two common methods:

- Differential bypass valve
- Pressure-regulated circulator

A differential bypass valve (Figure 19) is like an adjustable spring-loaded pressure relief valve. The setting knob adjusts the force exerted by the compression spring on the valve.

Figure 19 *Differential pressure bypass valve.*
(Skilled Trades BC, 2021) Used with permission.

Essentially, it gives the pump another route to pump through if most or all zone valves are closed (Figure 20).

The spring pressure should be set so there is just enough tension to keep it in the closed position when the system is balanced with all zones are open. As zone valves close and the differential pressure across the headers increases, the differential bypass valve should begin opening when the differential pressure reaches 0.5 to 1 psi above the differential pressure present when all zone circuits are open. The result is a minimal change in the differential pressure between the supply and return headers.

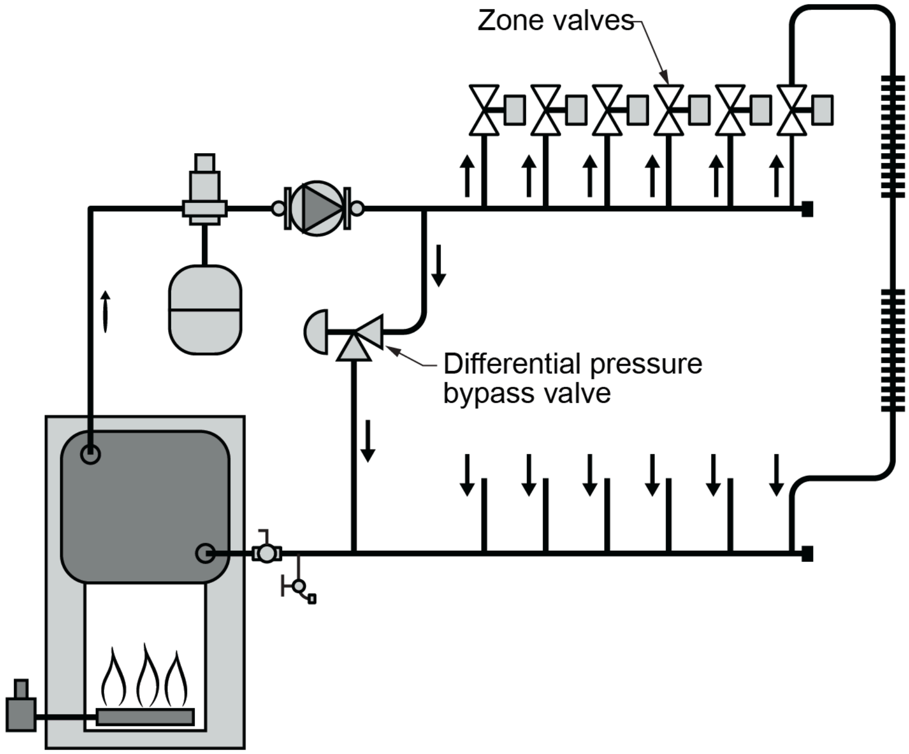

***Figure 20** Multiple zones with a differential pressure bypass valve. (Skilled Trades BC, 2021) Used with permission.*

The disadvantage of using a bypass valve is that, at times, when zone valves are closed, the pump is wasting some of its energy. As described in the Section B-4.1 (#chapter-b-4-1-system-components), another way of regulating excess pressure in hydronic systems is through the use of variable speed circulators. These pressure-regulated ECM circulators are ideal for systems using valve-based zoning and eliminate the need for a differential pressure bypass valve.

When a valve in a branch circuit closes or modulates to reduce flow, the circulator detects an increase in differential pressure across it. It quickly responds by lowering its speed to counteract this change in differential pressure. As additional valves in other branch circuits close or modulate to reduce flow, the circulator continues to adjust its speed accordingly to maintain the set differential pressure. This process, known as "constant differential pressure control," mode, conserves electrical energy that would otherwise be wasted by operating at a fixed speed.

Balancing Valves

Hydronic systems containing two or more parallel piping paths often require adjustments of the flow rates to ensure even heat distribution. This is especially true in two-pipe direct-return systems where, without balancing valves, these systems would produce higher flow rates in the piping paths closest to the circulator compared to those farther out in the distribution system. The proper use of balancing valves can correct for this situation.

Most balancing valves are a type of globe valve that has much less flow restriction through it. A globe valve with a convention disc or plug (Figure 21, left) has a quick opening characteristic which makes them much more difficult to use for the precise flow balancing required on hydronic heating systems. On the linear and equal percentage globe style valves (Figure 21, centre and right), the disc is more cone-shaped, making more of it protrude into the seat. This allows more precise setting of the flow control plug and thus, provides better control of flow rate.

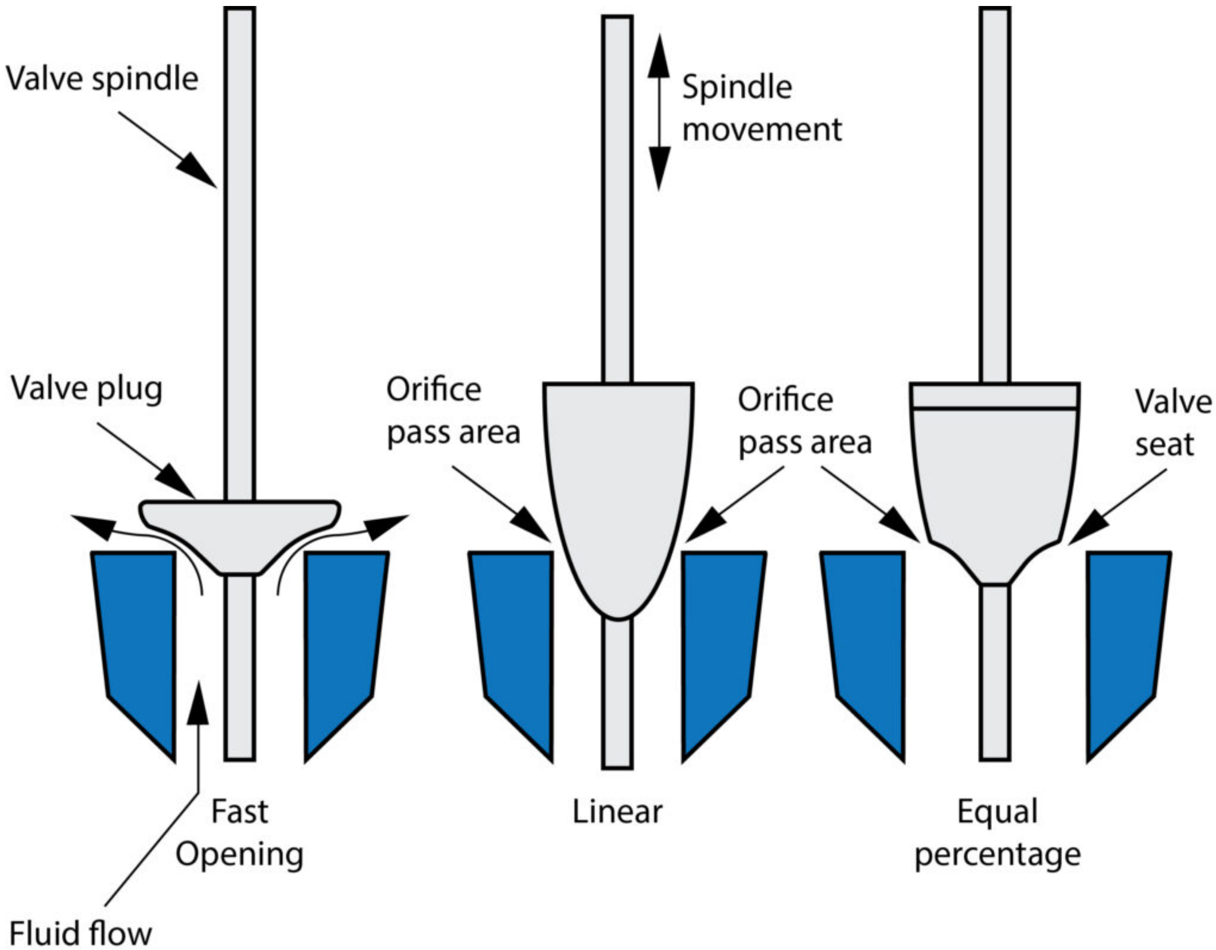

Figure 21 *Valve plug shapes. ([modified from] Automationforum.co, 2018) Fair Dealing (https://laws-lois.justice.gc.ca/eng/acts/c-42/page-6.html#docCont:~:text=Exceptions-,Fair%20Dealing,-Marginal%20note%3A)*

Selecting Balancing Valves

A balancing valve operates best at between 50% and 100% of the maximum opening. Select the balancing valve so that the required pressure drop will be within this range. Do not use a balancing valve that is larger than necessary. Not only does a larger valve cost more, but it will also operate near the closed position, which may give poor flow accuracy. The balancing valve should never be larger than the size of the pipe.

Manufacturers' specifications indicate the flow capacity and pressure drop limits of balancing valves.

There are a variety of balancing valves available to suit the needs of the different systems, some of these include:

- Lockshield valves
- Flow metering balancing valves
- Differential pressure balancing valves
- Automatic flow balancing valves

Lockshield Valves

Lockshield balancing valves are most commonly used to balance the flow on radiators. They are often paired with a thermostatic rad valve (Figure 22). To adjust the flow setting of a lockshield valve, the cap is removed, and the internal plug is rotated with an Allen key. The valves come complete with a half union, which allows the valve to be easily separated in position from the radiator.

Figure 22 *Radiator valves. (Xylem Canada, n.d.). Used with permission.*

Flow Meter Balancing Valves

Some balancing valves have a self-contained flow meter. On some valves, the flow can be read continuously; on others (Figure 23), the reading is taken by pulling an actuating pin.

Figure 23 *Caleffi Quicksetter™ balancing valve. (Caleffi, idronics™, 2010). Caleffi S.p.A. All rights reserved. Used with permission.*

Most manifolds for radiant in floor systems will have self-contained flow meter balancing valves for each radiant loop (Figure 24). For some types, the flow adjustments to each circuit are made by rotating the flow indicator column, which is directly connected to the shaft of the internal valve. For others, the flow adjustment may be located underneath the electric zone operator to hinder owners making their own adjustment after the system has been balanced.

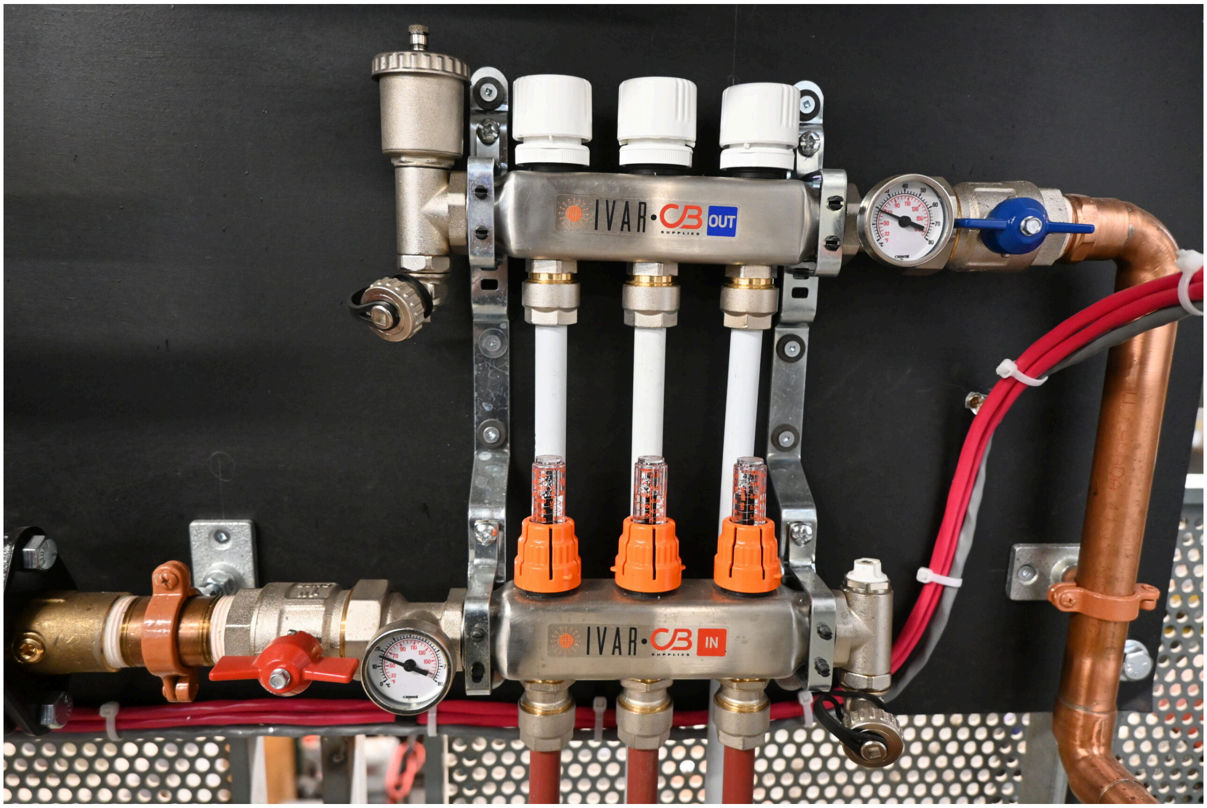

Figure 24 *Radiant manifold with flow meters.* (TRU Open Press) CC BY-NC-SA (*https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en*)

Differential Pressure Balancing Valves

Differential pressure type balancing valves work on a known relationship between flow rate and the pressure drop across the valve. The valves have two ports, one on each side of the disk/seat (Figure 25), that allow connection of a differential pressure measuring device. The flow rate through the valve can then be found using a chart, slide rule, or electronic device.

Figure 25 *Bell & Gossett Circuit Setter. (Xylem, n.d.). Used with permission.*

The ports are sometimes called Pete's plugs. This is a twist on the term PT plugs to indicate plugs or ports that can be used to measure pressure and/ or temperature.

Another variation of a differential pressure balancing valve locates the pressure ports on either side of an internal venturi (Figure 26). The venturi passage maintains a more stable relationship between differential pressure and flow rate than that of valves that measure differential pressure across the flow plug.

Figure 26 *Venturi balancing valve. (Skilled Trades BC, 2021) Used with permission.*

For both types of these types of differential pressure balancing valves, the adjusting knob has setting numbers or increments that must be used to select the proper flow scale on the manufacturer's chart.

Automatic Flow Balancing Valves

Automatic flow balancing valves use an internal cartridge that maintains a specific flow rate over a wide range of system differential pressure ranges. The cartridge consists of a cylinder, a spring-loaded piston, and a combination of fixed- and variable-shaped orifices through which flow passes (Figure 27). The piston automatically adjusts its position based on the amount of thrust created by the differential pressure across the valve. Different cartridges are available for different flow rate requirements.

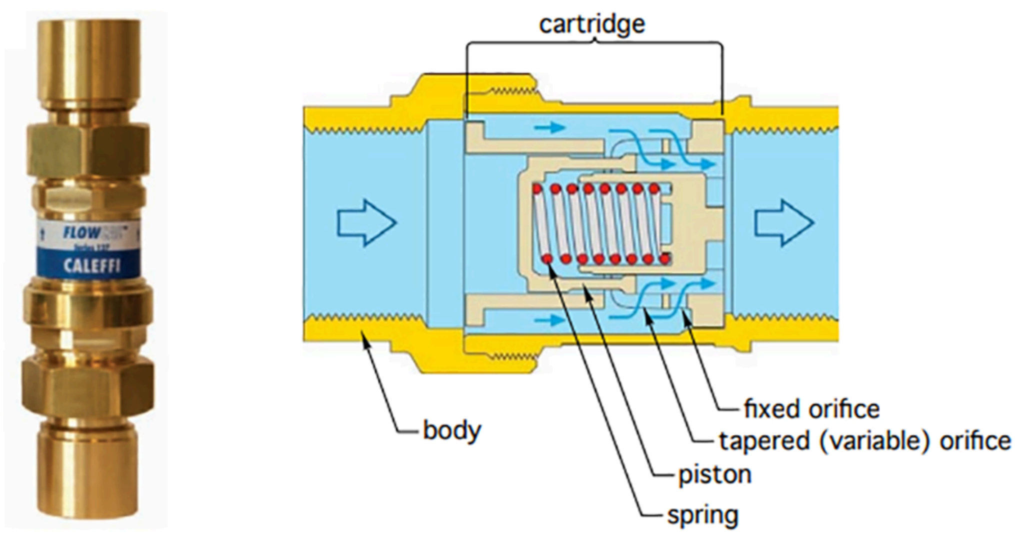

Figure 27 *Caleffi FlowCal™ automatic balancing valve. (Caleffi, idronics™, 2010). Caleffi S.p.A. All rights reserved. Used with permission.*

Mixing Valves (Tempering Valves)

Some hydronic distribution systems require water temperatures that are substantially lower than the temperatures supplied by the heat source. For example, a radiant floor heating system may require water at 43°C (110°F), while the water temperature from the non-condensing boiler may be over 82°C (180°F). In such cases, the lower water temperature is created by blending water returning from the distribution system with hot water from the heat source. The flow rate of each stream can be regulated by a mixing valve to attain the desired supply temperature.

There are several types of valves used in hydronic heating systems to achieve the water temperatures needed. They include valves operated by electrically motorized actuators, as well as by thermostatic sensors and actuators. The sections that follow describe several types of mixing valves and briefly illustrate how they are used. As well, it is important to note that the term "mixing valve" is used generically in the industry to mean any valve that blends two temperatures of water to achieve a lower temperature. The following section breaks that generic terminology down into more definite terms.

Diverting Valve

A diverting valve (Figure 28) is not actually a mixing valve but is simply a valve designed to divert flow. It has one inlet port and two outlet ports and is not designed to mix any fluids within its body.

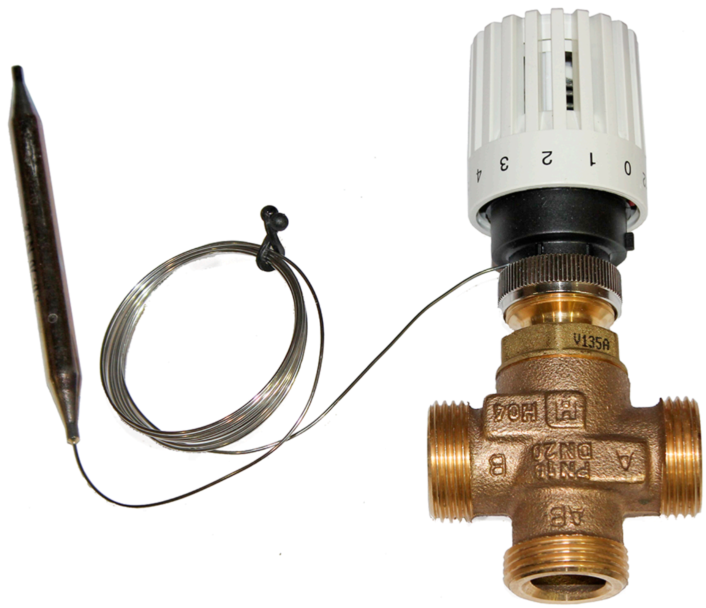

Figure 28 *Three-way valve with thermostatic operator. (Skilled Trades BC, 2021) Used with permission.*

Figure 29 shows the difference between using a three way valve as a mixing valve or a diverting valve.

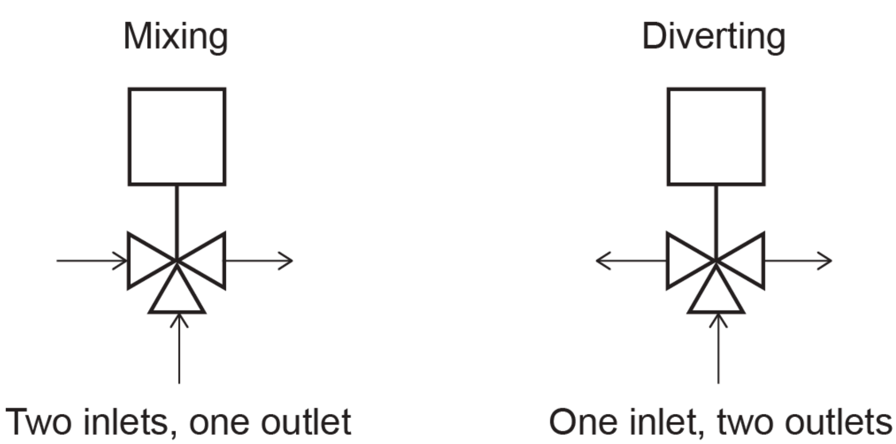

Figure 29 *Mixing valve versus diverting valve. (Skilled Trades BC, 2021) Used with permission.*

A diverting valve is located on the return side of the system, similar to a mixing valve (Figure 30). The flow coming into the valve is the return water from the system. Typically, a three-way diverting valve will divide the cooler system's return water into two flows. A portion of the flow (approximately 25%) goes to the boiler to be reheated. The rest (approximately 75%) bypasses the boiler to meet and mix with the heated water from the boiler in the system piping. These ratios can vary widely depending on the water temperature required for the heating application.

Diverting valves can be either manually or automatically controlled. If automatic control is desired, the valve must have a remote sensor bulb with a capillary tube mounted downstream of the system mixing point and connected to the valve. A diverting valve achieves finer control and has less head loss through it than a mixing valve.

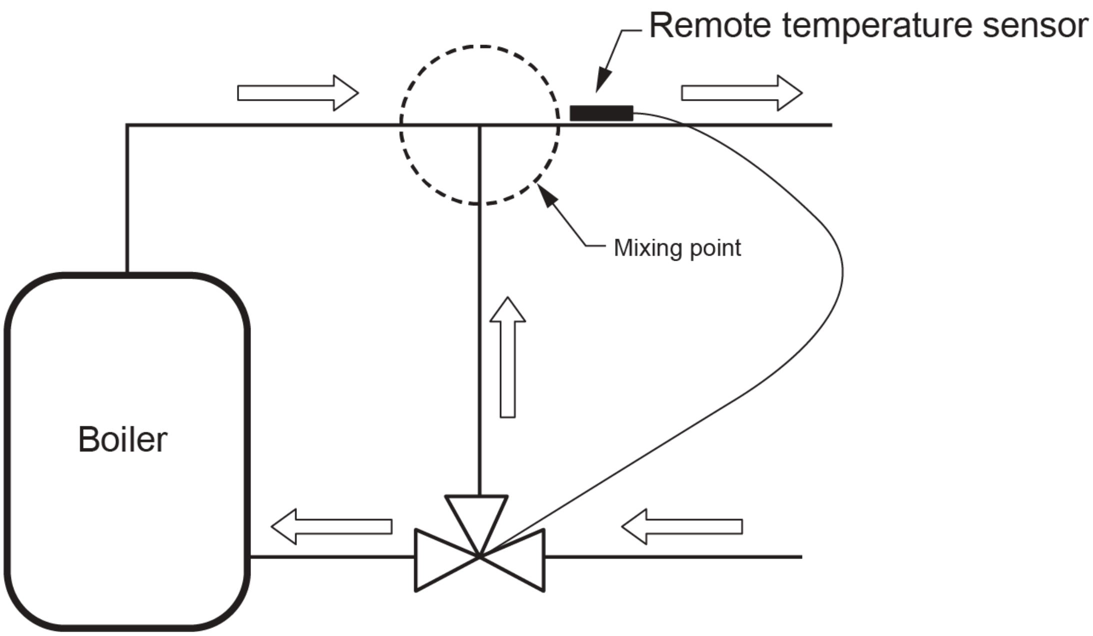

Figure 30 *Diverting valve piping arrangement. (Greg Wirachowsky/Skilled Trades BC, 2021) Used with permission.*

The mixture of hot boiler water and cool system return water is necessary to maintain the desired temperature needed in a radiant floor system and protect the boiler against lower-than-allowed return water temperatures.

Three-Way Mixing Valve

Like the three-way diverting valve, a three-way mixing valve is also a three-port valve, but it has two inlet ports (one for hot water and the other for cool water) and one outlet port, which is tempered water. Also, unlike the three-way diverting valve, the mixing of the two fluids with the three-way mixing valve occurs inside the valve body itself (Figure 31).

The positioning of the internal valve mechanism determines how much of each fluid will enter the valve body. Adjusting the knob on the valve adjusts the water from each of the hot and cool ports.

A three-way mixing valve can come with or without an actuator. Without an actuator, it cannot adjust itself to compensate for changes in the temperature of incoming water. If automatic water temperature control is required, the addition of an actuator allows the valve to adjust the outgoing water temperature automatically.

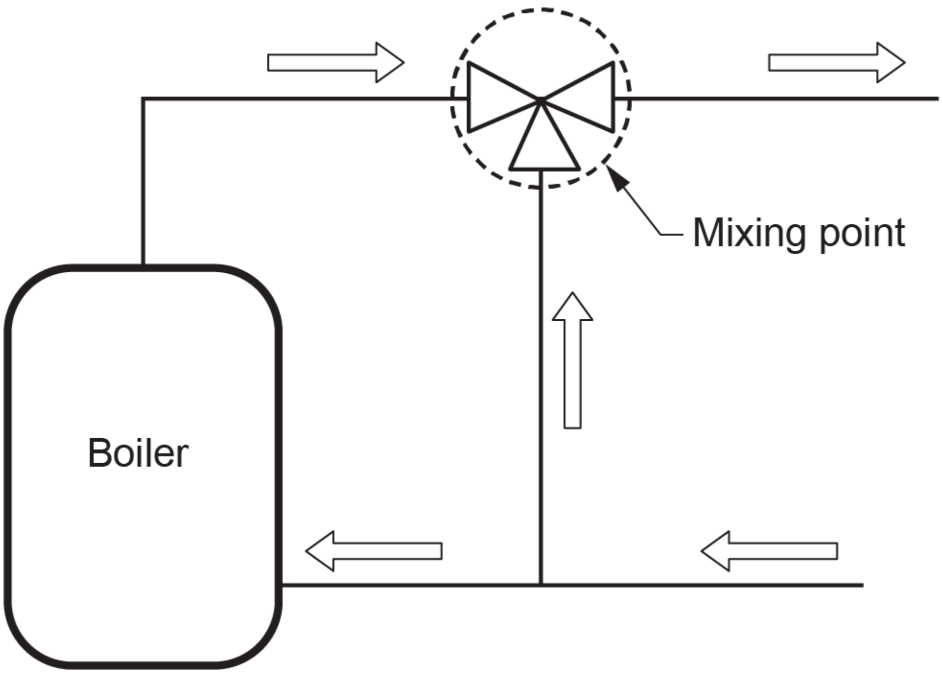

Figure 31 *Three-way mixing valve piping arrangement. (Skilled Trades BC, 2021) Used with permission.*

If a boiler is unable to handle lower water return temperature, which may result in condensation, then a three-way mixing valve may not be the best option. In that case, a four-way mixing valve might be a better option.

Four-Way Mixing Valve

The basic difference between three-way and four-way mixing valves is that four-way mixing valves (Figure 32) can control the water temperature and flow rates to both the supply piping and return piping to the boiler.

Cool return water is mixed with the hot supply water to achieve the desired temperature to supply the system. The valve also mixes hot supply water and cool return water to maintain boiler return water temperatures above 60° (140°F). This ensures that the water entering the boiler is hot enough to avoid any possible condensation issues.

Like the three-way mixing valve, a four-way mixing valve can be used either with or without an actuator to provide better mixed water temperature control. Motorized actuators for four-way valves often incorporate outdoor sensors to automatically raise or lower the system water temperature in response to changes in outdoor temperature. This control strategy is called outdoor reset.

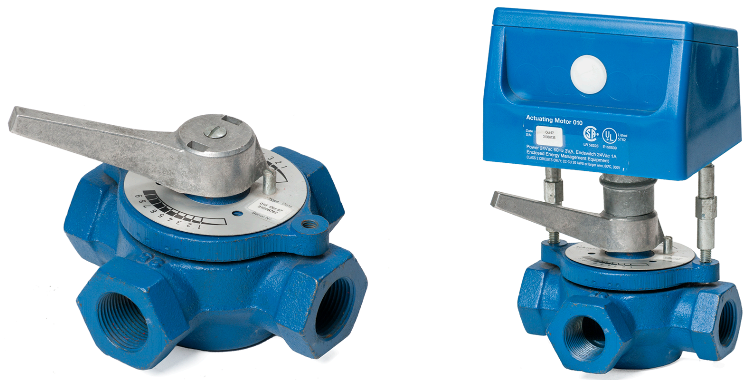

Figure 32 *Four-way mixing valve. (Skilled Trades BC, 2021) Used with permission.*

Figure 33 shows different internal water pathways and mixing created with different valve positioning.

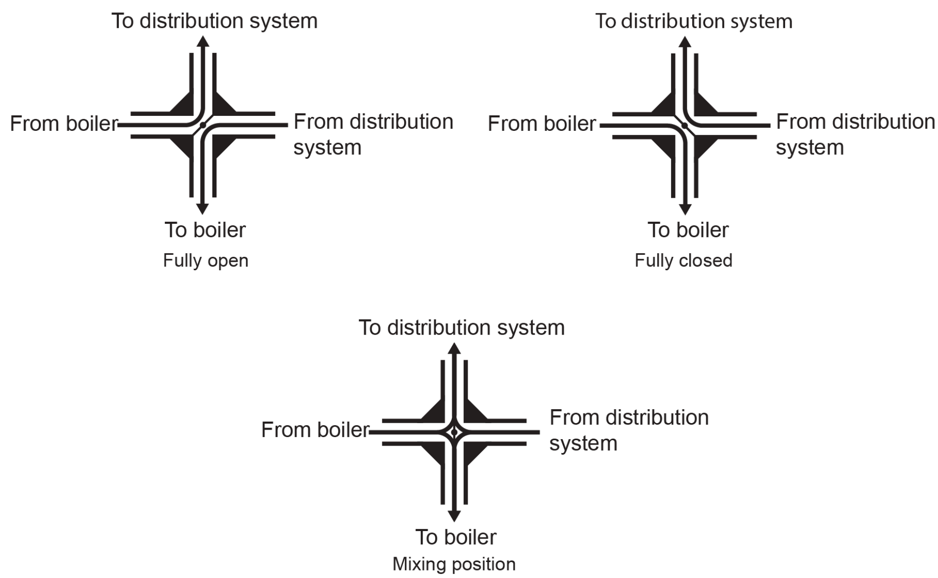

Figure 33 *Inside a four-way mixing valve. (Skilled Trades BC, 2021) Used with permission.*

Figure 34 shows the piping required for a four-way mixing valve configuration.

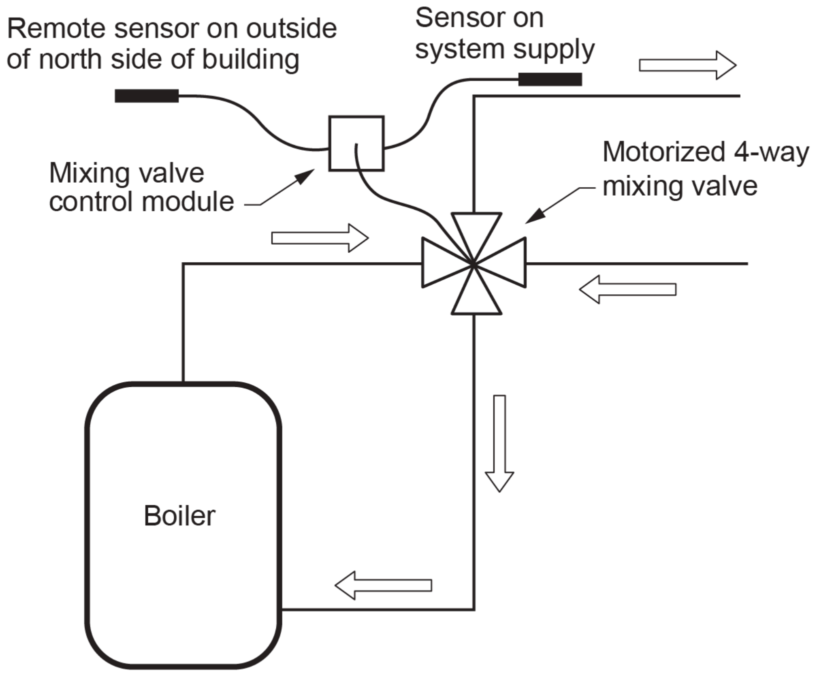

Figure 34—*Four-way mixing valve piping arrangement. (Skilled Trades BC, 2021) Used with permission.*

Self-Test B-4.2: Hydronic System Valves

Complete the chapter Self-Test B-4.2 and check your answers.

If you are using a printed copy, please find Self-Test B-4.2 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=60#h5p-10 (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=60#h5p-10)

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B-4.3 Distribution Systems

The piping mains connect the boiler to the heat transfer units. In some piping layouts, the piping mains connect directly to the heat transfer units, while in others, the piping mains connect to piping runs or branches that lead to the heat transfer units.

Types of Piping Configurations

There are a number of piping configurations available that deliver heated water from the source to the emitter, and the name of each configuration usually describes how the piping arrangement is installed.

The piping layouts in hot-water heating are named as follows:

- One-pipe series loop
- One-pipe split-series loop
- One-pipe diversion tee
- Two-pipe direct-return
- Two-pipe reverse-return
- Two-pipe primary/secondary

Radiant panels are essentially heat emitters and, therefore, are not categorized as piping layouts. The specifics of radiant heat systems will be covered in Level 3 of Plumber and Steamfitter/ Pipefitter Apprenticeship training.

One-Pipe Systems

In one-pipe systems, hot water is circulated through a single pipe to a number of heat transfer units and back to the boiler. In some cases, the return pipe from one heat transfer unit is the supply pipe for the next unit. In all one-pipe systems, the heat transfer unit nearest to the heat source will receive much hotter water than units farther down the line. One-pipe systems are most common in residential buildings because of their lower installation cost.

As in all hydronic systems, air vents are required at every high point so that air does not form a blockage and prevent water from circulating. As well, drains are required at all low points to allow servicing of piping and equipment.

Series Loop Systems

In a series loop system (Figure 1), the supply main joins directly to the first heat transfer unit, the return pipe from this unit supplies the next unit, and so on. Finally, the return pipe from the last heat transfer unit returns the water to the boiler. It can be said that the heat transfer units are part of the piping main. Series loop systems and one-pipe systems are very similar.

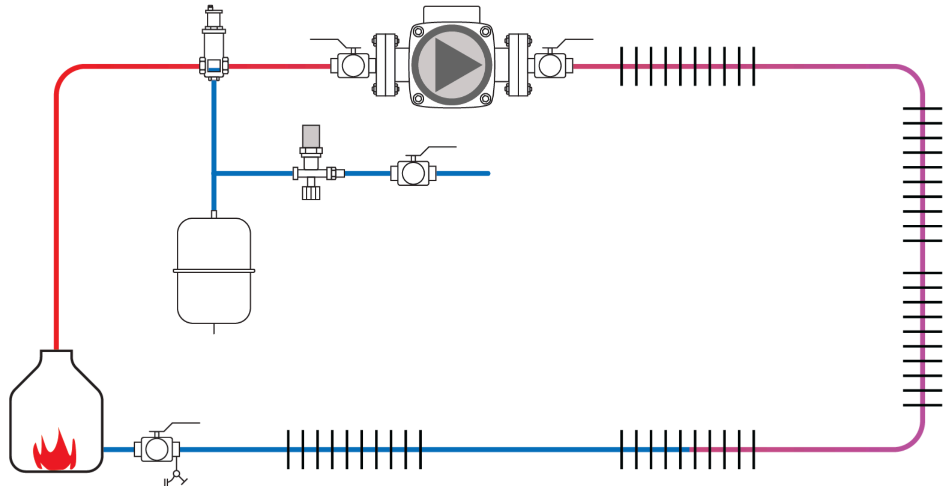

Figure 1 *Series loop system. (Skilled Trades BC, 2021) Used with permission.*

The series loop system is simple and is the least expensive system to install, but its heat transfer units cannot be individually shut off and should be progressively longer/larger in size, to give them equal heat output, the farther they are from the boiler. This is due to the lower water temperature available in the farther reaches of the system. A single pump responding to a lone thermostat controls the heat in the entire zone. This system is normally used in apartments or small single-family dwellings where the temperature will not vary much between rooms and the heat emitters are finned-tube baseboards. The temperature in any room is adjusted by allowing more or less airflow through each finned-tube baseboard cabinet by opening or closing the damper on the cabinet (see B-3 Hydronic Transfer Units (#part-b-3-hydronic-transfer-units)).

To avoid flow problems, one pipe size (normally $\frac{3}{4}$ in. NPS) should be maintained throughout a loop. The length of each loop and number of heat emitters on it becomes very important because the water releases heat and becomes cooler as it travels through each heat transfer unit. If return water to the boiler has had too much heat removed from it, condensation problems could occur, causing premature heat exchanger failure due to corrosion inside the combustion chamber. Therefore, a rule of thumb in the industry is that no more than 60,000 to 70,000 BTU/h (18–20 kW) should be allocated to each circuit in the system.

Split-Series Loop Systems

The split-series loop system (Figure 2) is a version of the series loop system, with the main difference being that the piping is split into a number of loops. Each loop is controlled by a thermostat connected to a zone valve that controls the heat flow to the heat transfer units within that loop.

In the split-series loop system shown in Figure 2, the supply main is piped from the boiler to the farthest outside wall. The main then splits and water is directed to each of the two loops. The return mains individually return the water to a point near the boiler, where they join together to become the boiler return. There can be more than just two loops in a split-series loop system, and the heat source would be sized to supply all the loops, but each loop is still limited to no more than 60,000 to 70,000 BTU/h output.

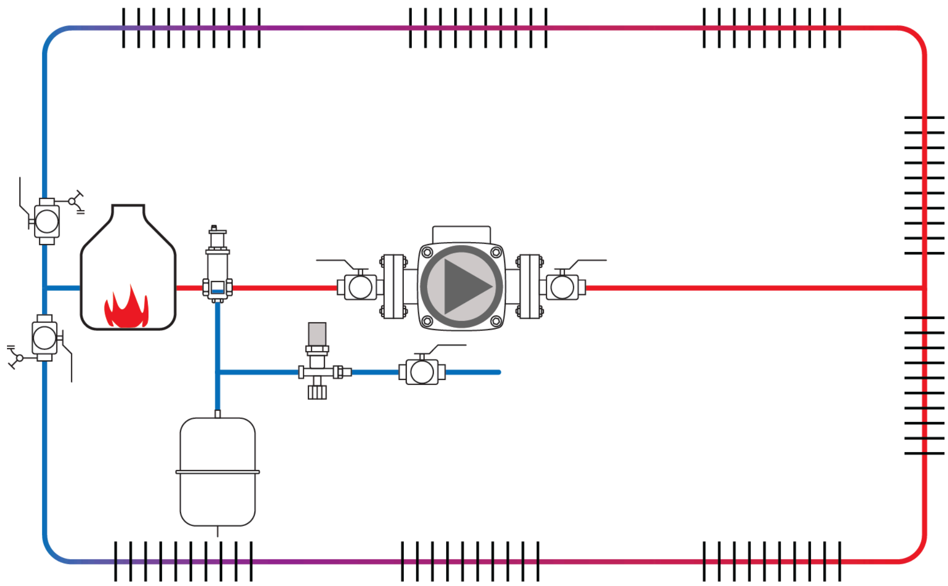

Figure 2 Split-series loop. (Skilled Trades BC, 2021) Used with permission.

The split-series loop system is suitable for larger buildings where there is a larger heat load, such as in small apartment blocks or similar structures.

One-Pipe Diversion Tee System

A diversion tee or Monoflo system is a one-pipe system, but the heat transfer units are placed on branch circuits, parallel to the main supply pipe. Any of the units may be shut off individually without disturbing the flow of hot water in the rest of the system. The layout of a one-pipe diversion tee system is shown in Figure 3.

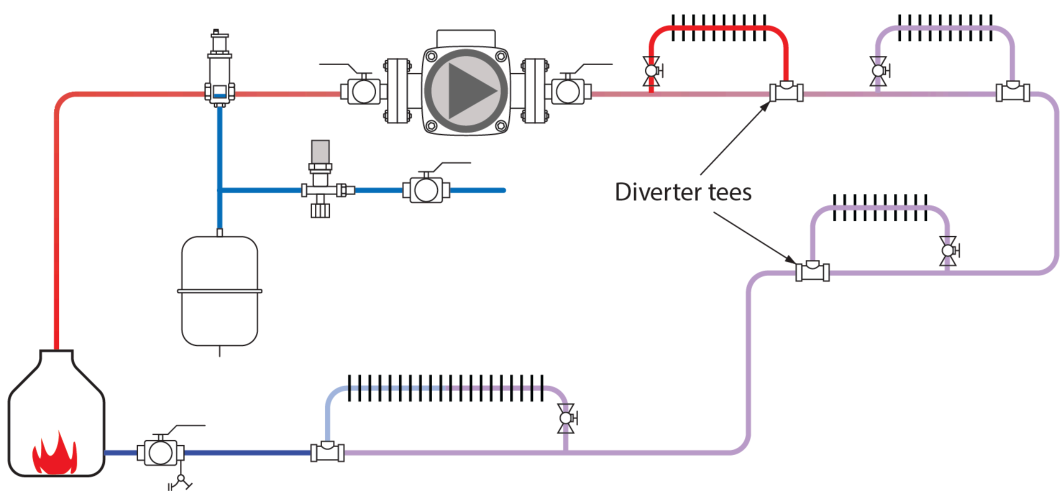

Figure 3 Diversion tee system. (Skilled Trades BC, 2021) Used with permission.

Diversion tees (Figure 4) are installed on the piping main to create flow through the branch piping. Monoflo is the trademarked name for a diversion tee that has been specifically engineered for use in hot-water heating systems. It operates through the use of a venturi and applies Bernoulli's principle, which states that "where velocity is greatest, pressure is least." For water to flow through the narrow opening within the tee, it must increase in velocity. This drops the pressure in an area behind the nozzle, which is where the branch outlet is connected, and water is drawn through the branch.

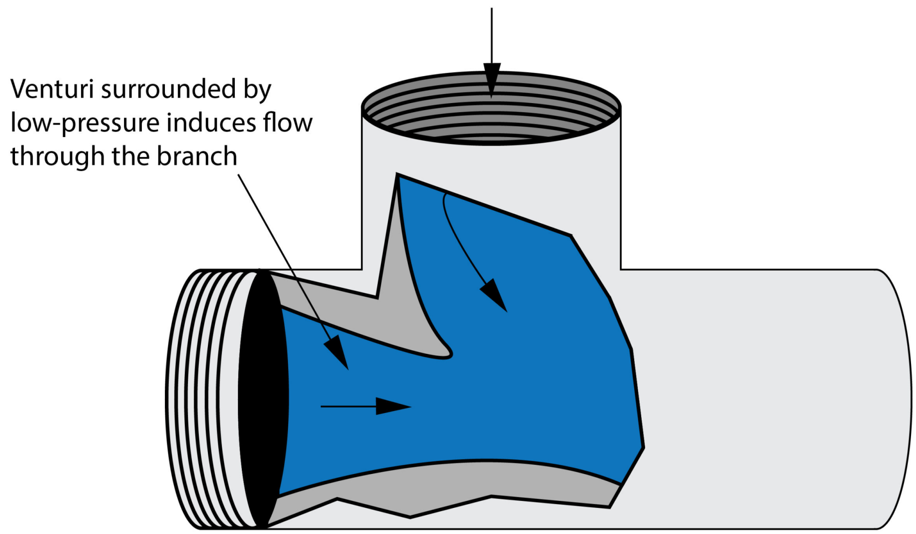

Figure 4 *Diversion tee water flow pattern through main and return connection. ([adapted] Skilled Trades, BC, 2021). Used with permission.*

To correctly install a Bell & Gossett (originator of the fitting) diversion tee on an **upfed system**, place the Monoflo tee on the heat emitter's return connection, with the red ring groove closest to the standard tee on the supply connection. Only one tee is normally needed due to the tendency of hot water to rise easily through the standard tee on the supply (Figure 5). If the heat transfer unit has a lot of flow resistance through it, then install two Monoflo tees, similar to the downfed configuration described below. For upfed heat transfer units, the tees should be installed at least the length of the heat transfer unit apart.

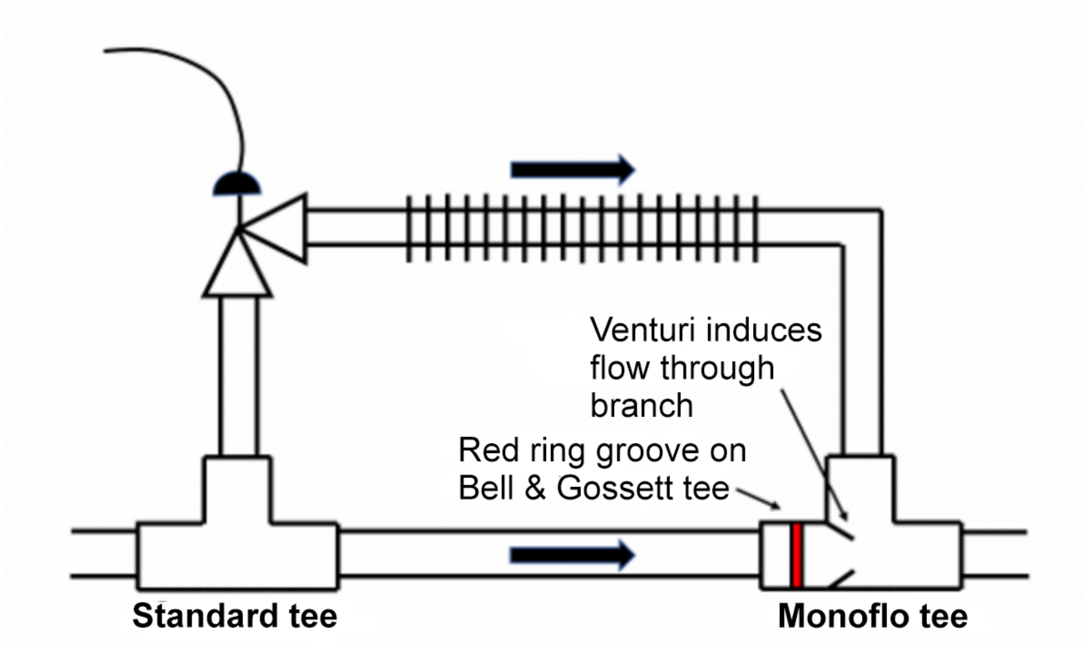

Figure 5 *Upfed heat transfer unit. (Greg Wirachowsky/ Skilled Trades BC, 2021) Used with permission.*

Downfed heat transfer units are located below the supply mains and require more definite flow diversion to make heated water fall below the main (Figure 6). Monoflo tees are installed on both the supply and return connections, with the red groove rings on the tees facing each other. The Monoflo tee on the supply acts to divert water flow through the branch outlet.

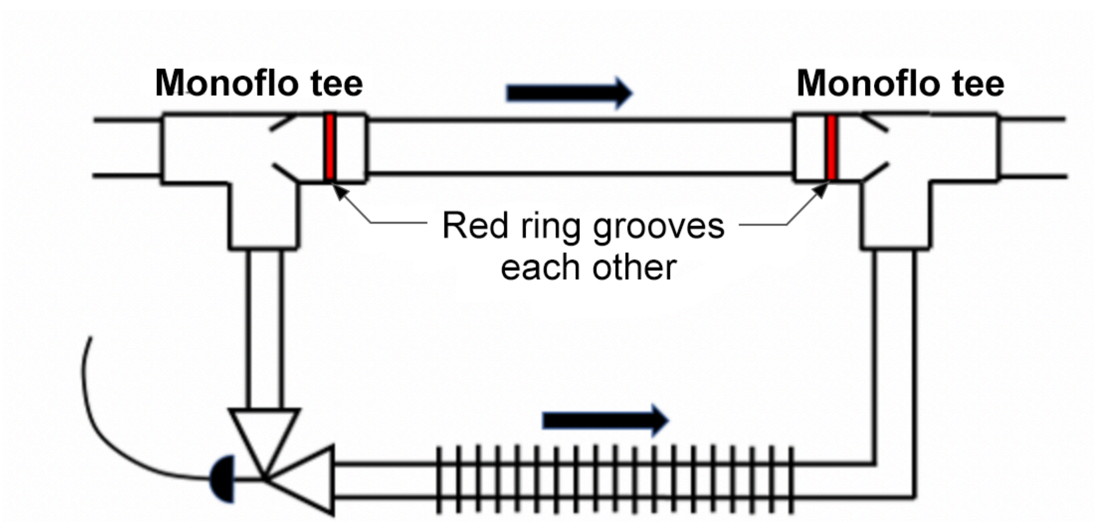

Figure 6 *Down fed heat transfer unit. (Greg Wirachowsky/ Skilled Trades BC, 2021) Used with permission.*

The diversion tee system is adaptable to almost any type or size of building, from a small single-family residence to a multi-storey office to an apartment complex. For more specific installation requirements, always consult the manufacturer's literature.

Two-Pipe Systems

Two-pipe systems have distinct supply and return mains. Water from the supply main is fed to each heat transfer unit and ends at the last HTU. The return water from each HTU is collected in a return main and delivered back to the boiler.

The supply main is gradually reduced in size as it feeds the circuits and, similarly, the return main is gradually increased in size as it receives the return water from each circuit. In this way, each heat transfer unit can and should receive water at the same temperature as when it left the boiler.

Two-pipe systems are generally found in large commercial or industrial buildings, or in smaller systems where better control of heat and flow is desired. Two-pipe systems are categorized as either direct-return or reverse-return.

Two-Pipe Direct-Return System

In a two-pipe direct-return system (Figure 7), each heat transfer unit has a supply line of hot water from the boiler and a return line to the boiler. This is also known as a "first fed, first return" system.

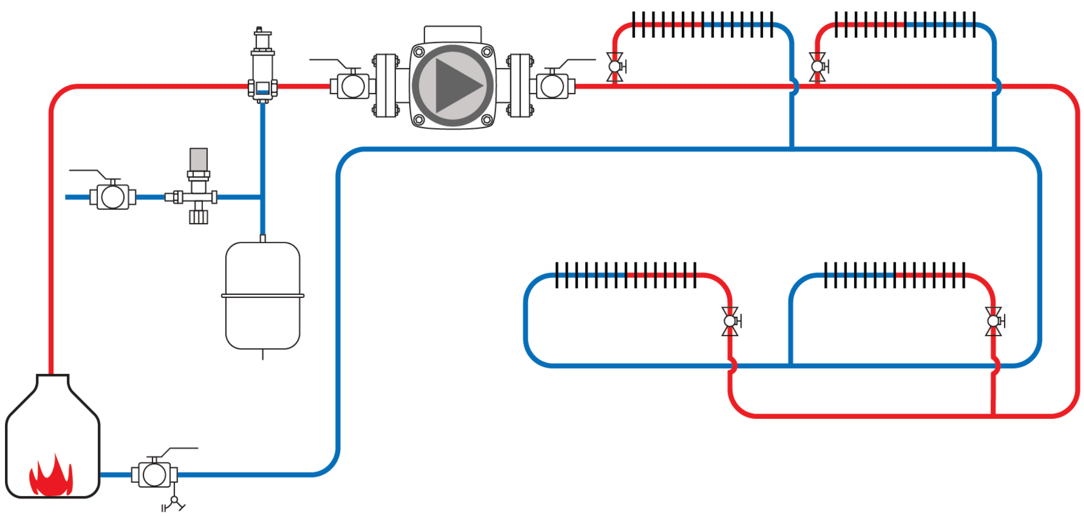

Figure 7 *Direct-return system. (Skilled Trades BC, 2021) Used with permission.*

A difficulty with direct-return systems is that the circuits from the boiler to different heat transfer units and back to the boiler are usually of different lengths. This difference in length influences the flow of water to certain units, which cause an imbalance of heat transfer. To counteract this imbalance, larger diameter pipes can be used for the longer circuits or the size of the heat transfer units on those units can be increased. The most common method of balancing the heat transfer is to install balancing valves at each heat transfer unit to restrict the flow. The heat transfer unit nearest the boiler would have its flow restricted more than those farther out along the supply line, with the farthest heat transfer unit not likely needing any flow restriction at all. When balanced, the resistance to flow through all the heat transfer units should be roughly equal to that of the furthest circuit.

A direct-return system can supply different amounts of heat simultaneously to a variety of equipment. The equipment may include heat exchangers and heat transfer units.

The direct-return system is unpopular for residential systems because it is:

- Difficult to balance
- More expensive to install because of the balancing components
- More expensive to maintain because of the balancing components

Two-Pipe Reverse-Return System

The two-pipe reverse-return system (Figure 8) was developed to provide a better balance of heat transfer between circuits of different lengths without the need for balancing valves. In the reverse-return piping layout, each circuit is of nearly equal length. The heat transfer unit that has the shortest supply pipe route has the longest return pipe route. Pipe size must still be matched to flow requirements in each section.

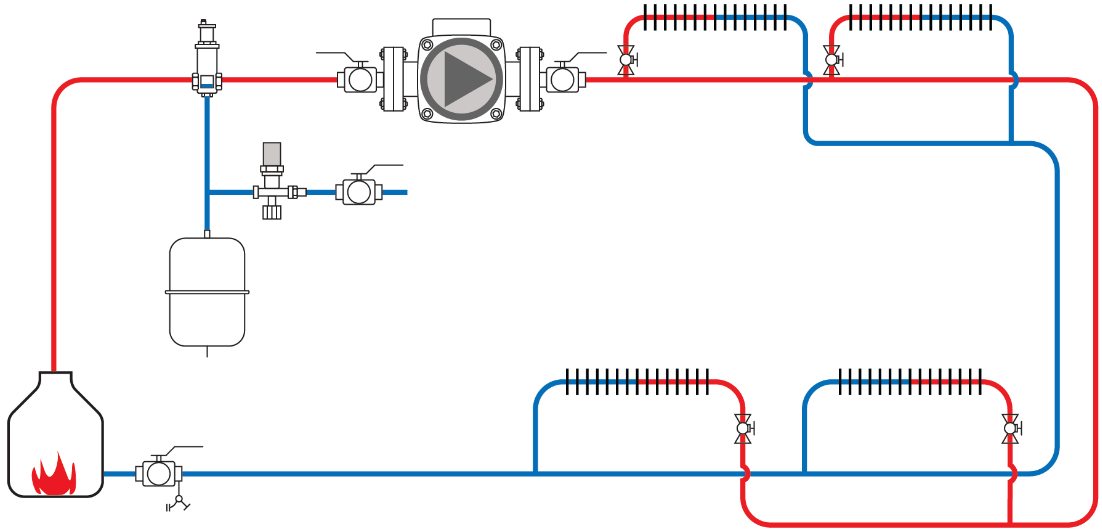

Figure 8 *Reverse-return system. (Skilled Trades BC, 2021) Used with permission.*

This system is also known as the "first fed, last return" system and is the most common system installed in commercial buildings.

Home-Run Distribution System

In the previously mentioned systems, it is assumed that rigid piping is used. The introduction of PEX (cross-linked polyethylene) in the piping industry has led to a piping system known as the home-run distribution system (Figure 9).

A home-run system consists of a supply and return manifold station placed in an easily accessible location within each dwelling, such as one for each storey. Supply and return mains to the manifolds are piped in a reverse-return configuration. In this way, the manifolds are treated much like heat transfer units and should have relatively equal temperatures of supply water available. From the supply manifold, a separate small-diameter PEX tube, such as $\frac{3}{8}$ in. or $\frac{1}{2}$ in., is run to each heat emitter and then returns back to the return manifold. In this way, with throttling valves on the tubing at the return manifold connections, the flow of water to each heat emitter can be controlled. It is similar to a radiant floor system in that each run leaves the supply manifold and returns to the return manifold, but a home-run system will have different heat emitters, such as a finned-tube baseboard (wallfin).

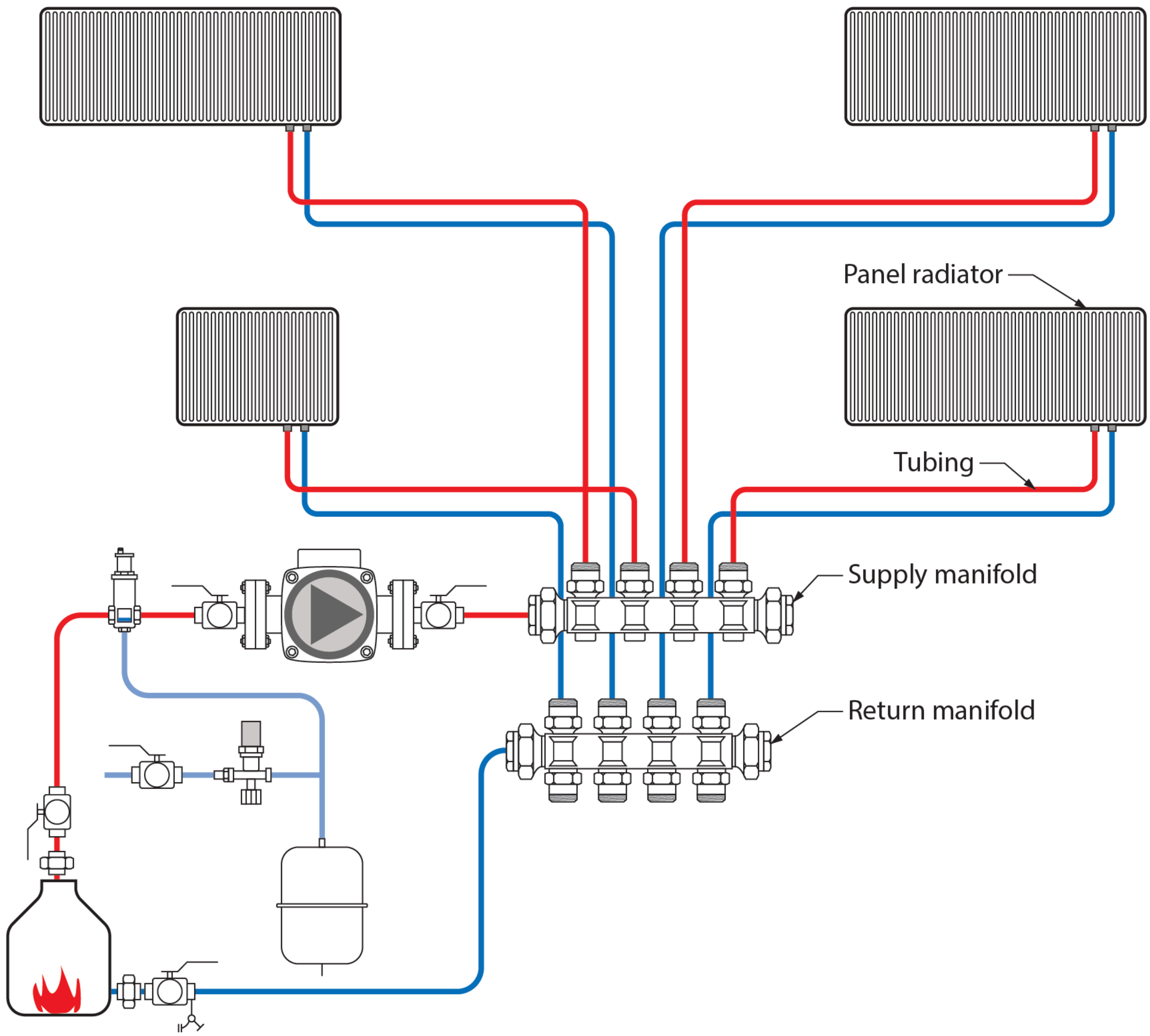

Figure 9 *Home-run distribution system. (Skilled Trades BC, 2021) Used with permission.*

The small diameter and flexibility of the PEX tubing allows for quick and easy installation. Some of the other benefits of the home-run system include the following:

- The heat output of each room can be individually controlled by flow rates.
- Water is delivered to each heat emitter at approximately the same temperature.
- Manifolds can be used in conjunction with a variety of heat emitters.
- Balancing valves can still be used to regulate flow through each separate home run.

Hydraulic Separation

In a hydronic system, it is often necessary to have two or more circulators operating simultaneously within the same system. Circulators work on the principle of creating a pressure differential between the inlet and outlet to move water. Ideally, each circulator works independently of the other, and the pressure differential created by one does not affect the other. When this occurs within a system, it is referred to as hydraulic separation. If the circulators create a situation where they interfere with each other, undesirable flow conditions can occur.

Primary/Secondary Systems

The degree to which two operating circulators interact with each other depends on the head loss of the piping path they have in common. Head loss is “pump-speak” for pressure loss. All systems need a pressure differential to create flow. If this common piping has low flow resistance through it, then very little head or pressure loss occurs.

The system shown in Figure 10 contains multiple pumps, each of which circulates water through a circuit. Hydraulic separation is achieved when the working of one pump does not affect the working of another. Once again, hydraulic separation is created when the head or pressure loss through common piping is limited. In Figure 10, the designer used what is known as closely spaced tees to achieve this effect. Spacing the tees closely together on common piping minimizes head loss between tees, thus ensuring hydraulic separation. If the tees were even only a few feet apart, there would be enough friction loss between the tees for flow through the primary circuit to cause small flows in the secondary circuit, which must be avoided.

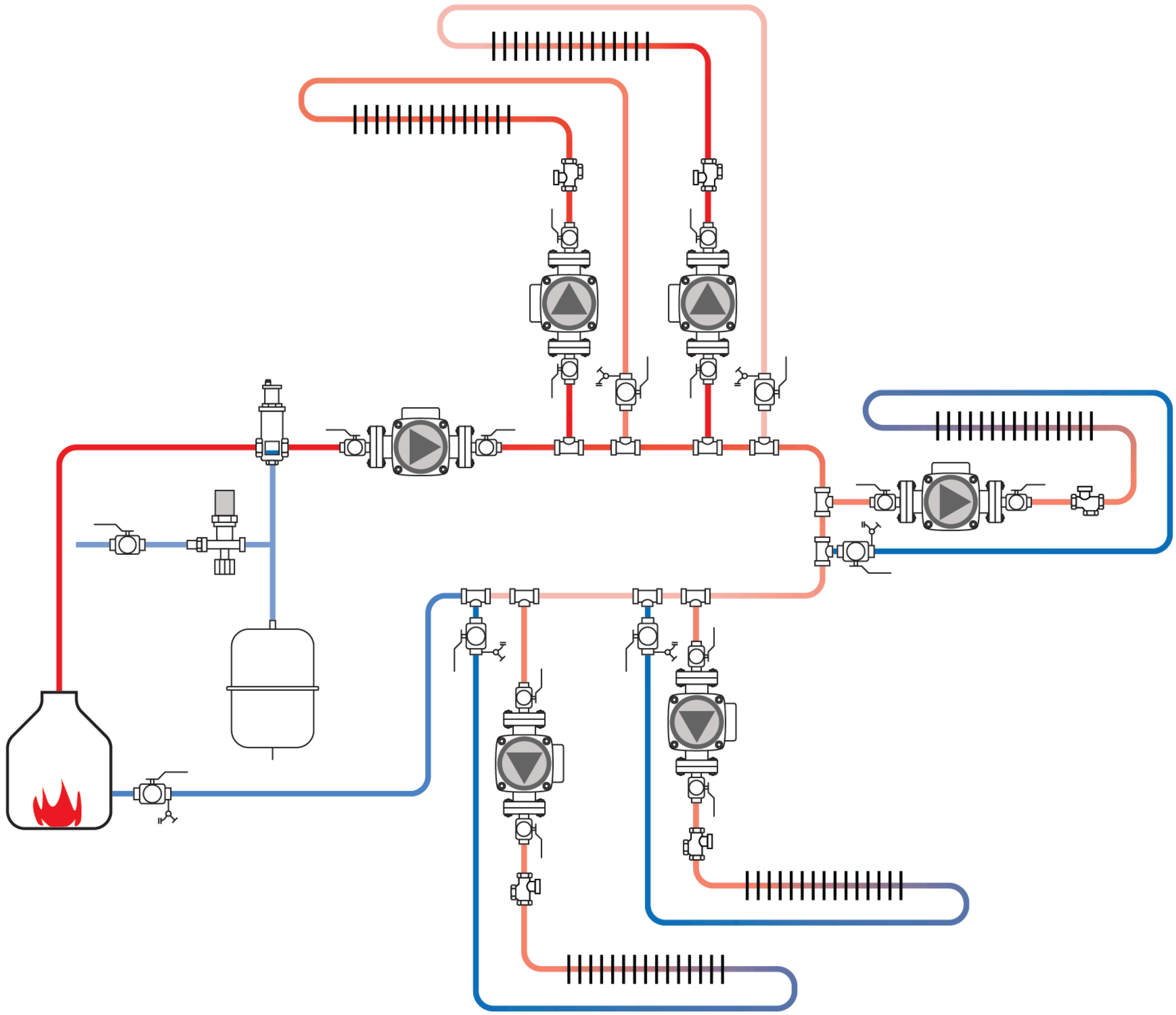

Figure 10 *Primary/secondary system using closely spaced tees. (Skilled Trades BC, 2021) Used with permission.*

The system illustrated in Figure 10 uses a piping system referred to as a primary/secondary system. Primary/secondary piping, originating in the 1950s, is one way to achieve hydraulic separation. Back then it was mainly used in large commercial heating and chilled water-cooling systems. Advances in technology and the complexity of residential and small commercial systems have led to an increase in the use of primary/secondary systems in those areas.

These systems consist of a primary circuit with secondary circuits connected to it. The primary circuit consists of a pump and piping large enough to carry the expected heating water for the entire system and long enough to have space for the closely spaced tees for the secondary circuits. This circuit has no other function than to keep a hot supply of water flowing through it.

The secondary circuits involve the heat source(s) and different types of heating loads. These loads could be for space heating, domestic water heating, pool heating, or any other heating load desired. Primary/secondary piping is ideal for systems with multiple smaller boilers, rather than one large boiler, feeding into the primary circuit as needed or when different heating circuits are connected to the same boiler.

All primary/secondary systems require protection against the tendency for hot water to migrate into and through inactive secondary circuits. This occurs because the less-dense hot water tends to rise. Although the closely spaced tees offer hydraulic separation when the pump is operating, they do not protect against thermal migration (**thermosiphoning**).

Thermal migration can be limited using circulators with integral spring-loaded check valves or installing an external spring-loaded check valve, known as a flow check. Thermal migration can also be limited with the use of a thermal trap (Figure 11). The thermal trap discourages convection currents from moving through it and into the system.

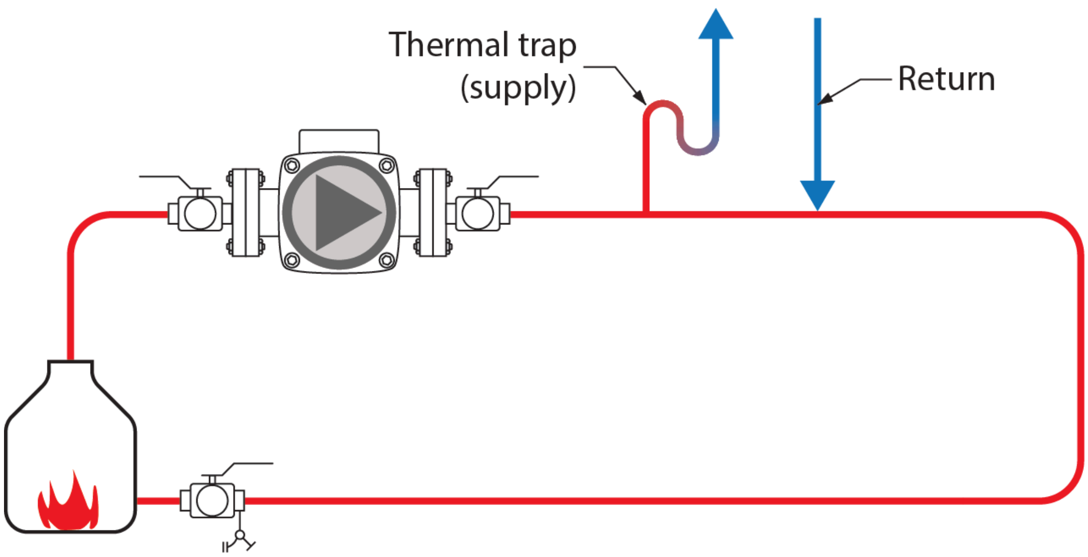

Figure 11 *Thermal trap used to lessen the effects of thermal migration. (Skilled Trades BC, 2021) Used with permission.*

Besides using closely spaced tees, hydraulic separation can also be accomplished using a hydraulic separator or low-loss header. Both use a large-diameter vertical chamber to slow down the water flow rate. This vertical chamber is generally three times larger in diameter than the diameter of the system piping. Slowing the water down creates very little head loss through the chamber and ultimately creates the hydraulic separation needed between systems to be effective (Figure 12).

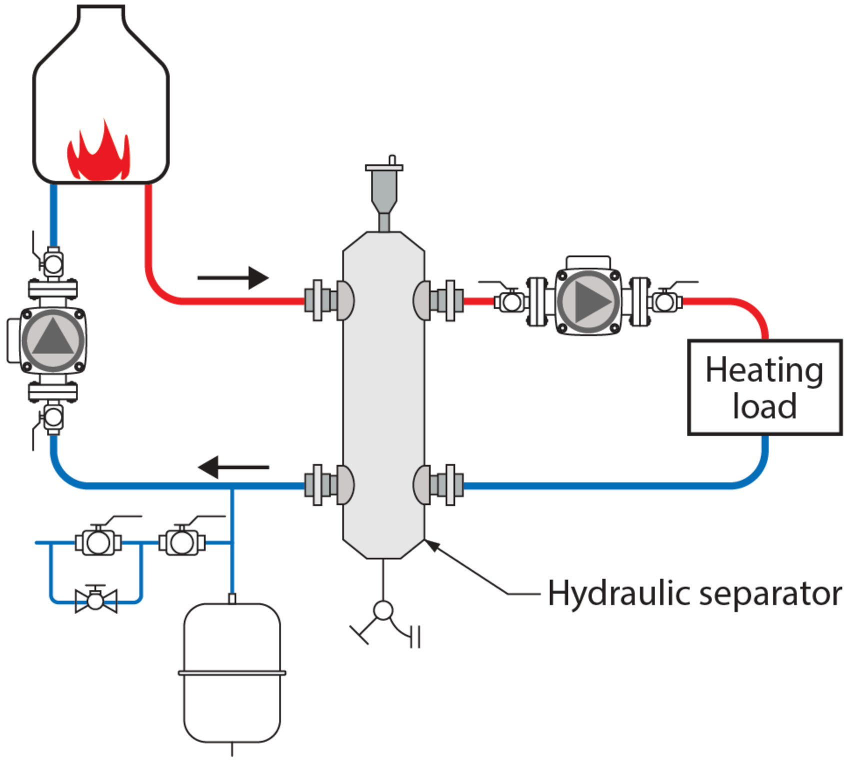

***Figure 12** Hydraulic separator piping arrangement. (Skilled Trades BC, 2021) Used with permission.*

The unit shown in Figure 13 also provides high-efficiency air and dirt separation for the system.

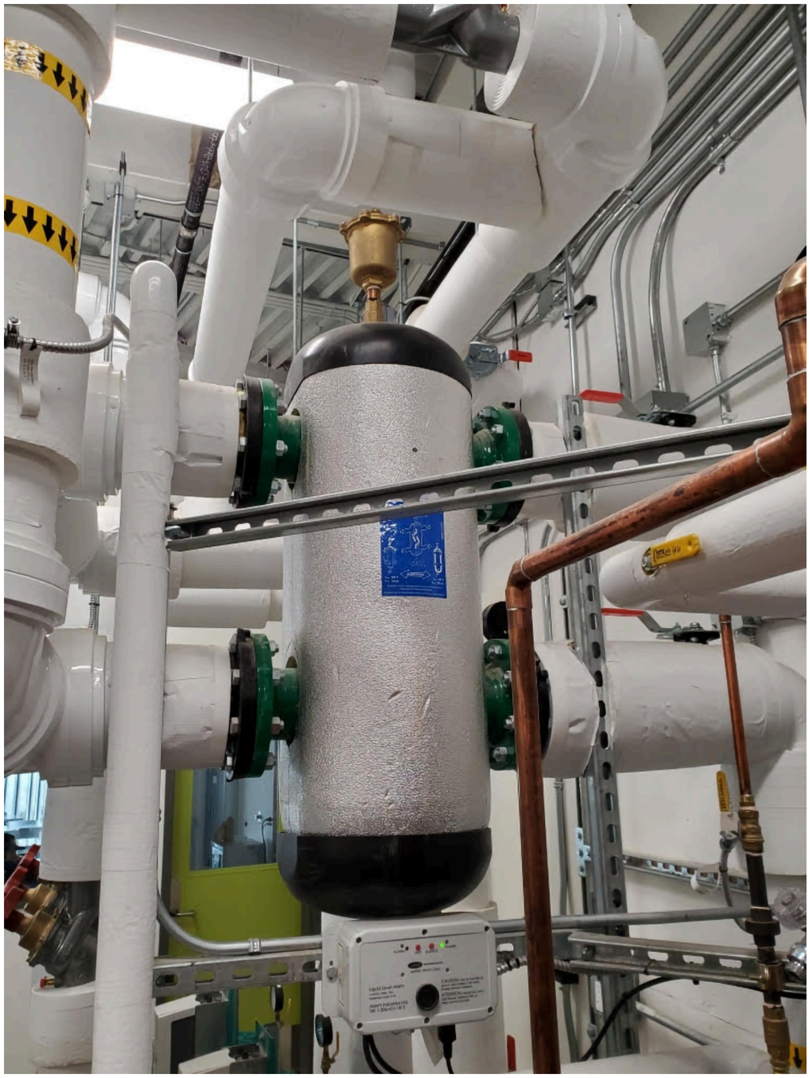

Figure 13 *Hydraulic separator. (TRU Open Press) CC BY NC SA (https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en)*

Self-Test B-4.3: Distribution Systems

Complete the chapter Self-Test B-4.3 and check your answers.

If you are using a printed copy, please find Self-Test B-4.3 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=62#h5p-11 (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=62#h5p-11)

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Trades Training BC. (2021). B-4: Install hydronic heating piping and components. In: *Plumber Apprenticeship Program: Level* 2. Industry Training Authority, BC.

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B-4.4 Distribution System Installation

As mentioned earlier, piping layouts are categorized by the configuration of the supply and return mains. Piping branches, also called runouts, connect the mains to the heat transfer units through drops, stubs, and spring pieces. All of these terms lack clear-cut definitions that relate to their sizing, in contrast to the definitions of piping in drainage, waste, and venting systems. Mains, **risers**, and branches are all sized according to the amount of heat they need to transport.

Regardless of the names describing the parts of a hydronic system, piping must be designed to prevent air blockages within the system. The correct installation of piping must also prevent the buildup of stress that would cause damage and leaks.

Parts of the Distribution System

The following terms identify pipes in hydronic systems:

- Supply main
- Return main
- Branch or spring piece
- Riser
- Runout
- Stub
- Drop

Supply and Return Mains

The supply and return mains are typically attached to the boiler in all systems except primary/ secondary and carry all of the system water to the other pipes. In larger buildings, the supply and return mains are usually run down a hallway, while the heat transfer units are positioned along the outside walls. This pattern is repeated on every storey.

Figure 1 shows piping connected to supply and return mains. Note that the spring pieces are installed to minimize the effects of expansion and contraction of the piping and are classified as branches.

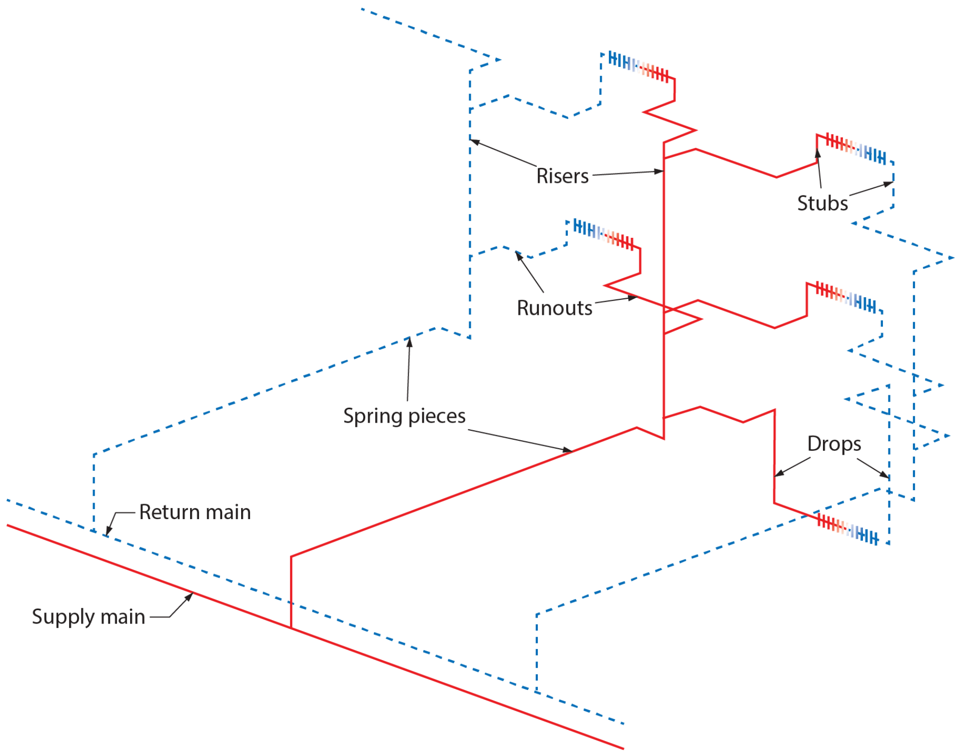

Figure 1 *Heating runs.*

Branches, Spring Pieces, and Risers

A branch in piping is simply a pipe connected to a main, much the same as a branch of a tree is connected to the trunk of the tree. Branches connect the heat transfer units to the mains via drops and stubs. A spring piece is a branch that connects a main to a riser. A riser runs vertically to the highest floor in the building and is usually located within an interior wall near the outside wall. This keeps the riser within the heating portion of the building, preventing freezing. The distance from this location to the heat transfer units is normally kept fairly short. Figure 2 shows the location of the riser.

Piping branches must be designed to prevent the buildup of stress through thermal expansion and contraction as well as to prevent air blockages within the pipes. Risers must be protected from stresses caused by thermal expansion, building shrinkage, and settlement.

Runouts

A runout is a horizontal pipe that connects the heat transfer unit to a riser or main. Runouts may connect directly to the heat transfer unit or by way of a stub or drop. Runouts may also form a series loop along the outside wall. Runouts on outside walls are usually installed below the floor, between the floor joists, which prevents them from freezing. Figure 2 shows how runouts are installed with respect to an outside wall.

Stubs and Drops

A stub is a short vertical pipe connected to a runout that passes up through a floor to a heat transfer unit. A drop runs down from a runout to a heat transfer unit.

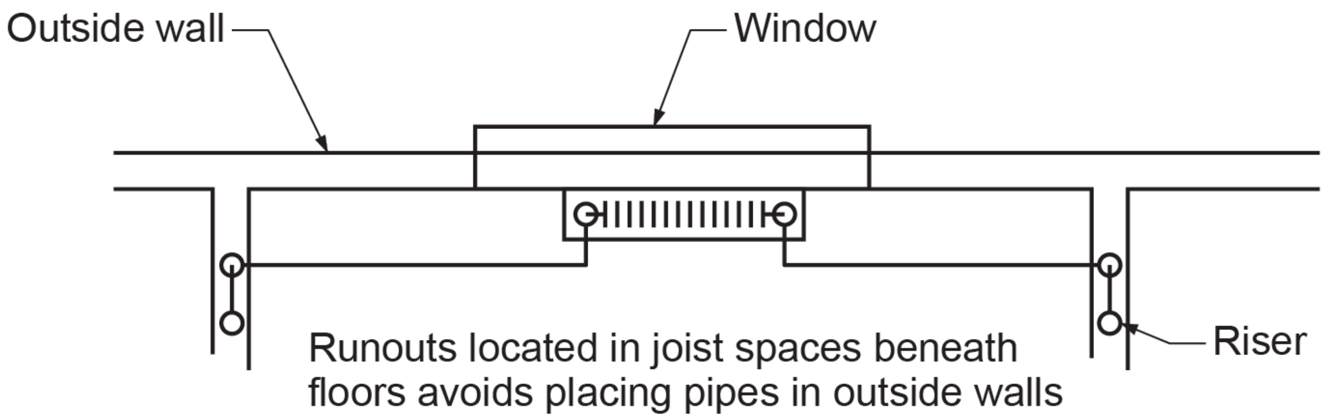

Figure 2 *Standard piping practices for runouts near an outside wall.*

Thermal Expansion and Other Forces

Pipes and connections can crack and leak if subjected to severe stresses. These stresses are created by thermal expansion and other forces that make a component move with respect to others. Allowance must be made for these movements to minimize these stresses.

All materials expand when heated. This is called thermal expansion. As a pipe becomes warmer, it becomes longer. When water in a 30 m (100') steel pipe is heated from its fill temperature of approximately 10°C (50°F) to operating temperature of 82°C (180°F), the pipe will become 25 mm (1 in.) longer. Copper tubes expand at a similar rate, and plastic tubes expand even more. Boilers, heat transfer units, and other components are also affected by thermal expansion, but these components are stationary, so they cannot be modified.

Other forces that cause stress in a hot-water piping system are fluid surges, pipe misalignments, impacts, and movements during an earthquake. The buildup of stress through thermal expansion and other forces is prevented using:

- Swing joints
- Expansion loops
- Expansion bellows
- Oversized holes through building structures

Swing Joints

Swing joints, such as spring pieces (Figure 3), are used to conveniently install piping that allows for stresses and for grade. Making a swing joint involves adding three or more elbows and connecting pipes to a piping run. The changes in direction created by the swing joint provide offsets that can move without breaking as pipes expand and contract.

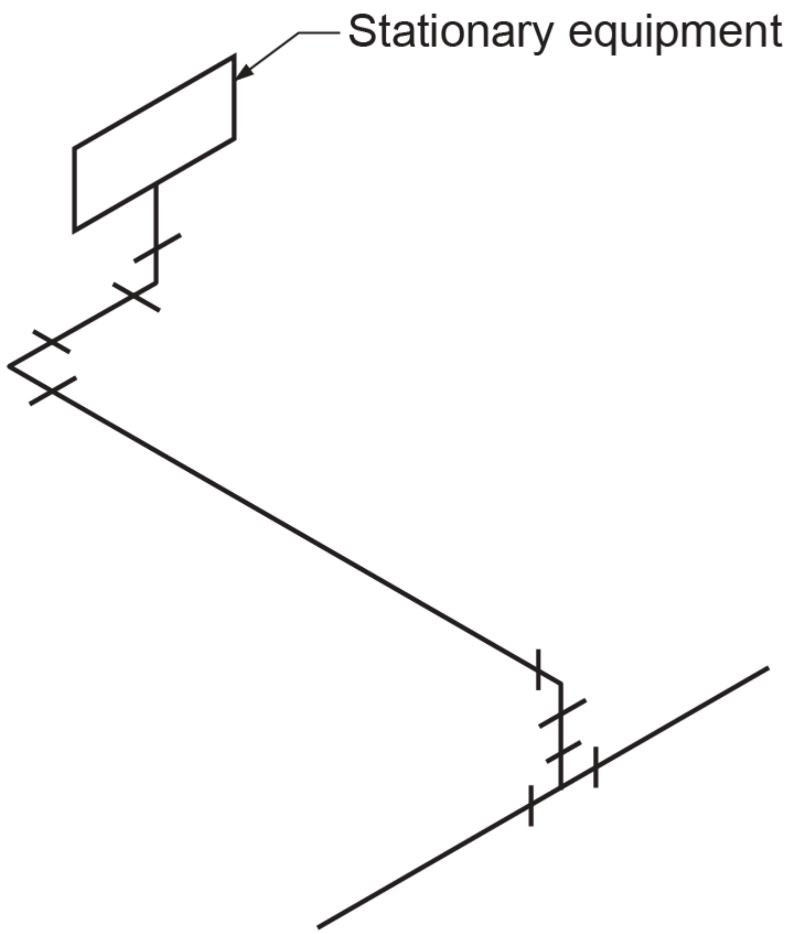

Figure 3 *A swing joint (spring piece).*

Figure 4 shows how a swing joint reacts to thermal expansion. The stub is rigidly fixed to the supply main. As the water in the supply main becomes warmer, the supply main expands so the stub moves in the direction of flow. The offset to the stationary component allows enough motion to prevent significant stress. The movement of swing joints responds to other forces as well.

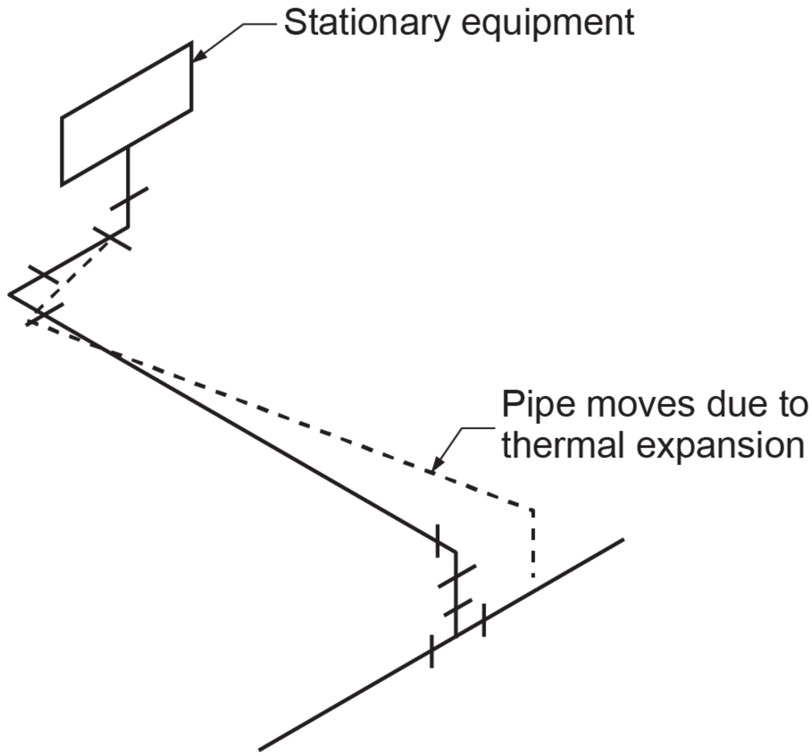

Figure 4 *Movement of swing joint caused by thermal expansion.*

Ease of Installation

Swing joints make installation and repair easier and leaks less likely. Swing joints make it easier to install a pipe with grade for draining and air elimination and easier to align fittings. For threaded pipe installations, alignment of threaded connections is less difficult if the installer is able to use an extra fitting to take up slight misalignments. A tee in a main is often not well positioned for good alignment. Turning the tee on the main would loosen one side and possibly cause a leak, but an extra elbow installed at the main would allow easy alignment and hook-up.

The elbows in swing joints can be 90° elbows or a combination of 45° and 90° elbows. Figure 5 shows the differences between 45° and 90° swing joint configurations.

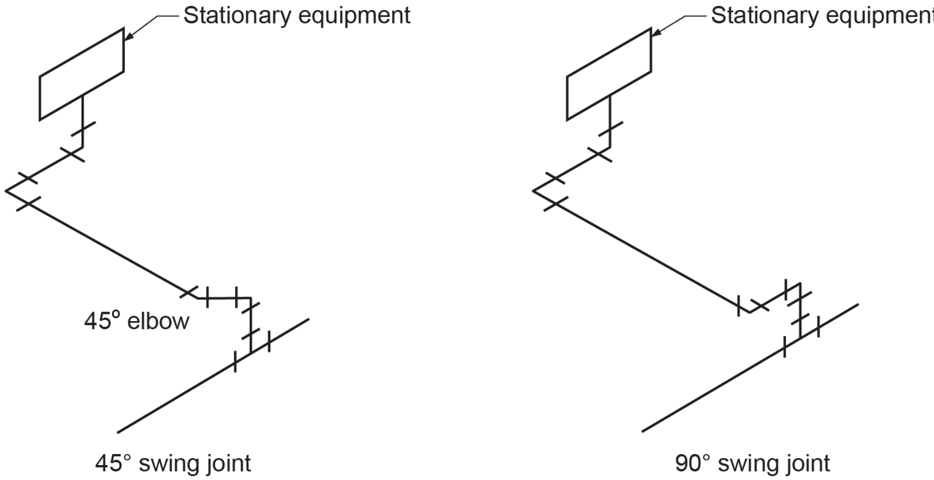

Figure 5 *Swing joint configurations.*

Expansion Loops

Expansion loops are a variation of a swing joint. Expansion loops allow a pipe to change in length as parts of the loop twist or bend. An expansion loop may be either U-shaped or scissor type (Figure 6). Expansion loops are most commonly used on long mains.

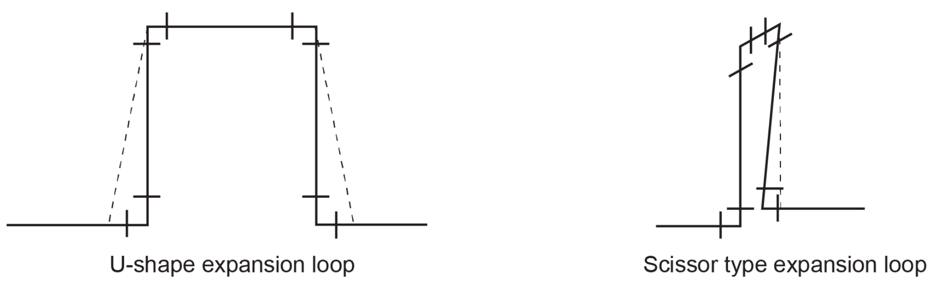

Figure 6 *Plan views of U-shaped and scissor-type expansion loops.*

Expansion Bellows

An expansion bellows has the same function as an expansion loop. However, the expansion bellows is made of materials, such as reinforced butyl rubber or corrugated metal, that collapses like an accordion when adjoining pipes expand. In other words, the expansion bellows becomes shorter as the pipes become longer and are much more compact than expansion loops.

Oversized Holes Through Building Structures

There must be room for pipe movement in any hole a pipe goes through. In some jurisdictions, the size of the holes is also specified by local seismic codes. For commercial applications, specific requirements for installation will be detailed by the mechanical engineer in the drawings and specifications. For instance, a 3 m (10 ft) horizontal pipe will expand 2.5 mm ($\frac{1}{8}$ in.) through its operating temperature range. If this pipe is connected to two vertical pipes that pass through a floor, the vertical pipes will move away from one another by 2.5 mm.

Pipes will expand in diameter as well as in length. To allow for both directions of expansion, drill all holes a minimum of 12 mm ($\frac{1}{2}$ in.) larger than the size of the pipe. After installing the pipe, seal the hole to prevent air leaks and create fire stops. Grommets or silicone caulk will seal the hole but still allow the pipe to expand and contract.

Prevention of Air Blockage

The installation of piping requires paying attention to more than just the prevention of stress caused by thermal expansion and contraction. Of equal importance is the control of air within the system. Pockets of air can cause a reduction in the transfer of heat as well as no heat transfer at all. Installing piping correctly will help to minimize or eliminate problems caused by the accumulation of air within the system piping.

Air blockage is prevented using:

- Correct grade on piping
- Vent tees at high points

Grade

Air blockages are prevented by installing some grade (slope) to piping runs. Horizontal runs must grade slightly upward in the direction of flow to allow air to move along with the heated water and reach an air vent. This grade can range from almost perfectly level to a rise of 4 mm/m (four millimetres per metre), which equates to roughly $\frac{1}{2}$ inch per 10 feet. The amount of grade will depend on the amount of space available and the ability to install swing joints to make up any misalignment caused by one pipe having grade and another not.

Although it is acceptable to install pipes in a level manner, it is advisable to install them with some grade so that air will be sure to clear the system. Figure 7 shows horizontal runouts that slope (exaggerated) upward, in the direction of flow, to vented high points.

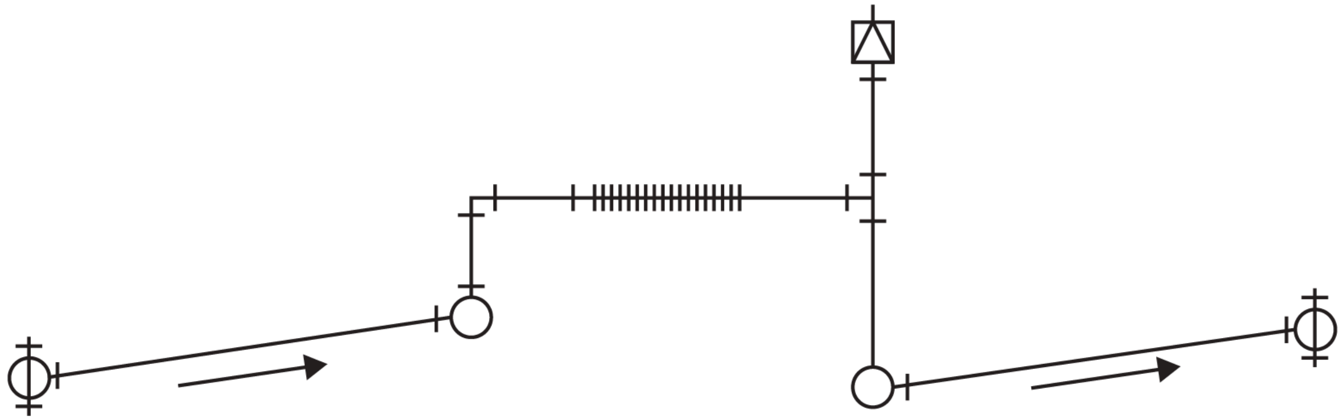

Figure 7 *Horizontal runouts sloping upward in the direction of flow.*

Air vents should be located at all high spots, where air will naturally accumulate. Occasionally, upward slope in the direction of horizontal flow involves the installation of an extra air vent. The extra air vent should be installed where it will be easily accessible, so that it can be serviced. Figure 8 shows the same runout as in Figure 7, but with an extra vent installed. If it appears that an air vent is going to be situated in an inaccessible area, do not install it there. Instead, run a vent pipe upward to an open area and install the vent there.

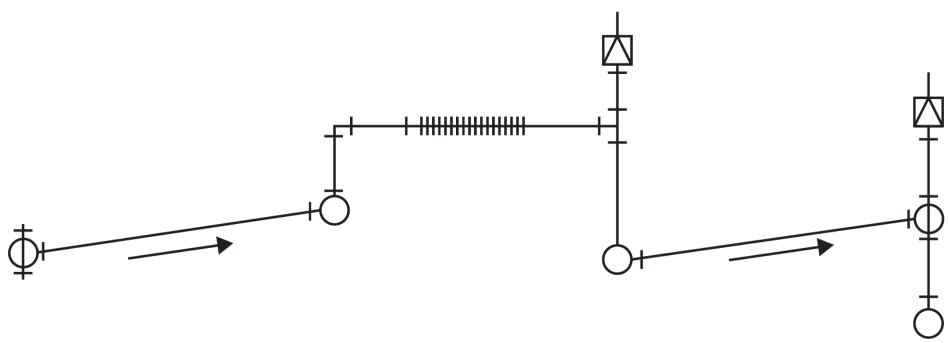

Figure 8 *Extra vent installed.*

Pumps Cannot Clear Air Blockages

Air blockages cannot be overcome by the pressure or flow developed by a heating system circulator and should be avoided. A pump is designed to overcome the friction of the piping as it pushes the water through the heating system. Velocities in hot-water heating systems are far slower than when the heating system was initially purged, and therefore any air that accumulates at high points cannot be carried downward and to an air eliminator by a pump.

A heating system must be entirely full of water so that the pump is not required to lift the water, only to move it. All circuits of a hot-water heating system must have water flow to deliver heat. When there is an air blockage in a circuit, there is not enough pressure for the air to be forced through the system. Water flow is then redirected to other heating circuits not obstructed by air.

Zoning in a Hydronic System

A zone is a heating area controlled separately from other heating areas. Each zone is typically controlled by its own thermostat.

Installing zones in a hot-water heating system allows for:

- Greater comfort
- Lower operating cost
- Better temperature control in buildings with areas difficult to heat

Zoning makes a building more comfortable because it can provide each area with the amount of heat appropriate to its heat loss. Zoning saves money because not all areas require the same temperature (occupied as opposed to unoccupied) and because people are less likely to open windows if they are comfortable. Temperature control is possible in buildings with comfort challenges because every part of the building can be given a different piping or control strategy.

Selecting Zones

A hydronic system should be divided into zones if rooms or areas within the building have differences or similarities of factors, such as:

- Heat losses
- Orientation
- Occupancy
- Use patterns
- Floor constructions
- Glazing

The larger a building, the greater the need for zones.

Different Heat Losses

Every room or space will experience heat loss differently. To achieve the same temperature in every room, each room requires a different amount of heat. Installing one zone for every room enables the system to supply a required amount of heat to each room, although this will increase the cost of installation.

Orientation

The orientation of a building will determine on which sides the sun will influence the temperature of the rooms. Consider the square building in Figure 9. The rooms on the southeast receive heat from the sun in the morning. On the southwest side, however, the sun is not contributing heat, so heat is in greater demand. If the thermostat were in an east room, it would reduce the demand for heat in the morning, and the west room would be cold.

In the afternoon, the west room would receive heat from the sun and the east room would not. Since the thermostat is in the east room, it signals for high heat transfer, which makes the west room too hot. If the building were divided into four zones as shown in Figure 9, both these situations would be avoided. However, it is usually only necessary to use two zones because during the heating season, the sun rises in the southeast and sets in the southwest. Thus, more heat is needed in the cooler north side.

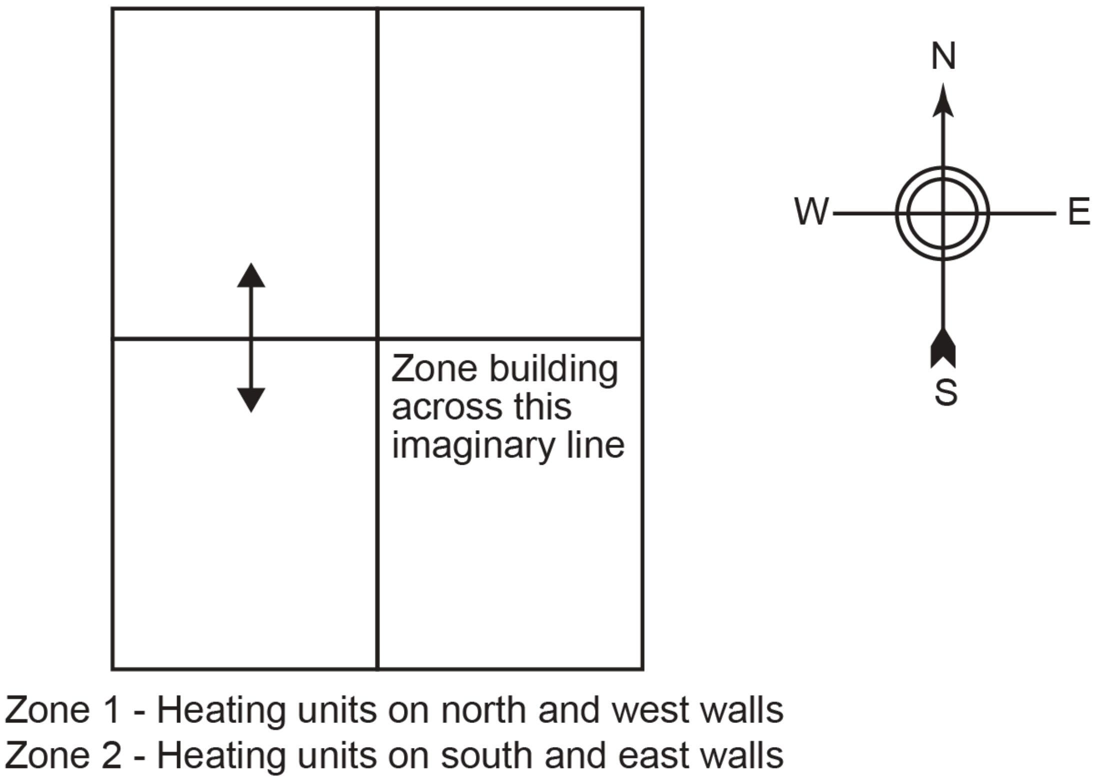

Figure 9 *Zones in a building lying north and south.*

Occupancy

There is also a greater need for zoning in commercial buildings than in residential ones. An office worker, for instance, will not wish to spend much of their workday fussing with dampers on baseboard heaters, while homeowners are more likely to take on those type of issues. These days, large buildings are usually controlled by remote means. Occupants call, text, or email a building operator to relay information on the level of discomfort they are feeling, and the building operator can make adjustments from a computer, sometimes in a different city or province. Most commercial buildings no longer give the occupants control of the room thermostats. Thermostats have been replaced by remote sensors.

Use Patterns

The intended use of each area will influence the desired temperature. Infrequently used rooms should be separately zoned so they may be set at a lower temperature to conserve energy.

In a home, some rooms, such as a playroom or a work area, are used for high-energy activities. These activities will be more comfortable if the temperature is somewhat lower than normal. Other rooms will be used for low-energy activities, such as watching TV or eating. These activities will be more comfortable if the temperature is somewhat higher.

Sleeping is a low-energy activity, but bedrooms should generally be kept at a lower temperature because bedding provides the necessary comfort. The level of clothing worn varies with the room as well. Less clothing is worn in a bathroom than in a living room, and heat loss from a person who is wet after getting out of a shower or bathtub will be much higher than normal, so the temperature is usually kept higher.

Commercial buildings usually have one or two types of activity, such as shopping and office work. The energy level of the activity and the amount of clothing that people will wear should be considered when selecting zones.

Industrial buildings may require different heat zones. Industrial processes, such as agriculture, manufacturing, and warehousing, may require a particular temperature or number of air changes per hour. This makes proper zoning critical. These processes often produce waste heat, which must be calculated before zones can be selected.

Use patterns may change over the life of the building. Zones should be versatile enough to accommodate changes in use patterns. The installation of flow-balancing valves in each zone can help minimize the impact to the rest of the system by altering flow rates when changes in use occur.

Different Floor Constructions

If radiant floor panel heating is used, different floor constructions require different zones. Concrete and wood allow the passage of heat but at very different rates. The type of thermostat used for a concrete floor installation is different from that used for a wood floor installation. As a result, the same zone cannot include these two types of floor construction without proper design and planning.

Additional Heat Gains and Losses

Consider additional heat gains and losses when selecting zones. Additional heat gains result from activities, such as cooking or bathing, or from the operation of the boiler or other equipment. Additional losses result from frequently opened doors or windows. In commercial and industrial buildings, additional gains may result from industrial processes, lighting, operation of equipment, or occupants.

Most large commercial buildings will typically have a higher rate of heat gain than heat loss. Lighting, the people themselves, and especially computers emit much heat, so the cooling systems tend to have more work to do and are, therefore, larger than the heating systems.

Higher storeys of a building require less heat than lower storeys because of the stack effect. The stack effect refers to the movement of heat upward in a multi-storey building. The heat moves up elevator shafts and staircases and, to some extent, through the floors themselves.

The amount of heat gained through exposure to the sun is influenced by the orientation of the building, amount of window area, and amount of shade created by trees or roof eaves.

South-facing windows can contribute a significant amount of heat (solar gain). East- and west-facing windows may contribute some heat. North-facing windows cannot produce a heat gain regardless of their construction. Wide eaves and other objects, such as trees or other buildings, in close proximity can shade the window and reduce the amount of exposure to the sun.

Windows may have a heat gain when it is sunny, but they will always have a heat loss when there is no sun. The heat loss through windows is reduced if multi-glazed windows or insulating drapes are installed. The presence of a large window area increases the need for precise local zone control. The amount and type of glazing will minimally affect the heat loss in a residential home but will significantly affect the heat loss in a very large building.

Residential and Commercial Zones

In both residential and commercial hot-water heating systems, a zone is a primary division of the piping system. In a residential system, a zone is normally the smallest division, whereas in a commercial system, the zones are further divided into sub-zones.

In a residential system, using finned-tube baseboards, each zone is typically a one-pipe circuit that starts and ends near the boiler or manifold off of the supply and return mains.

Each zone is controlled by a thermostat and zone valve. There is normally one zone for every major room or cluster of small rooms of a house (Figure 10).

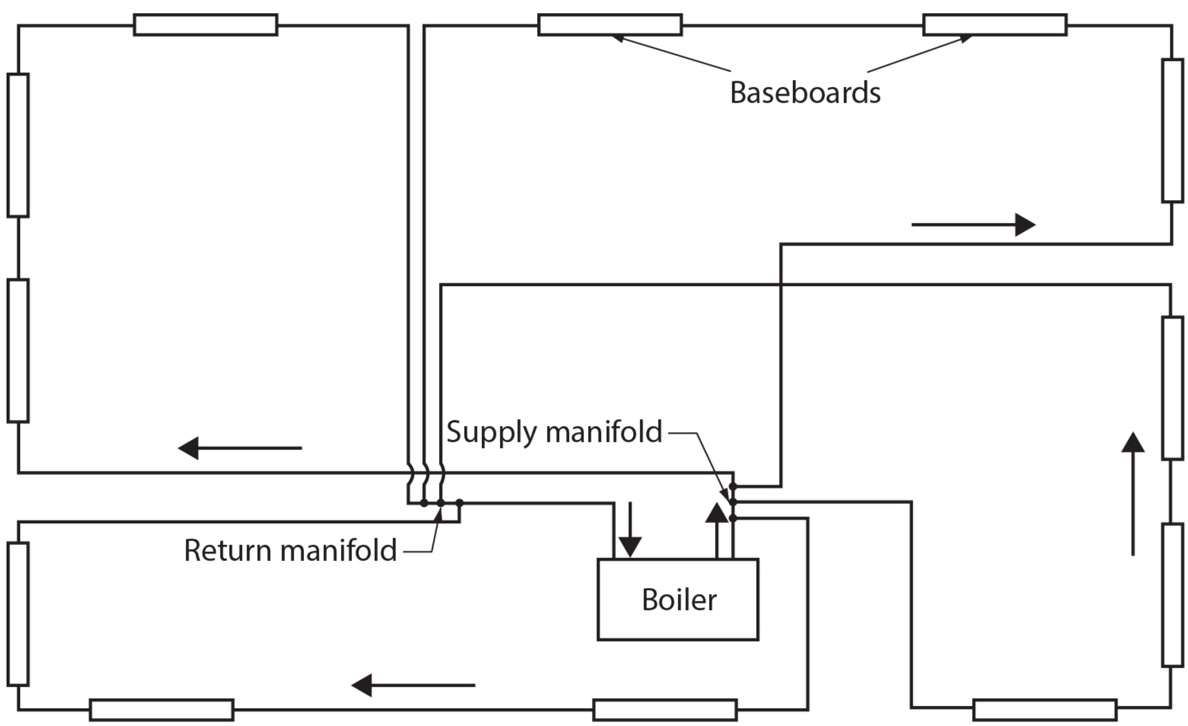

Figure 10 *A residential hot-water baseboard system that has four zones.*

In a commercial system, each zone is typically a two-pipe system supplying many circuits that start and end near the boiler. There is normally one zone for every wing of a large building. The rooms within the wing are served by circuits that connect to the zone piping. Zone valves are installed on each circuit. Figure 11 shows a commercial system that has four zones, with four circuits in each.

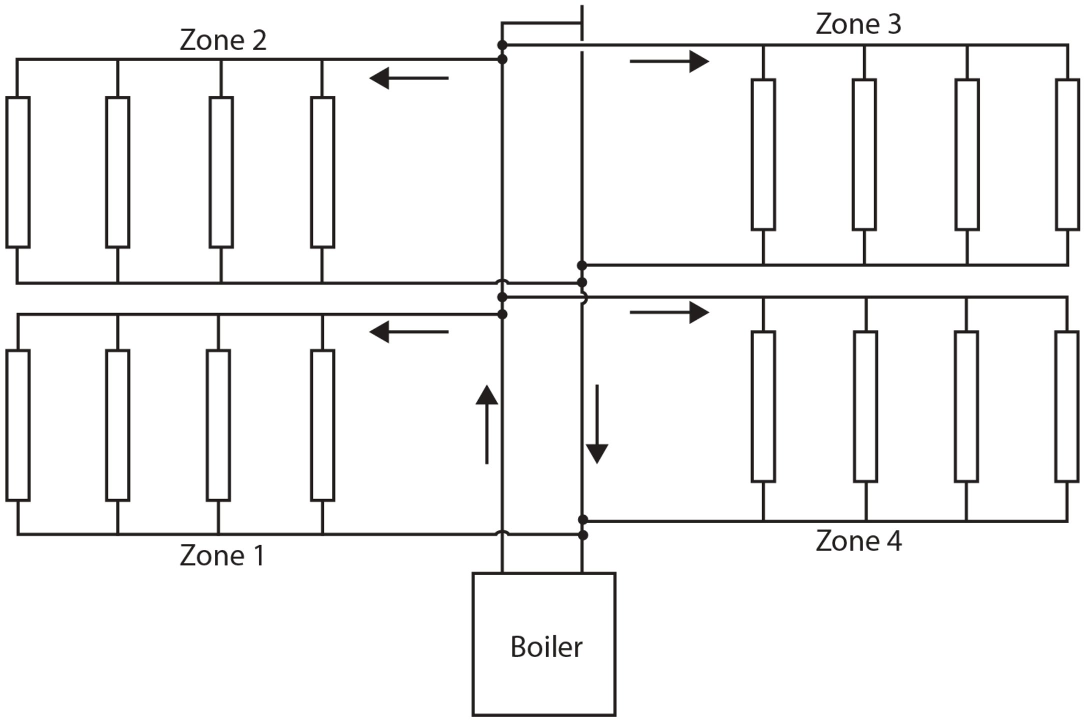

Figure 11 *A commercial system that has four zones, with four circuits in each.*

Piping a System With Zone Valves

Every zone requires its own piping run, thermostat, and zone valve or pump. In a single-pump system, there is only one pump on the supply main or on the return main (Figure 12). The zone valves are shown installed on the return piping of each zone, near where the return main joins the boiler.

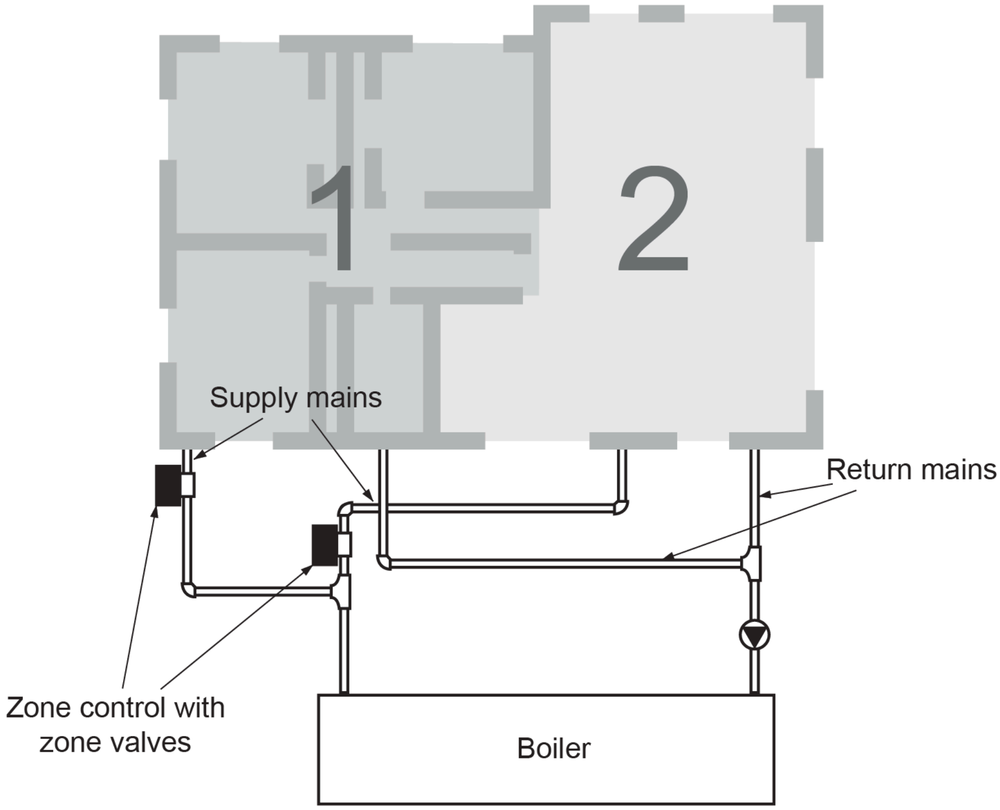

Figure 12 *Zone valves and one pump.*

In a multiple-pump system (Figure 13), there is a pump on the supply piping to each zone and a zone or flow control valve on the return piping from each zone.

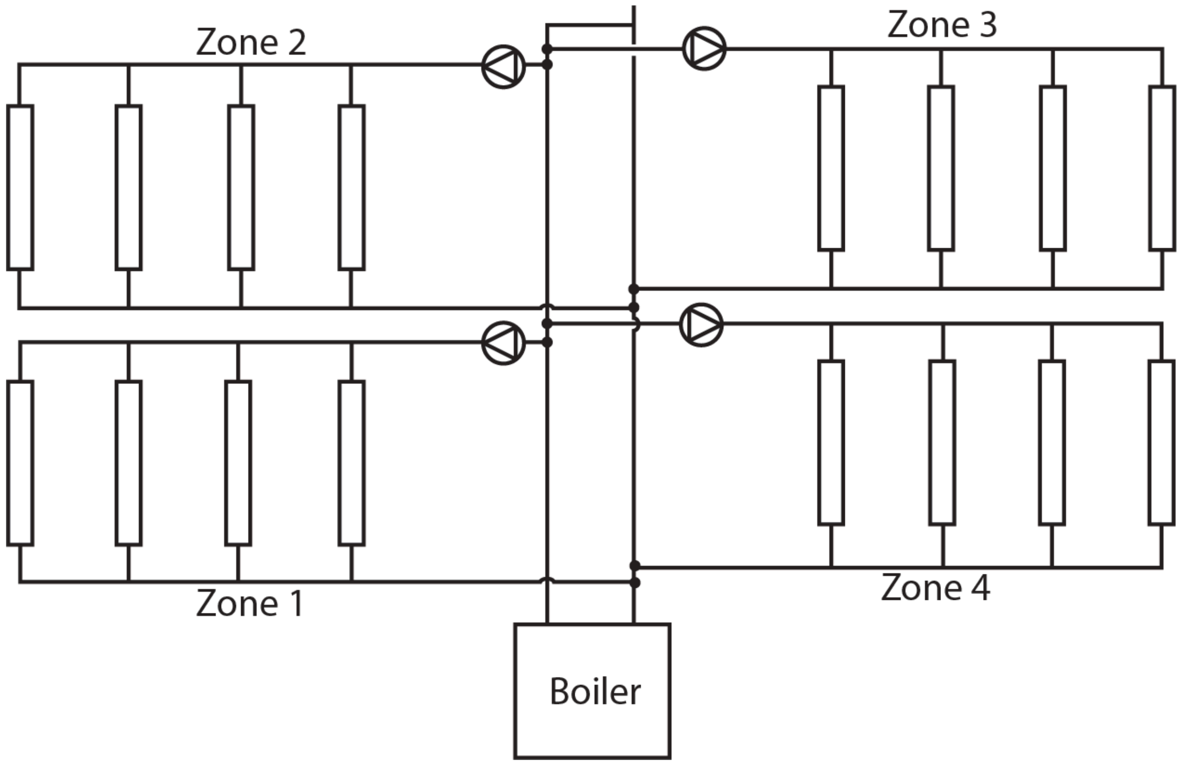

Figure 13 *Flow control with multiple pumps.*

Balancing a Hot-Water Heating System

Balancing is the measurement and control process used to obtain the required flow in hot-water circuits. Balancing valves adjust the flow through circuits by restricting the flow. The system is balanced for flow before the operating controls are adjusted.

Here are some of the reasons why balancing is necessary:

- The circuits must be balanced to obtain design flow in the boiler.
- Fluctuations in flow reduce the efficiency of the heat transfer units and make control difficult.
- The distribution system must be balanced to make sure that all heat transfer units get design flow.
- The control loops must be balanced to bring about the proper working conditions for the control valves and to make primary and secondary flows compatible.

Balancing a Series Loop System

The series loop system has all of its heat transfer units connected end to end, so there is only one circuit and no balancing valves, but a number of series loops can be combined in a multi-zoned system. In that case, the zones are supplied by mains that are either direct-return or reverse-return, so the zones must be balanced accordingly.

The split-series loop system has two circuits that come off a common supply main. In a split-series loop system, a balancing valve is installed at the beginning of each circuit to be able to control the flow to that circuit.

Balancing a Diversion Tee System

The diversion tee system does not use balancing valves. Diversion tees are used to induce flow through the heat transfer units, so any throttling done on any of the runouts or mains would defeat the purpose of the diversion tees. Each heat transfer unit is equipped with a valve for allowing or stopping flow.

A number of diversion tee circuits can be combined in a multi-zoned system. The zones are supplied by mains that are either direct-return or reverse-return. The zones must be balanced according to the heating requirements for each zone.

Balancing a Reverse-Return System

The layout of a reverse-return system results in a well-balanced system. Balancing valves may be required in some complex systems, but the majority of the simple systems do not require balancing valves.

Balancing a Direct-Return System

Direct-return systems are normally installed for commercial or industrial applications and have many zones and sub-zones. Due to the complexity of balancing direct-return systems for large buildings, this work is often performed by contract firms that specialize in this process.

Every circuit of a direct-return system should have a balancing valve installed in the return pipe. If the balancing valve contains a drain, the location on the return pipe will also allow the circuit to be drained without having to drain other piping. Balancing valves are usually installed where they are easy to access and where there is minimal turbulence within the piping. Also, by placing all balancing valves in the same location relative to the other circuits, such as where they all connect to the system return main, it will be easier to balance the system flows.

To ensure accurate flow measurements at a balancing valve, install a straight pipe line a minimum of five pipe diameters upstream of the valve and two pipe diameters downstream. Do not install any fittings within these distances. If the balancing valve is installed downstream of a pump or other component that creates strong disturbances in flow, increase the minimum length of straight pipe upstream of the valve to 10 pipe diameters.

How Balancing Valves Affect One Another

Flow adjustment at one balancing valve disturbs the flow at the other balancing valves, including those that have already been adjusted. Balancing methods differ in how they compensate for this interaction.

Figure 14 compares the flow through each of five heat units when all the balancing valves are open (left diagram) to when the valve on one unit is closed (unit 3 in right diagram). When that valve is closed, the flow in all the other heat transfer units will change, but not proportionally. The flow in the farther away heat transfer units will increase the most (from 100 to 109.7 in unit 5), while the flow in the closer heat transfer units will increase less, with the closest one increasing the least (from 100 to 102.8 in unit 1). The flow rate of 100 has been chosen at random to show the change and is not indicative of any system operation.

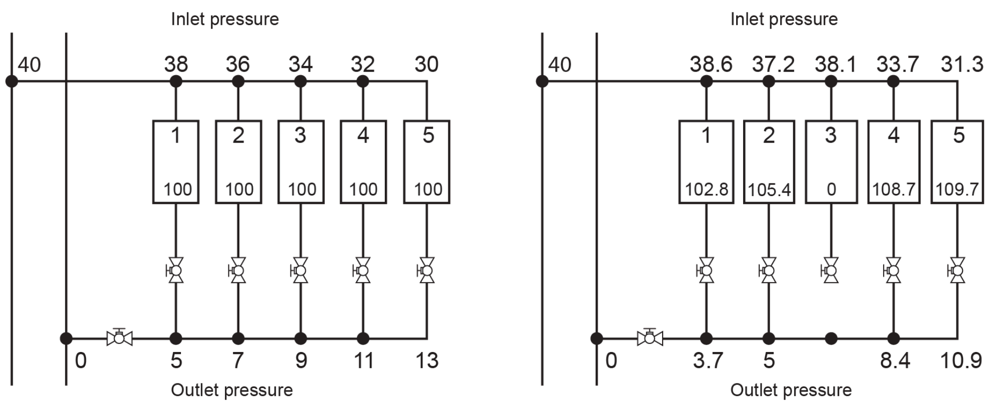

Figure 14 *Flow change when one valve is closed.*

Optimum balancing is achieved when the heat transfer units all receive their design flow and the balancing valves impose the least restriction on the flow.

After balancing a system, it is important that the valve actuators (handles, etc.) are locked in place or marked to discourage any inadvertent tampering. If system maintenance is necessary, always take note of the balancing valve positions to ensure that they are reset properly after maintenance is completed.

Self-Test B-4.4: Distribution System Installation

Complete the chapter Self-Test B-4.4 and check your answers.

If you are using a printed copy, please find Self-Test B-4.4 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=64#h5p-12 (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=64#h5p-12)

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Trades Training BC. (2021). B-4: Install hydronic heating piping and components. In: *Plumber Apprenticeship Program: Level* 2. Industry Training Authority, BC.

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Self-Test B-4.1 Hydronic Distribution System Components

Complete Self-Test B-4.1 and check your answers.

1. Where is the ideal location for a pump?
   a. Immediately downstream of the point of no pressure change
   b. Immediately upstream of the point of no pressure change
   c. Anywhere downstream of the boiler
   d. Anywhere upstream of the boiler

2. The pump in a hot-water heating system is also called a cavitator.
   a. True
   b. False

3. What is the location where the compression tank and its piping join the system piping called?
   a. Point of no return
   b. Point of no pressure change
   c. Circulation point
   d. Static fill point

4. A strainer should be installed upstream of the pump.
   a. True
   b. False

5. Some circulators have water-cooled and lubricated motors.
   a. True
   b. False

6. What effect will oversizing a circulator cause?
   a. Lower system heat output
   b. A marked increase in intake pressure
   c. Noisy operation
   d. No noticeable effect

7. What do closed-loop systems with pumps use to accommodate volume expansion?
   a. Overflow
   b. Expansion tank
   c. Solution tank

d. Standpipe

8. If volume expansion is properly accommodated, the pressure will not increase significantly in a closed system when the water is heated.
   a. True
   b. False

9. What occurs as water is heated in a hot-water heating system?
   a. Contraction
   b. Radiation
   c. Expansion
   d. Reduction

10. Complete the following statement: “Air contained in fresh water _____________.”
    a. Immediately separates and rises
    b. Slowly separates and rises
    c. Increases the water density
    d. Remains mixed as long as the water is heated

11. Complete the following statement: “Mixed air separates more quickly when the ____________ .”
    a. Water is heated
    b. Water is cooled
    c. Flow is greater
    d. Turbulence increases

12. Which one of the following is **not** normally added through the use of a chemical pot feeder?
    a. Degreasing agents
    b. Corrosion inhibitors
    c. Lubricants
    d. Glycol

13. What purpose do air vents serve on a heating system?
    a. Allow air to enter as required
    b. Maintain the correct water-to-air mixture
    c. Separate air from water
    d. Remove air from the system

14. Complete the following statement: “Automatic air vents open when the _____________ .”
    a. Pressure within them drops
    b. Temperature within them drops
    c. Water level within them drops

d. System requires more air

15. What component's operation is interrupted if the LWCO (low-water cutoff) operates?
    a. Circulator
    b. Burner
    c. Thermostat
    d. Mixing valve

16. When possible, purging valves should be located downstream of components such as circulators and heat exchangers so that the system debris is drawn through these components.
    a. True
    b. False

17. When there is a choice of more than one pump that meets the system requirements, it is usually best to choose the pump with the flattest curve.
    a. True
    b. False

18. What are the effects of an oversized hydronic heating circulator?
    a. Decreases efficiency
    b. Higher flow velocity and friction head
    c. Higher than design heat emitter operating temperature
    d. All of the above

Answer Key: Self-Test B-4.1 (#chapter-answer-key-self-test-b-4-1) is on the next page.

Answer Key: Self-Test B-4.1

1. a. Immediately downstream of the point of no pressure change
2. b. False
3. b. Point of no pressure change
4. a. True
5. a. True
6. c. Noisy operation
7. b. Expansion tank
8. a. True
9. c. Expansion
10. b. Slowly separates and rises
11. a. Water is heated
12. d. Glycol
13. d. Remove air from the system.
14. c. Water level within them drops
15. b. Burner
16. b. False
17. a. True
18. d. All of the above

Self-Test B-4.2 Hydronic System Valves

Complete Self-Test B-4.2 and check your answers.

1. A boiler's relief valve senses and reacts to what characteristic(s) of water?
   a. Pressure
   b. Temperature
   c. Temperature and pressure
   d. Pressure or vacuum

2. What is the purpose of balancing valves?
   a. Maintain the correct water-to-air mixture
   b. Ensure equal flow of water through each circuit
   c. Achieve the design flow for each heat transfer unit or circuit
   d. Ensure continuous flow in the system

3. What is the purpose of flow check valves?
   a. Balance flow
   b. Protect the potable water supply
   c. Stop thermal siphoning
   d. Isolate heat transfer units

4. Why is a differential pressure bypass used?
   a. Protects the boiler
   b. Ensures continuous flow
   c. Flushes the system
   d. Relieves high pressure from the radiators

5. What is the normal pressure setting on a feedwater or pressure-reducing valve for a residential hydronic system?
   a. 160–180 psig
   b. 68–72 psig
   c. 40–54 psig
   d. 12–20 psig

6. The feedwater valve should be located where in relation to the backflow preventer?
   a. Downstream of the backflow preventer
   b. Upstream of the backflow preventer
   c. Parallel to the backflow preventer
   d. On the opposite side of the piping as the backflow preventer

7. What is the purpose of a backflow preventer?
    a. Prevents thermal siphoning
    b. Creates continuous flow throughout the heating system
    c. Prevents contamination of the domestic water supply
    d. Creates positive pressure within the system

8. The backflow preventer, feedwater valve, isolation valves, and bypass all combine to form what part of the hydronic system?
    a. Zone of reduced pressure
    b. Makeup water line
    c. Thermal bypass loop
    d. Boiler bypass

9. Where should the pressure relief valve on a residential boiler be located?
    a. On the high point of the system piping
    b. Just downstream of the system circulator
    c. On the boiler
    d. On the return piping next to the purge valve

10. What does a purge valve purge?
    a. Water out of the system on initial filling
    b. Air out of the system on initial filling
    c. All impurities out of the system during operation
    d. Air out of the system during operation

11. Complete the following statement: "Balancing valves operate best when _____________ ."
    a. 25% open
    b. Between 25% and 50% open
    c. Between 50% and 100% open
    d. 100% open

Answer Key: Self-Test B-4.2 (#chapter-answer-key-self-test-b-4-2) is on the next page.

Answer Key: Self-Test B-4.2

1. a. Pressure
2. c. Achieve the design flow for each heat transfer unit or circuit
3. c. Stop thermal siphoning
4. b. Ensures continuous flow
5. d. 12-20 psig
6. a. Downstream of the backflow preventer
7. c. Prevents contamination of the domestic water supply
8. b. Makeup water line
9. c. On the boiler
10. b. Air out of the system on initial filling
11. c. Between 50% and 100% open

Self-Test B-4.3 Distribution Systems

Complete Self-Test B-4.3 and check your answers.

1. In this system, the flow through one heat transfer unit cannot be shut off without stopping the flow in the other heat transfer units.
    a. Series loop
    b. Diversion tee
    c. Direct-return
    d. Reverse-return

2. Which of the following systems provides the most uniform heat?
    a. Series loop
    b. Diversion tee
    c. Direct-return
    d. Radiant panel

3. Which system is a one-pipe system in which flow can be diverted to individual heat transfer units?
    a. Series loop
    b. Diversion tee
    c. Direct-return
    d. Reverse-return

4. In which system is it easiest to balance heat transfer units?
    a. Series loop
    b. Diversion tee
    c. Direct-return
    d. Radiant panel

5. Which system is also known as a first fed, first return system?
    a. Series loop
    b. Diversion tee
    c. Direct-return
    d. Radiant panel

6. What does a diversion tee use to induce flow in the branch?
    a. Balancing valve
    b. Friction loop
    c. Venturi
    d. Zone valve

7. What system is shown in Figure 1?

   a. Series loop
   b. Diversion tee
   c. Direct-return
   d. Reverse-return

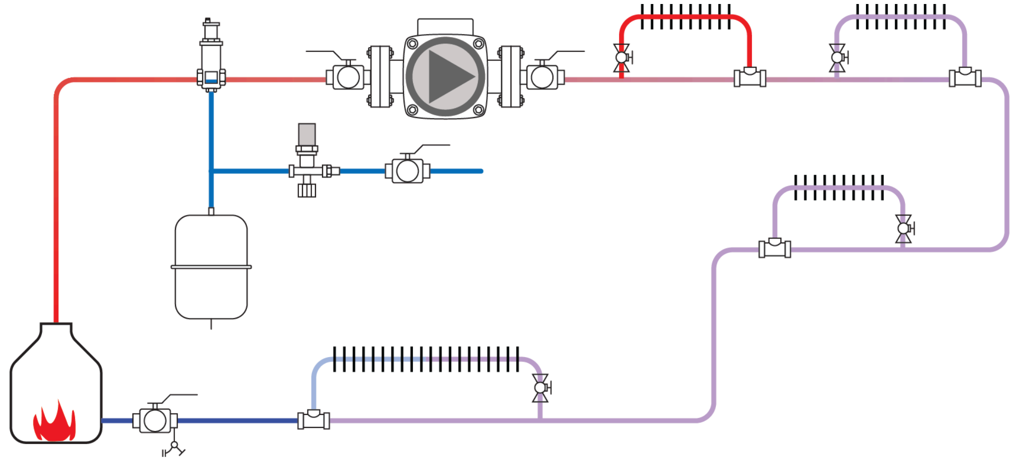

Figure 1

8. What system is shown in Figure 2?

   a. Series loop
   b. Diversion tee
   c. Direct-return
   d. Reverse-return

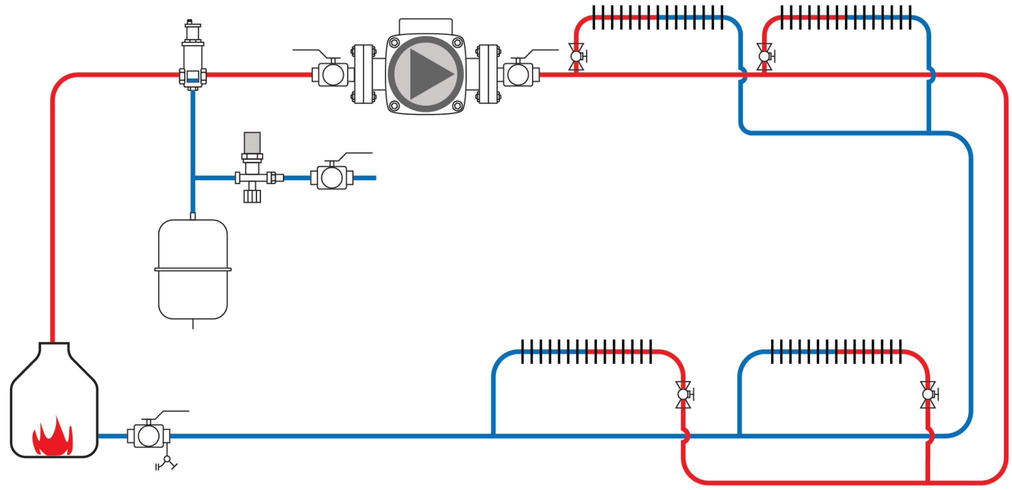

Figure 2

9. What system is shown in Figure 3?

   a. Series loop

b. Diversion tee
c. Direct-return
d. Reverse-return

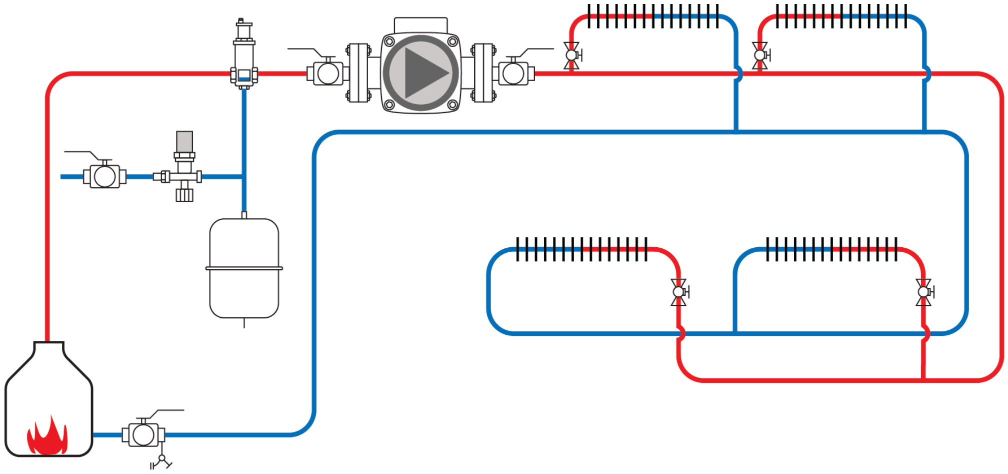

Figure 3

10. What system is shown in Figure 4?

a. Series loop
b. Diversion tee
c. Direct-return
d. Reverse-return

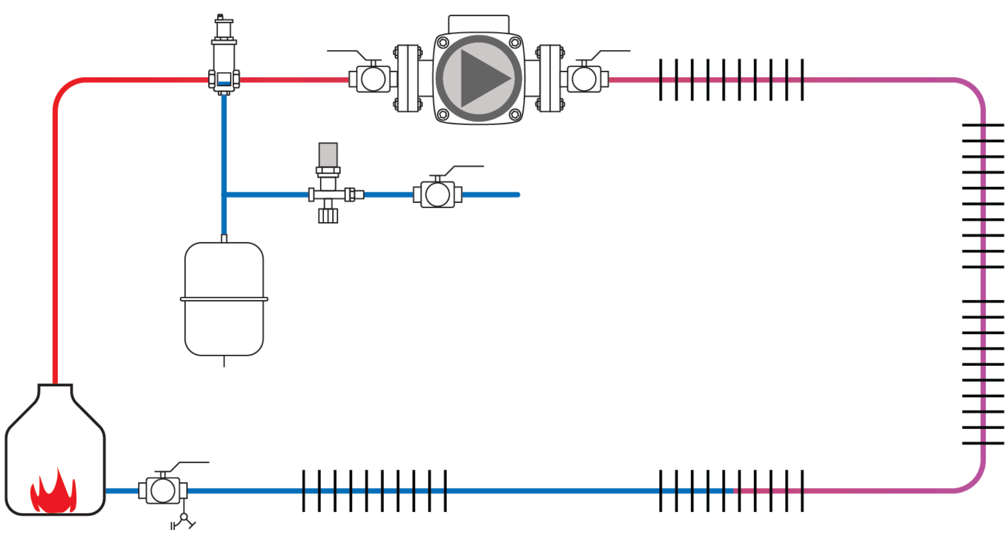

Figure 4

Answer Key: Self-Test B-4.3 (#chapter-answer-key-self-test-b-4-3) is on the next page.

Answer Key: Self-Test B-4.3

1. a. Series loop
2. d. Radiant panel
3. b. Diversion tee
4. d. Reverse-return
5. c. Direct-return
6. c. Venturi
7. b. Diversion tee system
8. d. Reverse-return system
9. c. Direct-return system
10. a. Series loop system

Self-Test B-4.4 Distribution System Installation

Complete Self-Test B-4.4 and check your answers.

Match the definitions in Column B to the correct term in Column A:

Column A	**Column B**
1. Riser	a. The horizontal pipe that connects a main to a riser
2. Runout	b. A run of pipe with three or more elbows that allow parts of a run to have different slopes and movement without severe stress
3. Spring piece	c. A pipe that connects a heat transfer unit to other parts of a heating system
4. Swing connection	d. An arrangement of pipes and fittings that allows the movement caused by thermal expansion to occur within parts of a piping run without causing excessive stress
5. Expansion loop	e. A vertical pipe connected to runouts on more than one floor
	f. A vertical pipe in a runout that passes down to a heat transfer unit on a lower level
	g. A vertical pipe in a runout that passes up through a floor up to a heat transfer unit

6. Complete the following statement: “Piping runs in a hot-water heating system should ________________.”
   a. Be almost level or have an upward grade of 4 mm/m ($\frac{1}{2}$ in./10 ft)
   b. Slope down in the direction of the flow
   c. Slope down from the supply pipes and up to the returns
   d. Slope up from the supply pipes and down to the returns

7. What are the fittings in a swing connection?
   a. Elbows and tees
   b. Only 90° elbows
   c. Only 45° elbows
   d. Either all 90° elbows or a combination of 90° and 45° elbows

8. Piping runs should not be placed in outside walls.
   a. True
   b. False

9. Pump circulation can be stopped by air bubbles accumulating at a high point.
   a. True
   b. False

10. Drops to downfed heat transfer units should connect from the ______ of the mains.

a. Top
b. Side
c. Bottom
d. Top or the bottom

11. Complete the following statement: "Installing zones allows for _________________.."
    a. Lower installation cost
    b. Ease of installation
    c. Greater comfort
    d. Greater heat transfer

12. Which one of the following factors is not a consideration when selecting zones?
    a. Heat losses
    b. System layout
    c. Use patterns
    d. Floor constructions

13. In multi-storey buildings, why do the higher floors typically require less heat than the lower floors?
    a. Due to different use patterns between storeys
    b. Because they have additional insulation
    c. Because they use larger boilers
    d. Due to the stack effect

14. Complete the following statement: "Rooms that may not be used for long periods should ____________."
    a. Have double-glazed thermally broken windows installed
    b. Not have any heat transfer unit installed
    c. Be zoned separately
    d. Be sealed off

15. Which one of the following rooms is normally kept at a higher setpoint temperature than the others?
    a. Dining room
    b. Living room
    c. Bathroom
    d. Bedroom

16. Which one of the following rooms is normally kept at a lower setpoint temperature than the others?
    a. Dining room
    b. Living room
    c. Bathroom
    d. Bedroom

17. Balancing is the process of what?
    a. Balancing flows in circuits
    b. Balancing temperatures in circuits
    c. Adjusting the control system
    d. Adjusting the pressure that enters a hot-water heating system

18. How is the flow through each loop of a split-series loop system balanced?
    a. Adjusting gravity flow control valves
    b. Adjusting balancing valves
    c. Adjusting radiator valves
    d. The size of pipe used in each loop

Answer Key: Self-Test B-4.4 (#chapter-answer-key-self-test-b-4-4) is on the next page.

Answer Key: Self-Test B-4.4

1. e. A vertical pipe connected to runouts on more than one floor
2. c. A pipe that connects a heat transfer unit to other parts of a heating system
3. a. The horizontal pipe that connects a main to a riser
4. b. A run of pipe with three or more elbows that allow parts of a run to have different slopes and movement without severe stress
5. d. An arrangement of pipes and fittings that allows the movement of parts of a piping run caused by thermal expansion without excessive stress
6. a. Be almost level or have an upward grade of 4 mm/m ($\frac{1}{2}$ in./10 ft)
7. d. Either all 90° elbows or a combination of 90° and 45° elbows
8. a. True
9. a. True
10. c. Bottom
11. c. Greater comfort
12. b. System layout
13. d. Due to the stack effect
14. c. Be zoned separately
15. c. Bathroom
16. d. Bedroom
17. a. Balancing flows in circuits
18. b. Adjusting balancing valves

Glossary - Block B: Heating and Cooling Systems

active (solar watering heating) systems

These use electric pumps, valves, and controllers to circulate water or other heat-transfer fluids through the collectors. There are three types: direct, indirect/ closed-loop, and drainback. (Section B-2.1 (#chapter-b-2-1-heat-and-cooling-sources))

adjustable louvre

A type of window or vent with slats that can be moved or tilted. These slats can be adjusted to control the amount of light, air, and noise that comes through, making them useful for ventilation and privacy. (Section B-3.1 (#chapter-b-3-1-types-of-hydronic-transfer-units))

air elimination

The process of removing trapped air from a hydronic heating system to ensure efficient operation. Usually accomplished using air vents placed at high points in the piping. (Section B-3.2 (#chapter-b-3-2-heat-transfer-units-installation))

air purger

(Also called air separators or air scoops); A device used in heating and cooling systems to remove larger air pockets and air bubbles from water, which can cause problems like noisy pipes or reduced efficiency. The device helps to keep the system running smoothly by ensuring that the water is free from air. Also see **microbubble resorber**. (Section (#chapter-b-4-1-system-components)B- (#chapter-b-2-1-heat-and-cooling-sources)4.1 (#chapter-b-4-1-system-components))

air vents

Steam cannot circulate nor can radiators emit heat until air has been vented from the system. Thermostatic air vents are installed on each radiator and at the end of each steam main. Thermostatic steam traps also act as air vents. (Section B-1.1 (#chapter-b-1-1-heat-and-heat-transfer), Section B-3.1 (#chapter-b-3-1-types-of-hydronic-transfer-units) and Section B-3.2) (#chapter-b-3-2-heat-transfer-units-installation)

aquastat

A device used in heating systems to control the temperature of the water. It works like a thermostat but specifically for water, turning the boiler on or off to keep the water at the desired temperature. (Section B-2.1 (#chapter-b-2-1-heat-and-cooling-sources))

Authority Having Jurisdiction (AHJ)

An organization or person responsible for enforcing safety and building codes. They make sure that buildings and structures follow the law and safety standards, such as proper electrical wiring and fire safety measures. (Section B-2.2 (#chapter-b-2-2-installation-of-heating-and-cooling-sources-2))

backflow preventer

A device that stops water from flowing backward into the water supply. It ensures that water doesn't get contaminated by preventing dirty or used water from flowing back into clean water lines. (Section B-4.2 (#chapter-b-4-2-valves))

balancing valve

A valve used in a piping system to control and balance the flow of fluid to ensure that each part of the system gets the right amount of flow. It also helps to make sure that all sections of the system work efficiently and evenly. (Section (#chapter-b-4-3-types-of-distribution-systems)B- (#chapter-b-2-1-heat-and-cooling-sources)4.3) (#chapter-b-4-3-types-of-distribution-systems)

ball valve

A valve that controls the flow of liquid using a ball with a hole through the center. When the ball is turned so that the hole lines up with the pipe, liquid flows through. When the ball is turned so that the hole is perpendicular to the pipe, the flow is blocked. Ball valves are known for their quick and easy on-off operation. (Section (#chapter-b-4-2-valves)B- (#chapter-b-2-1-heat-and-cooling-sources)4.2 (#chapter-b-4-2-valves))

baseboard wallfin units

Heating devices installed along the baseboards of rooms. They use electricity or hot water to produce heat, which is then radiated into the room. These units are effective for heating spaces efficiently and are often controlled by thermostats to maintain desired temperatures. (Section B-3.1) (#chapter-b-3-1-types-of-hydronic-transfer-units)

bypass valve (quick fill valve)

A valve that allows water to quickly flow around a system or component. It is used to quickly fill up or bypass parts of the system, making it easier to manage and maintain. (Section B-4.2 (#chapter-b-4-2-valves))

cast-iron sectional boiler

Water is contained in tanks called sections, with hot flue gases passing around the sections. (Section B-2.1 (#chapter-b-2-1-heat-and-cooling-sources))

cavitation

The process where tiny bubbles or vapor pockets form in a liquid when the pressure drops below the liquid's vapor pressure. These bubbles can collapse suddenly, creating strong shockwaves and high temperatures. Cavitation can occur in pumps, propellers, and other machinery, and while it can be useful in some processes (like cleaning or mixing), it can also cause damage to equipment over time. See also **cavitator.** (Section (#chapter-b-4-1-system-components)B- (#chapter-b-2-1-heat-and-cooling-sources)4.1 (#chapter-b-4-1-system-components))

cavitator

A device used to create cavitation in a liquid. Cavitation happens when rapid changes in pressure cause tiny bubbles to form and then collapse. These collapsing bubbles can generate powerful forces that help mix, stir, or break down materials. Cavitators are used in various applications like cleaning, chemical processing, and in some industrial processes to improve efficiency. See also **cavitation**. (Section (#chapter-b-4-1-system-components)B- (#chapter-b-2-1-heat-and-cooling-sources)4.1 (#chapter-b-4-1-system-components))

centrifugal pump

A device that moves liquids by using a rotating impeller. The impeller spins the liquid outward through centrifugal force, pushing it through the pump and into the pipes of a system. Centrifugal pumps are commonly used in water supply, heating, and cooling systems to efficiently move fluids. (Section (#chapter-b-4-1-system-components)B- (#chapter-b-2-1-heat-and-cooling-sources)4.1 (#chapter-b-4-1-system-components))

check valve

A valve that allows liquid to flow in only one direction. It automatically closes when the liquid starts to flow backward, preventing backflow. Check valves are used to keep liquids from flowing the wrong way in a pipe system. (Section (#chapter-b-4-2-valves)B- (#chapter-b-2-1-heat-and-cooling-sources)4.2) (#chapter-b-4-2-valves)

circulating pump (or circulator)

A device that moves water through a heating or cooling system. It helps distribute hot or cold water to different parts of a building, ensuring even temperature control. Circulating pumps are essential for systems like radiators and underfloor heating. (Section B-4.1 (#chapter-b-4-1-system-components))

component isolation

The process of shutting off or separating a specific part of a system, like a pipe or valve, from the rest of the system. This is done to allow for repairs or maintenance without affecting the entire system. It ensures that only the isolated part is affected while the rest continues to operate normally. (Section (#chapter-b-4-2-valves)B- (#chapter-b-2-1-heat-and-cooling-sources)4.2) (#chapter-b-4-2-valves)

conduction

The transfer of heat through direct contact between materials. Heat travels from warmer to cooler areas within an object or between two objects in contact. (Section B-1.1 (#chapter-b-1-1-heat-and-heat-transfer))

convection

The transfer of heat through the movement of liquids or gases. Warmer particles rise, while cooler particles sink, creating a circular flow that distributes heat. (Section B-1.1 (#chapter-b-1-1-heat-and-heat-transfer))

convector

A heating device that warms up a room by circulating air over a heated surface. The warm air rises and spreads through the room, while cooler air is drawn in to be heated. This process creates a continuous flow of warm air, making the room comfortable. (Section (#chapter-b-3-1-types-of-hydronic-transfer-units)B- (#chapter-b-2-1-heat-and-cooling-sources)3.1) (#chapter-b-3-1-types-of-hydronic-transfer-units)

counterflow

A term used to describe a situation where two substances, such as fluids or gases, flow in opposite directions relative to each other. This arrangement maximizes the efficiency of heat or mass transfer between the substances by allowing the greatest temperature or concentration difference across the exchange interface. (Section (#chapter-b-1-2-low-pressure-steam-heating-systems)B- (#chapter-b-3-1-types-of-hydronic-transfer-units)1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems))

dedicated branch circuit

An electrical circuit that supplies power to only one specific piece of equipment or appliance, without sharing the circuit with other devices. (Section B-2.2 (#chapter-b-2-2-installation-of-heating-and-cooling-sources-2))

direct systems

In active systems, use pumps to circulate water through the collectors. These systems are appropriate in areas that do not freeze for long periods and do not have hard or acidic water. Systems that are installed in hard or acidic water conditions may not survive the “payback period” if care is not taken to address water chemistry. In off-grid situations where solar energy may be the only option, water chemistry must be considered. (Section B-2.1 (#chapter-b-2-1-heat-and-cooling-sources))

direct-return

A piping system design where the water or fluid returns directly to the source or starting point after passing through each section of the system. This means that each section gets the same temperature fluid and helps in balancing the system evenly. (Section B-4.3 (#chapter-b-4-3-types-of-distribution-systems))

diversion tee

A pipe fitting that splits the flow of a fluid into two separate paths. It looks like a "T" shape and allows part of the fluid to be redirected or sent to a different part of the system while the rest continues along the original path. (Section (#chapter-b-4-2-valves)B- (#chapter-b-2-1-heat-and-cooling-sources)4.2) (#chapter-b-4-2-valves)

drainback systems

In active systems, are direct systems that use pumps to circulate water through the collectors, then drain themselves automatically to prevent freezing. Because the water in the collector loop drains into a reservoir tank when the pumps stop, this is still a good system for colder climates and does not require antifreeze and a heat exchanger. (Section B-2.1 (#chapter-b-2-1-heat-and-cooling-sources))

dry return

The dry return is the portion of the return main located above the boiler water level. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems))

equalizer line

The vertical piping at the end of the header going back to the boiler return connection. Its job is to return any water that slips out of the boiler with the steam, and to balance the pressure between the supply and the return sides of the boiler. Without a properly-sized equalizer, water can back out of the boiler. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems) and Section B-4.2 (#chapter-b-4-2-valves))

expansion tank

A special tank in a heating or cooling system that helps manage the pressure caused by changes in temperature. When the water heats up and expands, the expansion tank provides extra space for the water to go, so the system doesn't get too much pressure. (Section (#chapter-b-4-1-system-components)B- (#chapter-b-2-1-heat-and-cooling-sources)4.1 (#chapter-b-4-1-system-components))

feedwater valve (pressure-reducing valve)

A valve that controls the amount of water that enters a system and lowers the pressure to a safe level. It helps keep the water pressure steady and safe for the system. (Section B-4.2 (#chapter-b-4-2-valves))

fire-tube boiler

Heated flue gases travel through tubes that are surrounded by the water in the boiler. (Section (#chapter-b-2-1-heat-and-cooling-sources)B- (#chapter-b-1-2-low-pressure-steam-heating-systems)2.1 (#chapter-b-2-1-heat-and-cooling-sources))

flat-plate (or transpired air collectors)

Solar energy systems that consist of dark metal plates mounted on building walls or roofs. These plates absorb solar radiation, heating the air which is then circulated for heating purposes inside the building. They are a passive method of harnessing solar energy for space heating and ventilation. (Section (#chapter-b-2-1-heat-and-cooling-sources)B- (#chapter-b-1-1-heat-and-heat-transfer)2.1 (#chapter-b-2-1-heat-and-cooling-sources))

floor drain

A plumbing fixture installed in the floor of a building, typically found in areas like basements, bathrooms, or utility rooms. Its purpose is to remove excess water and prevent flooding by directing water into the building's drainage system. (Section (#chapter-b-2-1-heat-and-cooling-sources)B- (#chapter-b-1-1-heat-and-heat-transfer)2.1 (#chapter-b-2-1-heat-and-cooling-sources))

flow regulation

The control of how much fluid flows through a pipe or system. It involves adjusting valves or other devices to manage the flow rate, pressure, or speed of the fluid. This helps ensure that the system works efficiently and that different parts of the system receive the correct amount of fluid. (Section (#chapter-b-4-2-valves)B- (#chapter-b-2-1-heat-and-cooling-sources)4.2 (#chapter-b-4-2-valves))

forced circulating convectors

Heating units that use a fan or pump to circulate air or water through the convector. They are more powerful than gravity systems and can distribute heat more evenly throughout a room. These systems are often used in larger buildings or where rapid heating is required. (Section (#chapter-b-3-1-types-of-hydronic-transfer-units)B- (#chapter-b-2-1-heat-and-cooling-sources)3.1 (#chapter-b-3-1-types-of-hydronic-transfer-units))

friction loop

Part of a system where friction losses occur due to the flow of fluid through pipes or other components. In systems where friction loops are managed, the aim is to reduce friction losses and improve efficiency. (Section (#chapter-b-4-3-types-of-distribution-systems)B- (#chapter-b-2-1-heat-and-cooling-sources)4.3 (#chapter-b-4-3-types-of-distribution-systems))

gate valve

A type of valve that controls the flow of liquid by raising or lowering a gate or barrier inside the valve. When the gate is fully open, the flow of liquid is unimpeded. When the gate is closed, it blocks the flow completely. Gate valves are good for stopping or allowing flow but are not ideal for regulating flow. (Section (#chapter-b-4-2-valves)B- (#chapter-b-2-1-heat-and-cooling-sources)4.2) (#chapter-b-4-2-valves)

gauge glass

Used to identify the water level in the boiler. Expect to see some minor movement in the water line when the boiler is operating. When the boiler is off, the “normal” water line is the centre of the gauge glass. When the system is running, the “normal” water line is near the bottom of the gauge glass. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems))

globe valve

A valve that controls the flow of liquid by moving a disc up and down inside the valve. This movement allows for precise control of the flow rate. Globe valves are often used when it's important to adjust or regulate the flow of liquid rather than just stopping or allowing it. (Section (#chapter-b-4-2-valves)B- (#chapter-b-2-1-heat-and-cooling-sources)4.2 (#chapter-b-4-2-valves))

gravity circulating convectors

Heating units that use natural convection to circulate warm air. They are typically placed near windows and walls where cold air enters. As the air near the heater warms, it rises, creating a convection current that circulates throughout the room. (Section (#chapter-b-3-1-types-of-hydronic-transfer-units)B- (#chapter-b-2-1-heat-and-cooling-sources)3.1 (#chapter-b-3-1-types-of-hydronic-transfer-units))

Hartford loop

A piping arrangement designed to prevent complete drainage of the boiler if a leak develops in the wet return. The wet return is connected to an equalizing line between the supply and return opening of the boiler. This connection is made about 2” below the normal water level of the boiler. This connection between the loop and the equalizer must be made with a close nipple to prevent water hammer. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems))

header

Boilers, depending upon their size, have one or more outlet tappings. The vertical steam piping from the tapped outlet joins a horizontal pipe called a header. The steam supply mains are connected to this header. If the boiler has more than one outlet, it is important to remember to pipe the headers with swing joints. This will help alleviate any stress on the boiler when the header heats up and expands. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems) and Section B-4.2 (#chapter-b-4-2-valves))

heat emitters (units)

Steam heating systems use convectors, cast-iron radiators, wall fin tubes, and similar heat-emitting units. (Section B-1.4 (#chapter-b-1-4-hydronic-heating-and-cooling-systems) and Section B-3.1 (#chapter-b-3-1-types-of-hydronic-transfer-units))

heat exchanger

A device used to transfer heat between two fluids (liquids or gases) without them coming into direct contact. It facilitates the efficient exchange of thermal energy, commonly found in HVAC systems, refrigeration units, and industrial processes. (Section (#chapter-b-2-1-heat-and-cooling-sources)B- (#chapter-b-1-1-heat-and-heat-transfer)2.1 (#chapter-b-2-1-heat-and-cooling-sources))

heat exchangers

Devices designed to transfer heat between two fluids or between a fluid and a solid surface. They facilitate the exchange of thermal energy without the fluids coming into direct contact with each other. They work by maximizing surface area contact between the fluids to efficiently transfer heat from a warmer fluid to a cooler one, or vice versa, depending on the application's requirements. (Section (#chapter-b-3-1-types-of-hydronic-transfer-units)B-(#chapter-b-3-1-types-of-hydronic-transfer-units)3.1) (#chapter-b-3-1-types-of-hydronic-transfer-units)

hot flue gases

The exhaust gases produced from combustion processes, such as those in furnaces, boilers, or industrial equipment. These gases are typically very hot and contain by-products of combustion such as carbon dioxide, water vapor, carbon monoxide, and other pollutants. Hot flue gases are often directed through flues or exhaust pipes to safely remove them from the combustion chamber or heating system. They may also be used in heat exchangers to recover some of their thermal energy before being vented to the atmosphere. (Section (#chapter-b-3-1-types-of-hydronic-transfer-units)B- (#chapter-b-3-1-types-of-hydronic-transfer-units)3.1 (#chapter-b-3-1-types-of-hydronic-transfer-units))

housekeeping pads

A raised concrete platform on which mechanical equipment, such as a boiler, is mounted. (Section B-2.2 (#chapter-b-2-2-installation-of-heating-and-cooling-sources-2))

hydronic fan coil

A unit that uses circulating water to heat or cool air by passing it over coils, adjusting the room temperature efficiently. (Section B-3.1 (#chapter-b-3-1-types-of-hydronic-transfer-units))

hydronic heating

A system that uses water to heat a building. Water is heated in a boiler and then pumped through pipes to radiators or underfloor tubing. As the hot water moves through these pipes, it releases heat into the rooms, keeping them warm. (Section (#chapter-b-3-1-types-of-hydronic-transfer-units)B- (#chapter-b-3-1-types-of-hydronic-transfer-units)3.1 (#chapter-b-3-1-types-of-hydronic-transfer-units))

impeller

A rotating part of a pump or other machine that moves fluid by spinning. It has blades that push the fluid outward from the center, creating flow and increasing pressure. Impellers are commonly found in devices like centrifugal pumps and are essential for moving liquids efficiently. (Section (#chapter-b-4-1-system-components)B-(#chapter-b-2-1-heat-and-cooling-sources)4.1 (#chapter-b-4-1-system-components))

impeller "eye"

The center part of an impeller where liquid or gas enters before being pushed out by the spinning blades. It's like the entrance point that leads the fluid into the impeller. (Section B-4.1 (#chapter-b-4-1-system-components))

indirect/closed-loop systems

In active systems, these pump heat-transfer fluids, such as a mixture of glycol and water, through collectors. Heat exchangers then transfer the heat from the fluid to the water within the heating system. These systems are used in climates subject to freezing. (Section B-2.1 (#chapter-b-2-1-heat-and-cooling-sources))

input (boilers)

The amount of energy the boiler consumes in order to produce heat. (Section B-2.1 (#chapter-b-2-1-heat-and-cooling-sources))

insulation

A material that reduces the transfer of heat. It traps air or uses materials like foam or fiberglass to slow down heat loss or gain, helping to maintain comfortable temperatures in buildings. (Section (#chapter-b-1-1-heat-and-heat-transfer)B- (#chapter-b-3-1-types-of-hydronic-transfer-units)1.1 (#chapter-b-1-1-heat-and-heat-transfer))

integral collector storage (ICS) systems

This type of passive solar watering heating system consists of one or more storage tanks placed in an insulated box with a glazed side facing the sun. During the winter, the connecting piping must be drained or protected from freezing. (Section 2.1 (#chapter-b-2-1-heat-and-cooling-sources))

low-water cut-off

The job of the low-water cut-off is to shut off the burner should the water level fall to an unsafe level. The boiler manufacturer determines this level, but it is usually within one-half inch of the bottom of the gauge glass. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems) and Section B-2.1 (#chapter-b-2-1-heat-and-cooling-sources))

main stop valve

A valve that controls the flow of water or other fluids into or out of a system. It can completely stop the flow when needed, allowing you to turn off the entire system or isolate it for repairs or maintenance. (Section B-4.2 (#chapter-b-4-2-valves))

microbubble resorber

A device used in heating and cooling systems to remove very tiny air bubbles (microbubbles) from water that may not be captured by standard air purgers. By getting rid of the bubbles, the microbubble resorber may more efficiently help the system work better and more quietly. See also **air purgers**. (Section (#chapter-b-4-1-system-components)B- (#chapter-b-2-1-heat-and-cooling-sources)4.1) (#chapter-b-4-1-system-components)

outlet tapping

An outlet tapping is when a hole is made in a pipe to add another pipe or valve. This lets water or gas flow from the main pipe to a new area, like a faucet or another system. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems))

output (boilers)

The amount of energy that is actually transferred to the medium being heated (water, heating fluid, glycol, etc.). (Section B-2.1 (#chapter-b-2-1-heat-and-cooling-sources))

parallel flow

A situation where two substances, such as fluids or gases, flow in the same direction relative to each other. In heat exchangers, parallel flow occurs when both the hot and cold fluids move in the same direction through adjacent channels or tubes. This configuration typically results in a lower temperature difference between the two fluids compared to counterflow, but it is simpler to construct and often more compact. (Section (#chapter-b-1-2-low-pressure-steam-heating-systems)B- (#chapter-b-3-1-types-of-hydronic-transfer-units)1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems))

passive (solar water heating) systems

Solar water heating systems that move water or heat-transfer fluid without pumps. There are two types of passive systems: Integral collector storage (ICS) and thermosiphon systems. (Section B-2.1 (#chapter-b-2-1-heat-and-cooling-sources))

potable water system

A water supply system that provides water safe for drinking and other domestic uses, free from harmful contaminants. (Section B-2.2 (#chapter-b-2-2-installation-of-heating-and-cooling-sources-2))

pump curve

A graph that shows how well a pump can move water at different speeds. It helps us see how much water the pump can push out at different pressures or flows. (Section (#chapter-b-4-1-system-components)B- (#chapter-b-2-1-heat-and-cooling-sources)4.1 (#chapter-b-4-1-system-components))

push nipples

Small connectors used in boilers and heating systems to join sections of piping together securely. They allow for easy assembly and disassembly when maintaining or repairing the system. (Section (#chapter-b-2-1-heat-and-cooling-sources)B- (#chapter-b-1-1-heat-and-heat-transfer)2.1 (#chapter-b-2-1-heat-and-cooling-sources))

radiant panels

Heating devices that are installed in ceilings, walls, or floors of buildings. They emit infrared radiation, which directly heats objects and people in the room without heating the air. This method of heating is efficient and provides comfortable warmth evenly throughout the space. (Section B-3.1 (#chapter-b-3-1-types-of-hydronic-transfer-units))

radiation

The transfer of heat through electromagnetic waves. Unlike conduction and convection, radiation does not require a medium and can travel through vacuum, transferring heat from the Sun to Earth and between objects. (Section (#chapter-b-1-1-heat-and-heat-transfer)B- (#chapter-b-3-1-types-of-hydronic-transfer-units)1.1 (#chapter-b-1-1-heat-and-heat-transfer))

radiator valves

Radiator valves control the steam supply to the system radiators. Each radiator is equipped with an angle pattern radiator supply valve. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems) and Section 4.2 (#chapter-b-4-2-valves))

radiators

Heating devices that use hot water or steam to warm a room. They consist of metal panels or pipes that emit heat through radiation and convection. Radiators are commonly found under windows or along walls and are controlled by thermostats to maintain desired temperatures. (Section (#chapter-b-3-1-types-of-hydronic-transfer-units)B- (#chapter-b-2-1-heat-and-cooling-sources)3.1 (#chapter-b-3-1-types-of-hydronic-transfer-units))

relief valves

These valves protect the boiler against a runaway fire. On space-heating steam boilers, the relief valve is set to pop open and relieve pressure at 15 psi. This is the limit for any low-pressure boiler. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems), Section B-4.1 (#chapter-b-4-1-system-components), and Section B-4.2 (#chapter-b-4-2-valves))

residual heat

The leftover warmth retained by an object or substance after the source of heat has been removed. It can be useful in conserving energy or maintaining temperatures in systems like engines or household appliances. (Section (#chapter-b-2-1-heat-and-cooling-sources)B- (#chapter-b-1-1-heat-and-heat-transfer)2.1 (#chapter-b-2-1-heat-and-cooling-sources))

reverse-return

A piping system design where the fluid flows in a way that the return path is the opposite of the supply path. This means that the last section to receive the fluid is the first to return it, helping to balance the system and ensure even heating or cooling throughout. (Section (#chapter-b-4-3-types-of-distribution-systems)B- (#chapter-b-2-1-heat-and-cooling-sources)4.3 (#chapter-b-4-3-types-of-distribution-systems))

riser

A vertical pipe or duct that carries water, steam, air, or other fluids up through different floors of a building. It's used to move fluids between different levels or stories in a building. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems), Section B-4.1 (#chapter-b-4-1-system-components), and Section B-4.4 (#chapter-b-4-4-distribution-system-installation))

runout

A horizontal pipe or section of piping that extends from a riser to other parts of a system. It helps direct the flow of fluids from the vertical riser to different areas or equipment. (Section (#chapter-b-4-4-distribution-system-installation)B- (#chapter-b-2-1-heat-and-cooling-sources)4.4 (#chapter-b-4-4-distribution-system-installation))

series loop

A type of piping arrangement where the water or other fluid flows through one section of the system, then directly into the next section, like a chain. In a series loop, all the sections are connected in a single path, so the fluid passes through each one in order. (Section (#chapter-b-4-2-valves)B- (#chapter-b-2-1-heat-and-cooling-sources)4.2 (#chapter-b-4-2-valves))

solution tank

A container where a mix of substances, like water and chemicals, is stored. It's used to hold and sometimes mix these substances before they are used in a process or system. (Section (#chapter-b-4-1-system-components)B- (#chapter-b-2-1-heat-and-cooling-sources)4.1 (#chapter-b-4-1-system-components))

spring piece

A type of pipe or fitting that includes a spring to allow for movement or adjustment. It helps accommodate changes in temperature, pressure, or alignment in the piping system, reducing stress and preventing damage. (Section (#chapter-b-4-4-distribution-system-installation)B- (#chapter-b-2-1-heat-and-cooling-sources)4.4) (#chapter-b-4-4-distribution-system-installation)

standpipe

A vertical pipe used to carry liquids or gases from one place to another. It's often found in systems where a pipe needs to reach a higher level or where it helps manage the flow of liquids. (Section (#chapter-b-4-1-system-components)B- (#chapter-b-2-1-heat-and-cooling-sources)4.1 (#chapter-b-4-1-system-components))

steam boiler

A steam boiler is a device that heats water until it turns into steam. This steam is then used to provide heat or power. It works by burning fuel like coal, oil, or gas, or by using electricity to generate heat. The steam produced can be used for various purposes, such as heating buildings, running engines, or powering machines. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems))

Note: Steam boilers differ from hot water boilers because they are only partially filled with water. They have a sight glass for checking the water level and a relief valve to prevent damage from excessive pressure. A pressure switch, or pressuretrol, controls the burner and determines the boiler's operating pressure. When heat is needed, the boiler runs until it reaches the pressuretrol's cut-out setting, then the pressuretrol shuts off the burner. Commercial boilers also have a manual-reset high-limit pressuretrol to turn off the burner if the pressure gets too high.

steam supply main

The steam supply main carries steam from the header to the radiators connected along its length. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems))

steam traps

Steam traps prevent steam from getting into the condensate returns, because they close in the presence of steam, creating a separation from the return piping of the system. The steam trap has three jobs: to let air pass through the radiators, to close when steam reaches it, and to open when condensate accumulates. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems))

swing connection

A type of flexible pipe fitting that allows for movement and adjustment. It helps connect pipes or equipment while accommodating changes in position or alignment, making it easier to install and maintain the system. (Section (#chapter-b-4-4-distribution-system-installation)B- (#chapter-b-2-1-heat-and-cooling-sources)4.4 (#chapter-b-4-4-distribution-system-installation))

thermosiphon systems

This type of passive solar watering heating system relies on convection created between the fluids in the tank and in the collector. The fluid in the collector becomes less dense and rises into the tank above, while the denser fluid in the bottom of the tank falls through piping into the bottom of the collector to be reheated. The fluid to be heated is circulated through a separate path within the tank (heat exchanger) where it absorbs the heat created and returns to the building for use. (Section (#chapter-b-2-1-heat-and-cooling-sources)B- (#chapter-b-1-2-low-pressure-steam-heating-systems)2.1 (#chapter-b-2-1-heat-and-cooling-sources))

thermosiphoning

A process where a liquid moves naturally without the need for a pump, because of temperature differences. When a liquid gets heated, it becomes less dense and rises. Cooler, denser liquid then moves in to take its place. This creates a natural circulation of the liquid. It's often used in heating systems and solar water heaters. (Section B-4.3 (#chapter-b-4-3-types-of-distribution-systems))

throttling

The process of controlling the flow of a fluid (liquid or gas) by partially obstructing or restricting the passage through a valve or other device. This adjustment allows for precise control over the flow rate, pressure, or speed of the fluid. Throttling is commonly used in various systems, like heating and cooling systems, engines, and pipelines, to manage the performance and efficiency of the system. (Section (#chapter-b-4-2-valves)B- (#chapter-b-2-1-heat-and-cooling-sources)4.2 (#chapter-b-4-2-valves))

tridicator

A device that measures and displays three different things at once: pressure, temperature, and altitude (or level) of a liquid in a system. It's commonly used in heating systems to monitor these conditions and ensure everything is working properly. (Section B-2.1 (#chapter-b-2-1-heat-and-cooling-sources))

upfed system

A way of moving water in a building where the water comes in from the bottom and gets pumped up to higher floors. This is often used in places where the water pressure isn't strong enough to reach the top on its own. (Section B-4.3 (#chapter-b-4-3-types-of-distribution-systems))

venturi

A device that controls the flow of fluid through a pipe by narrowing the pipe at a certain point. This narrowing causes the fluid to speed up and the pressure to drop. Venturis are often used to measure flow rates or to mix fluids. (Section (#chapter-b-4-3-types-of-distribution-systems)B- (#chapter-b-2-1-heat-and-cooling-sources)4.3 (#chapter-b-4-3-types-of-distribution-systems))

volute

A spiral-shaped casing in a pump that surrounds the impeller. It helps direct the flow of liquid as it leaves the impeller, converting the high-velocity flow into a more controlled, higher-pressure flow. The volute design ensures efficient movement and pressure management of the liquid within the pump system. (Section (#chapter-b-4-1-system-components)B- (#chapter-b-2-1-heat-and-cooling-sources)4.1) (#chapter-b-4-1-system-components)

waste heat (or waste energy)

Energy that is produced but not used efficiently, often escaping as heat during processes like running machines or producing electricity. Instead of being used, this energy is usually lost to the environment. (Section 2.1 (#chapter-b-2-1-heat-and-cooling-sources))

water makeup

The process of adding water to a system to replace water that has been lost due to evaporation, leakage, or other reasons. This is commonly done in systems like boilers, cooling towers, and HVAC systems to maintain the proper water levels and ensure the system operates efficiently. The added water is often treated or conditioned to match the quality and chemistry requirements of the system. The term "water makeup" is used to indicate the piping and accessories connected to the system that not only fills it but keeps a constant pressure within it. (Section (#chapter-b-4-2-valves)B- (#chapter-b-2-1-heat-and-cooling-sources)4.2 (#chapter-b-4-2-valves))

water-tube boiler

Water travels through tubes that are surrounded by the hot flue gases within the fire chamber. (Section B-2.1 (#chapter-b-2-1-heat-and-cooling-sources))

wet return

The portion of the return main, located below the boiler water level. It is always completely filled with water and does not carry air or steam in the same way the dry return does. (Section B-1.2 (#chapter-b-1-2-low-pressure-steam-heating-systems))

zone valve

A valve used in heating or cooling systems to control the flow of fluid to different areas or zones of a building. It allows you to control the temperature in each zone separately, so you can heat or cool only the areas that need it. (Section (#chapter-b-4-4-distribution-system-installation)B- (#chapter-b-2-1-heat-and-cooling-sources)4.4 (#chapter-b-4-4-distribution-system-installation))

Plumbing Apprenticeship & Trade Resources in BC

A successful career in plumbing requires a strong foundation of skills, knowledge, and workplace safety awareness. Below are key resources to support plumbing apprentices in BC, including educational pathways, trade certifications, workplace safety guidelines, and mental health and wellness support.

Plumbing Apprenticeship & Certification Resources

- **SkilledTradesBC – Plumbing Apprenticeship (https://skilledtradesbc.ca/plumber)** — Overview of plumbing training, certification requirements, and apprenticeship pathways in British Columbia.
- **Red Seal Program – Plumber (https://www.red-seal.ca/eng/trades/plumbers/overview.shtml)** — National certification program with exam prep guides and trade mobility information.
- **BC Building Codes & Standards (https://www.bccodes.ca/)** — Official building and plumbing codes for British Columbia.

Workplace Safety & Regulations

- **WorkSafeBC (https://www.worksafebc.com/en)** — Essential safety resources for plumbers, including:
    - Health & Safety – WorkSafeBC (https://www.worksafebc.com/en/health-safety)
    - Report Unsafe Working Conditions (https://www.worksafebc.com/en/contact-us/departments-and-services/health-safety-prevention)
    - Report a Workplace Injury or Disease (https://www.worksafebc.com/en/claims/report-workplace-injury-illness)
    - Submit a Notice of Project Form (https://www.worksafebc.com/en/for-employers/just-for-you/submit-notice-project)
    - Get Health and Safety Resources (Videos, Posters, Publications, and More) (https://www.worksafebc.com/en/resources-health-safety)
    - Search the OHS Regulations (and Related Materials) (https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation)
    - Conduct an Incident Investigation (https://www.worksafebc.com/en/health-safety/create-manage/incident-investigations/conducting-employer-investigation)
- **CCOHS: OHS Answers Fact Sheets – Plumber (https://www.ccohs.ca/oshanswers/occup_workplace/plumber.html)** — Safety guidelines and best practices for plumbers in various work environments.

Financial Supports

- **Financial Support (SkilledTradesBC)** (https://skilledtradesbc.ca/financial-support) — Information about grants, tax credits, Canada apprentice loans, employment insurance, and the Indigenous Skills and Employment Training

(ISET) program.

- **StudentAidBC (https://studentaidbc.ca/)** — Complete post-secondary education through student loans, grants, and scholarships. There is also programs that help with loan repayment.
- **WorkBC (Government of BC)** (https://www.workbc.ca/find-loans-and-grants/students-and-adult-learners/services-apprentices-and-employers) — Services for apprentices and employers.

Mental Health & Wellness Support

- **HealthLink BC – Mental Health and Substance Use** (https://www.healthlinkbc.ca/mental-health-and-substance-use) — HealthLink BC resources for mental health and wellness support.
- **Here2Talk** (https://here2talk.ca/) — Free and confidential counseling services available to all post-secondary students registered at a BC school.
- **Help Starts Here** (https://helpstartshere.gov.bc.ca/) — A database with over 2,500 listings of services related to mental health and substance use supports.
- **Hope for Wellness Helpline** (https://www.hopeforwellness.ca/) — 24/7 online chat and phone line with experienced and culturally competent counselors available to all Indigenous people in Canada.
    - First Nations Health Authority Mental Health Supports Info Sheet [PDF] (https://www.fnha.ca/Documents/FNHA-mental-health-and-wellness-supports-for-indigenous-people.pdf) by First Nations health Authority — List of culturally safe services for Indigenous people.
- **HeretoHelp – BC** (https://www.heretohelp.bc.ca/) — Mental health resources, including videos, articles, and support services in BC.
- **BC Construction Industry Rehabilitation Plan** (https://www.constructionrehabplan.com/) — Mental health and substance use services for CLRA and BCBT members and their families.
- **Virtual Mental Health Supports (Government of BC)** (https://www2.gov.bc.ca/gov/content/health/managing-your-health/mental-health-substance-use/virtual-mental-health-supports) — Virtual services are available for British Columbians who are experiencing anxiety, depression, or other mental health challenges.

Crisis Support

- **Interior Crisis Line Network** — Call 1-888-353-2273 (tel:+1-888-353-2273) for 24/7 emotional support, crisis intervention, and community resource information.
- **Talk Suicide Chat Service** (https://talksuicide.ca/) — An alternative if calling is difficult; available for crisis intervention.
- **310Mental Health Support** — Call 250-310-6789 (tel:+1-250-310-6789) for emotional support, information, and resources specific to mental health.
- **1-800-SUICIDE** — Call 1-800-784-2433 (tel:+1-800-784-2433) if you are experiencing feelings of distress or despair, including thoughts of suicide.
- **Opioid Treatment Access Line** — Call 1-833-804-8111 (tel:+1-833-804-8111) between 9 am and 4 pm to connect with a doctor, nurse, or healthcare worker who can prescribe opioid treatment medication that same day.
- **KUU-US Crisis Response Service** — Call 1-800-588-8717 (tel:+1-800-588-8717) for culturally-aware crisis support for Indigenous peoples in BC.
- **Alcohol and Drug Information and Referral Service** — Call 1-800-663-1441 (tel:+1-800-663-1441) to find resources and support.

Emergency Services — For life-threatening situations, call 911 or visit your nearest emergency department.

Version History

This page provides a record of changes made to this learning resource, Plumbing Apprenticeship Level 2, Block B (https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/). Each update increases the version number by 0.1. The most recent version is reflected in the exported files for this resource.

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Version	Date	Change	Details
1.0	September, 2025	Plumbing Apprenticeship Level 2 Block B learning resource from STBC content converted to open and freely accessible digital platform and published at TRU.	