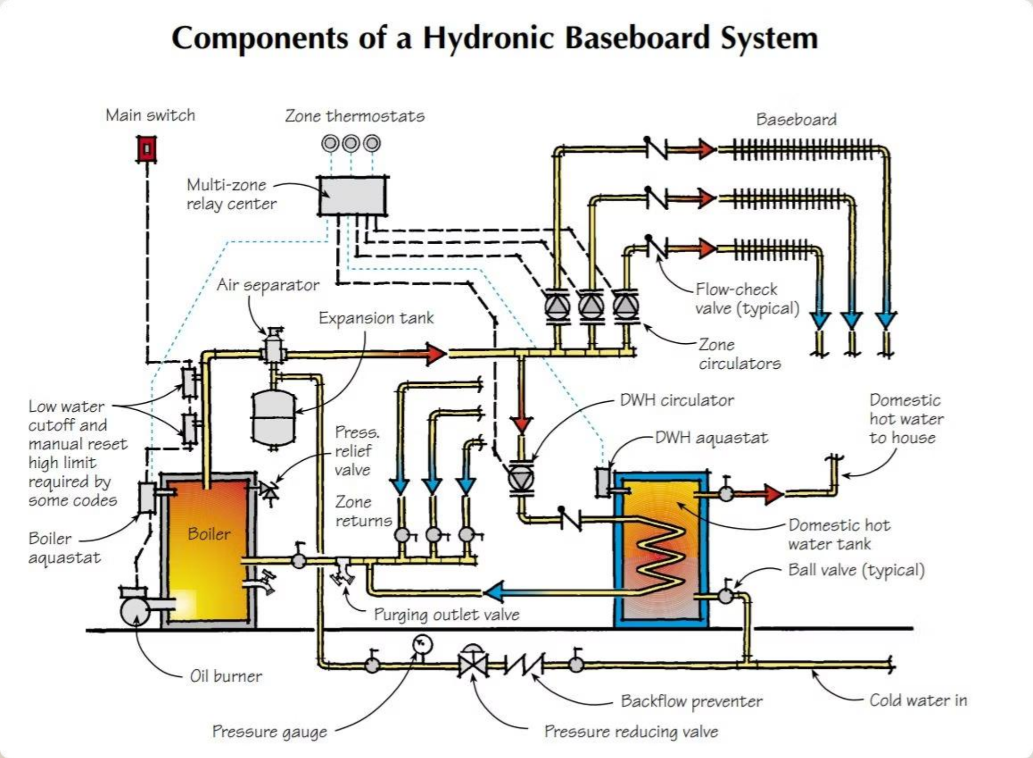


CSA Unit 20 - Hydronic Heating Systems

Chapter 1
Boilers: Understanding Hydronic Heating Systems

A gas-fired boiler transfers the heat produced from the combustion of the gas to the water contained in the boiler. It is important that the gas technician/fitter know the proper procedures for mounting and installing gas-fired boilers and their components as a major subsystem of hydronic space heating systems.

Created

MK by Mike Kapin

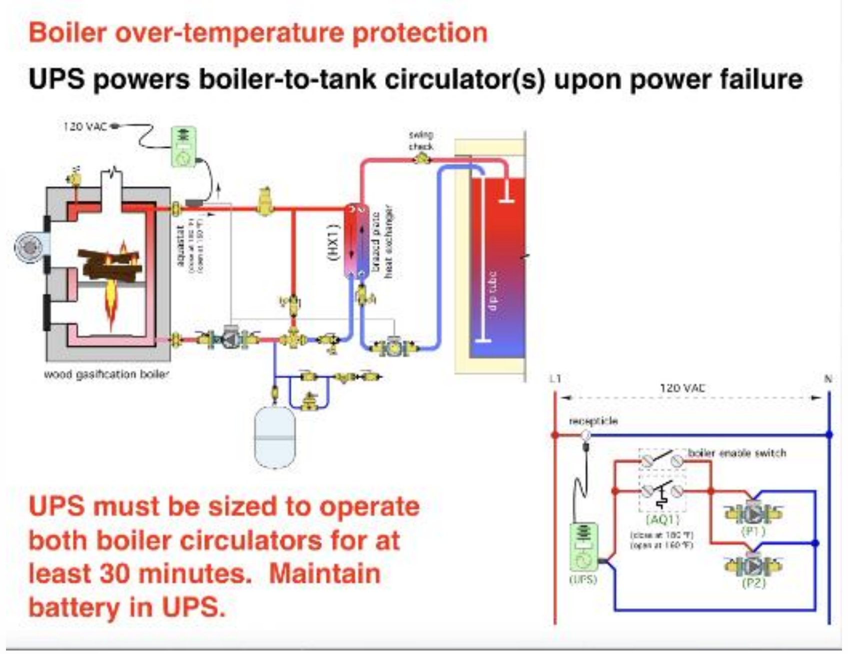
Hydronic Heating System Overview

Purpose

A gas-fired boiler transfers the heat produced from the combustion of the gas to the water contained in the boiler. This heated water is then distributed throughout a building to provide space heating.

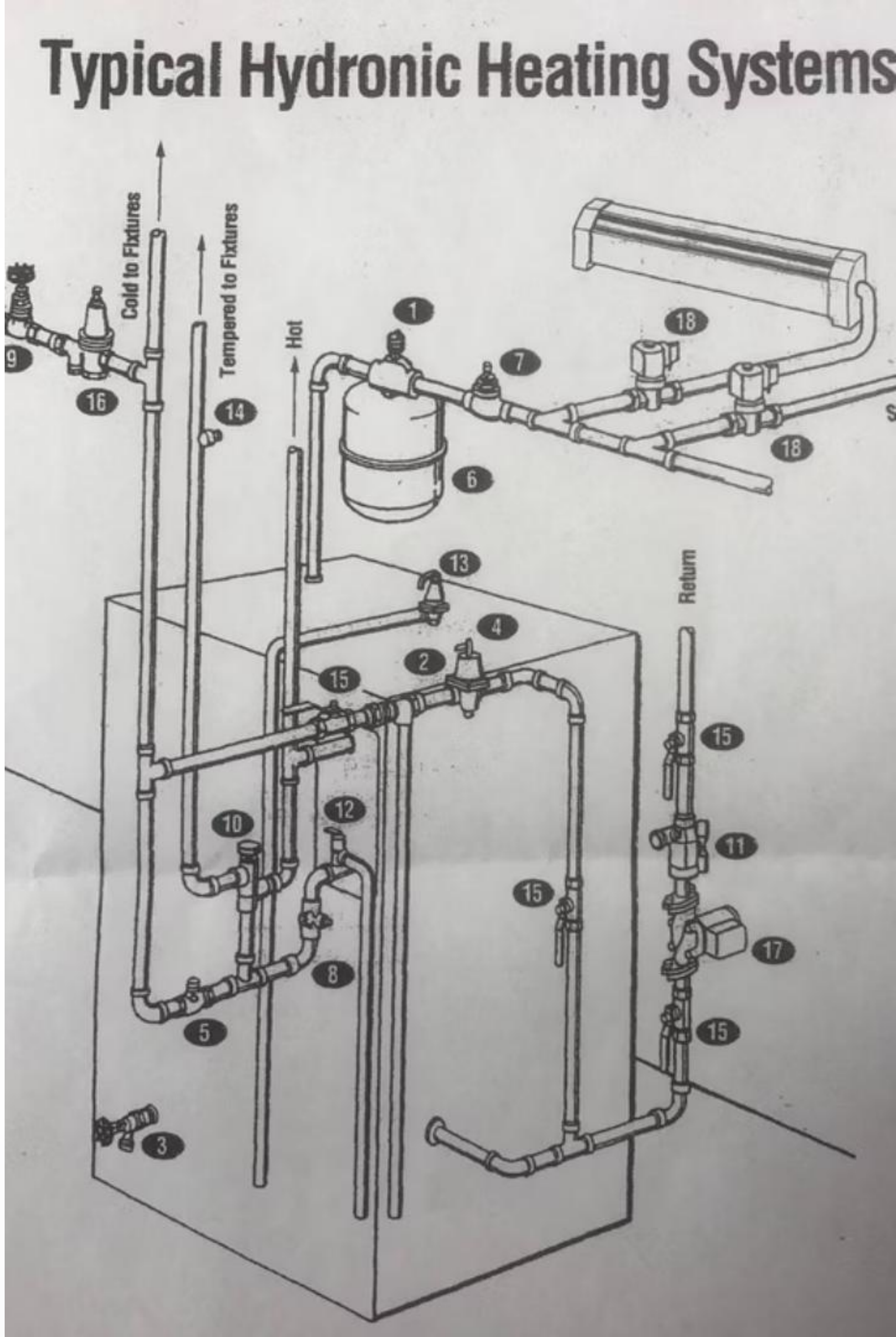
Objectives

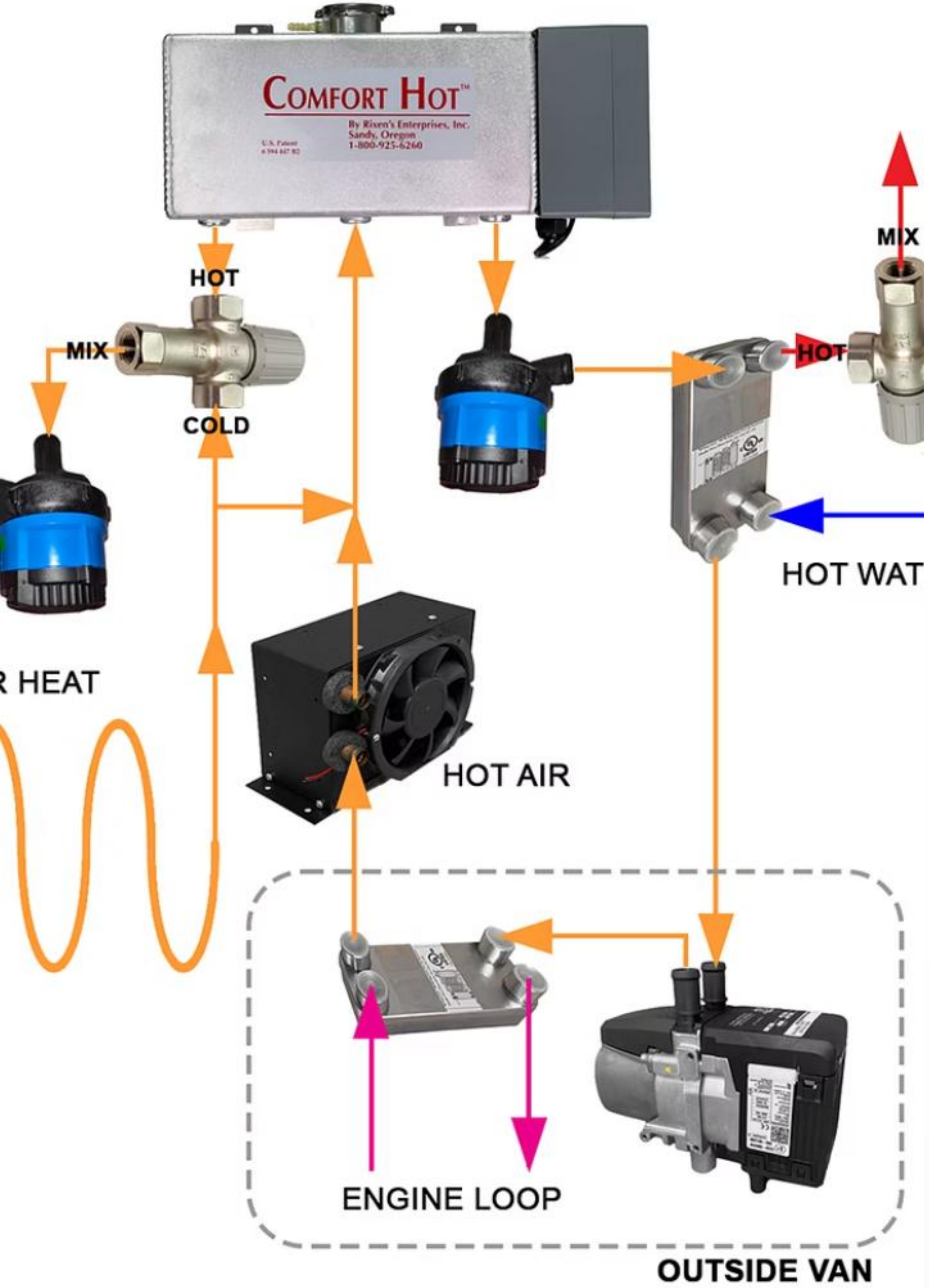
- Describe hydronic heating systems
- Describe hydronic heating system boilers
- Describe boiler components



Key Terminology

Term	Definition
Hydronic space heating system	Uses water to transfer thermal energy from the source to its point(s) of use
Spillage	When there is no draft, a backdraft, or a blockage beyond the draft hood, the flue gases exit the draft-hood instead of enter the appliance





Introduction to Hydronic Heating

Heat Transfer

A space heating system moves thermal energy (heat) from a heat source to the space(s) to be heated.

Hydronics

Hydronics involves the heating and cooling of spaces using liquids as the heat transfer medium.

Temperature Range

Hydronic systems use water only in its liquid state, over a practical temperature range of 50 to 250°F (10 to 121 °C).

Evolution of Hydronic Systems

Early Systems

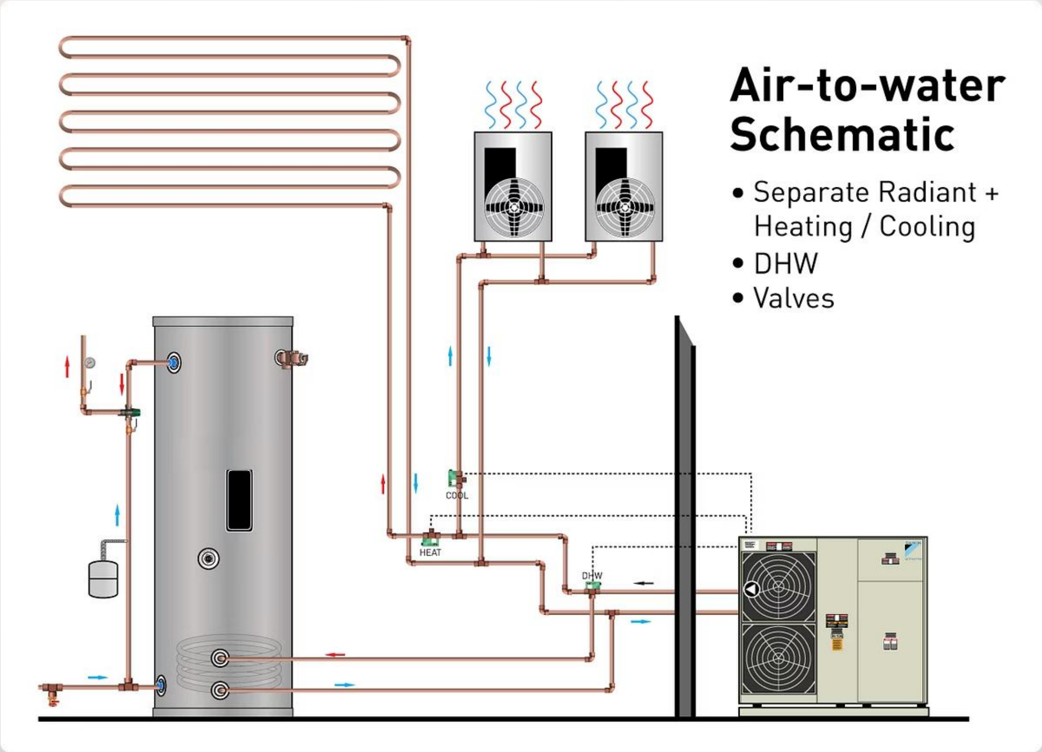
Early hydronic systems relied on the natural convection created by hot rising water and cool descending water streams for distribution and circulation in the system piping.

Modern Systems

Through the use of technology, modern hydronic heating systems are able to distribute heat exactly where and when it is required to maintain desired temperature levels.

Future Developments

Continued advancements in efficiency, control systems, and integration with renewable energy sources.



Scope of Gas Technician's Work

Provincial Regulations

Gas technicians/fitters are limited in the scope of work that they may perform in areas covered by other trades. This may vary from province to province since the gas technician's/fitter's responsibilities and limitations are governed by provincial regulations.

Ontario Example

Ontario regulations state that a gas technician/fitter must not perform any work beyond the gas side of a hydronic system unless the gas technician/fitter also holds a certificate of qualification issued under the Trades Qualification and Apprenticeship Act as a plumber or steamfitter.

Permitted Work

"Disconnect and reconnect water piping in order to exchange, service or install an approved appliance and carry out the replacement of water pipe necessary to complete the reconnection or controls, control systems, components and accessories that are essential to the operation of the appliance."

Hydronic Subsystems

Heat Source

Usually a boiler or hot water heater

Distribution System

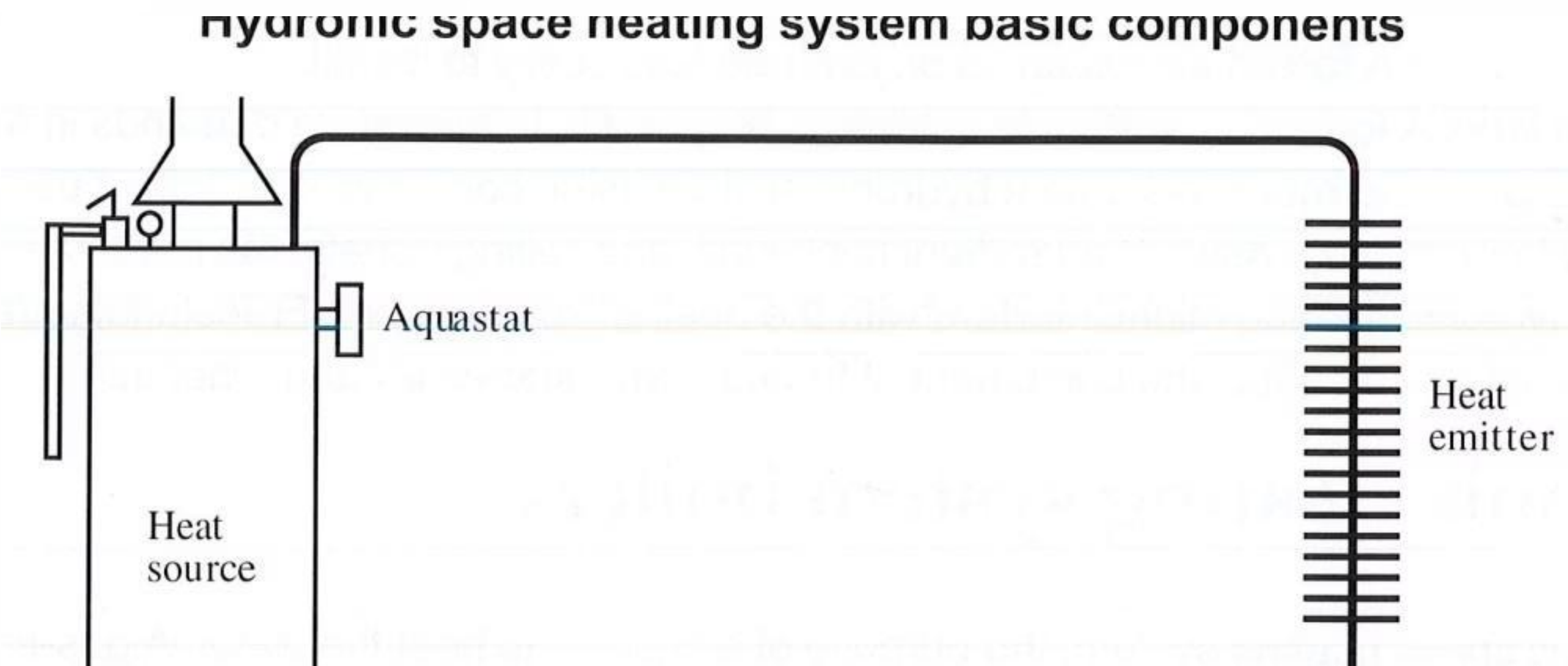
Piping, valves, and circulators

Control System

Thermostats, aquastats, controllers, switches, relays

Heat Emitters

Baseboard convector unit, wall-mounted radiators, or radiant floors



Advantages of Hydronic Heating Systems

Energy Efficiency

Many studies have consistently shown lower heating energy use than equivalent structures with forced air heating and similar ducted heating systems.

Clean, Quiet Operation

When a hydronic system operates properly, it is silent in comparison to the noise of airflow through ducts and outlets.

Increased Comfort Levels

One big advantage of heating through radiation is that surfaces in rooms tend to be warmer. This reduces the effect of radiant heat loss from the body and increases comfort.

Zoning Capability

A hydronic system can have as many areas of control (called zones). A forced air system typically has one thermostat location.

More Advantages of Hydronic Heating

Design Flexibility

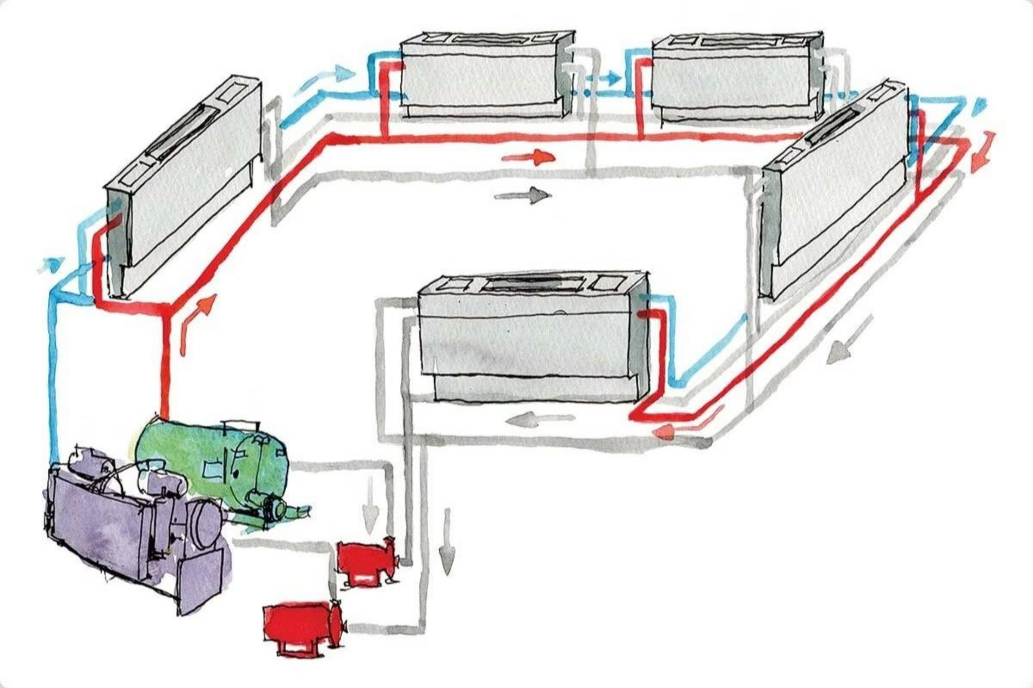
Hydronic heating offers almost unlimited possibilities to accommodate space heating, domestic water heating, snow melting, and pool heating.

Less Air Stratification

Stratification is the tendency of warm air to rise and accumulate at the ceiling while cold air falls and gathers at the floor. Hydronic systems reduce this effect.

Fewer Contaminants

Hydronic systems do not circulate as much dust and pollen through the air as do forced air systems.



Disadvantages of Hydronic Heating Systems

Installation Cost

A forced air system is on average less costly to install than a hydronic system.

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.

Heat Emitter Intrusion

Aside from radiant floor, wall, and ceiling panels, the heat transfer units used in hydronic heating might interfere with the aesthetics of a room. Freestanding radiators and convectors can affect the placement of furniture and drapes among other things.

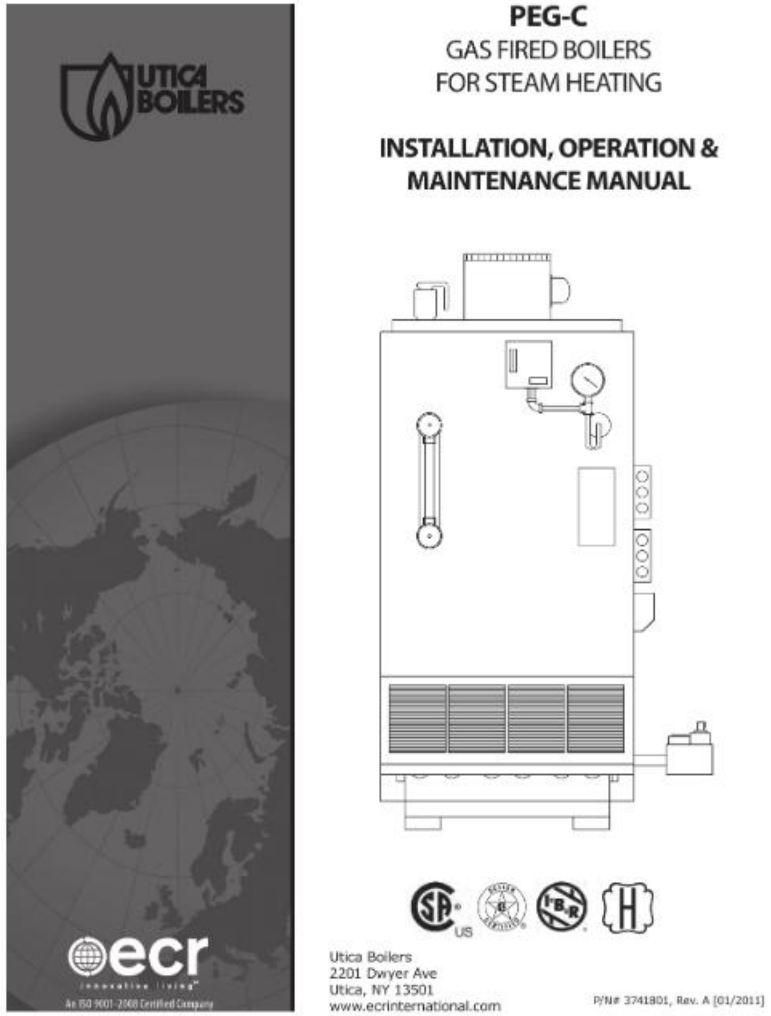
Hydronic Heating System Boilers

Purpose

In a hydronic space heating system, the purpose of a boiler is to heat the water. A gas-fired boiler transfers the heat produced from the combustion of the water contained in the boiler.

Operation

The hot water circulates through the hydronic system piping to space heating units where it gives up its heat to the building before returning to the boiler to be reheated.



Installation Requirements

Code Compliance

Section 7 of CSA B149.1 includes installation requirements for propane-fired and natural gas-fired boilers.

Provincial Regulations

Boilers must also conform to the requirements of the applicable provincial Boiler and Pressure Vessel Regulations.

Permits

Ensure that when applicable, permits have been applied for before starting any work.

Manufacturer Instructions

Review and implement manufacturer's installation instructions in all boiler installations.

Mounting Bases and Clearances

Firm and Level Base

Mounting of a boiler must be on a firm and level base. The floor or supporting surface must be non-combustible, except where the boiler is certified for installation on a combustible surface.

Combustible Surface Installation

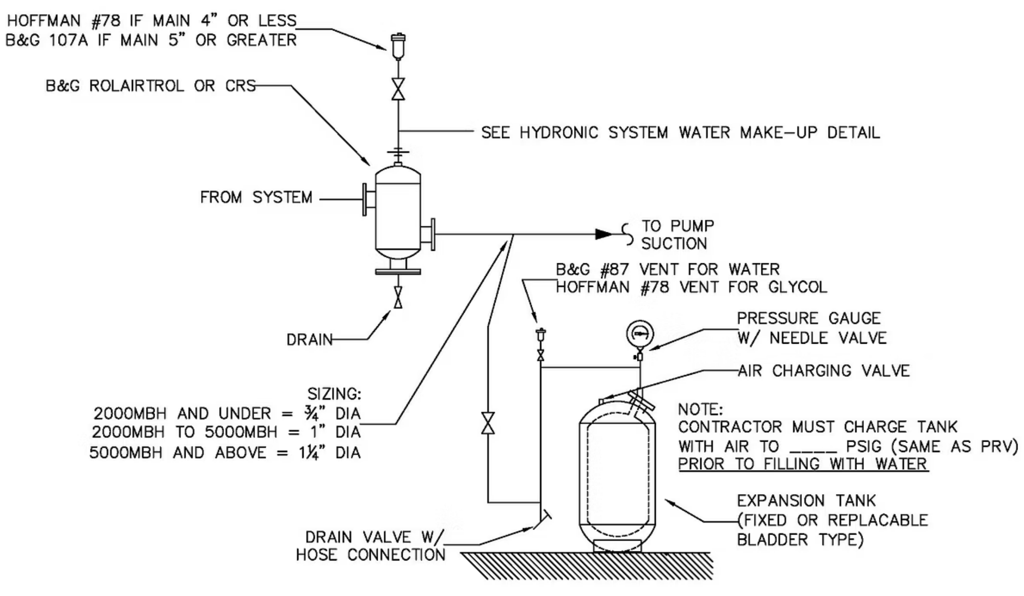
A boiler that does not yet have a certification for installation on a combustible floor may only be installed on combustible surfaces if one of the following conditions is met:

- A base designed by the boiler manufacturer is used; or
- The boiler (up to 400 MBtu/h /120 kW) is mounted on a platform that extends 6 inches (150 mm) beyond the edge of the boiler and is made of two rows of 4 inch (100 cm) block laid sideways and covered with a piece of sheet metal with a minimum thickness of 0.0195 inch (0.56 mm).

Clearances

Maintaining clearances between the boiler and combustible materials is a must, as specified in applicable Codes and the manufacturer's installation instructions.

Piping Specifications



VERTICAL BLADDER TANK INSTALLATION DETAIL

Sizing

Sizing of near boiler piping and supply and return piping must be in accordance with approved trade practices

Code Compliance

All piping must comply with applicable Codes

Manufacturer Instructions

Follow equipment manufacturer's instructions for proper installation

Cross-Contamination, Overpressure, and Low Water Hazards

Backflow Prevention

Hydronic system boilers require installation of valves to prevent backflow (cross-contamination) between potable water and non-potable boiler water.

Overpressure Protection

Safety relief valves are required to protect against dangerous pressure buildup in the system.

Low Water Protection

Low water cut-off devices prevent the boiler from operating when water levels are insufficient, which could cause damage or unsafe conditions.

Backflow Prevention

Air Gap Device (AG)

Physical separation between potable water supply and non-potable water

Dual Check with Atmospheric Port (DCAP)

Prevents backflow with atmospheric venting capability

Double Check Valve Assembly (DCVA)

Two independent check valves in series

Reduced Pressure Principle (RP)

Provides maximum protection against backflow

A qualified individual must install, test, and maintain the backflow prevention device. This will typically be a Red Seal Plumber or Steamfitter/Pipefitter with additional backflow certification subject to approval by the authority having jurisdiction.

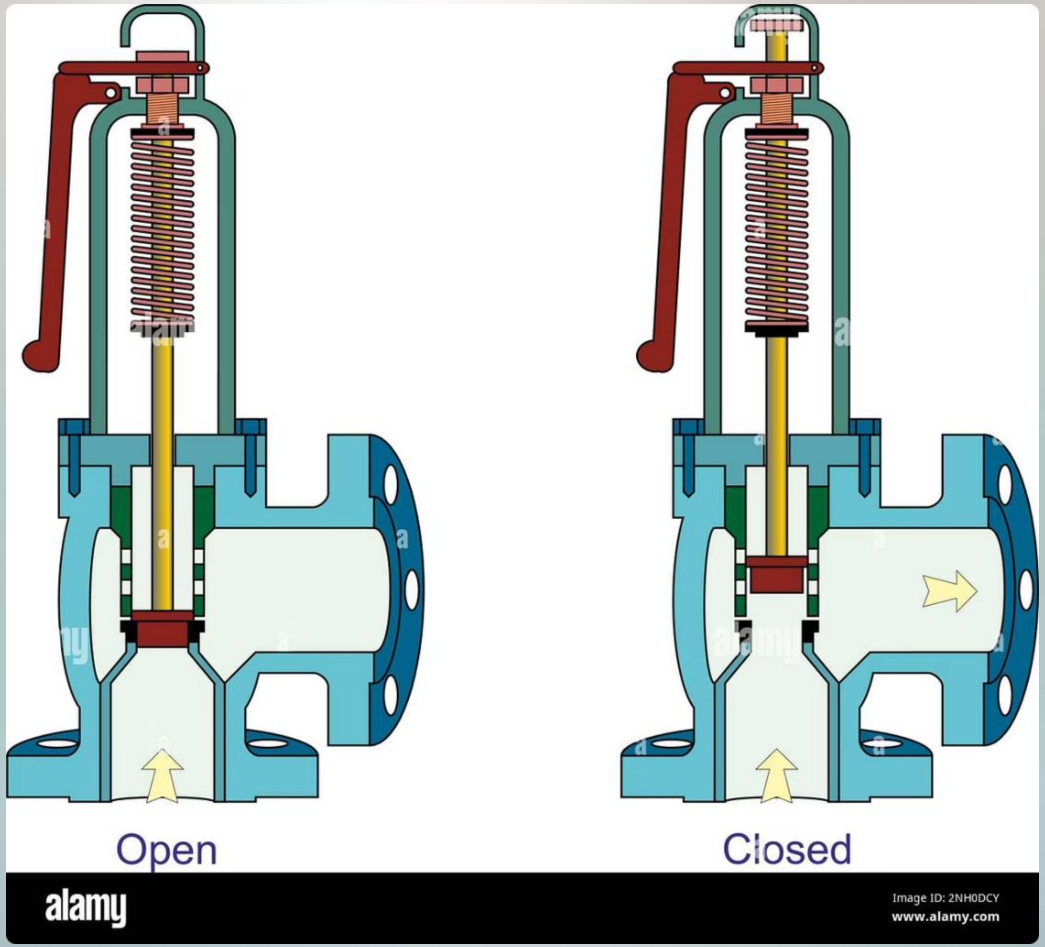
Overpressure Protection

Safety Relief Valve Requirements

- Comply with all applicable Code requirements, including temperature and pressure ratings
- Be certified as the proper type and capacity for the application
- Be equipped with a try-lever for testing

Installation Requirements

- Be installed in the proper location on the boiler as per manufacturer's instructions
- Be protected from the effects of lime or scale buildup
- Be piped according to local Code requirements



Low Water Safety Control

Purpose

A low water level in a boiler can result in damage to the boiler and/or an unsafe condition, especially if the boiler is fired when it is dry or nearly dry.

Code Requirements

It is a Code requirement that all steam boilers have at least one automatic low water cut-off (LWCO). In addition, hot water boilers with inputs over 400 MBtu/h (120 kW), or systems of any input with circulation piping entirely below the boiler, must come with a low-water fuel cut-off.

Operation

If the boiler's water drops below a pre-set safe level, the cut-off automatically acts to shut off the gas supply to the burner.

Boiler Types

Cast-Iron Sectional

Multiple cast-iron sections connected together

Steel Fire-Tube

Hot gases flow through tubes surrounded by water

Copper Fin-Tube

Copper tubes with fins for increased heat transfer

Steel Water-Tube

Water flows through tubes surrounded by hot gases

Evolution of Boiler Design

Traditional Boilers

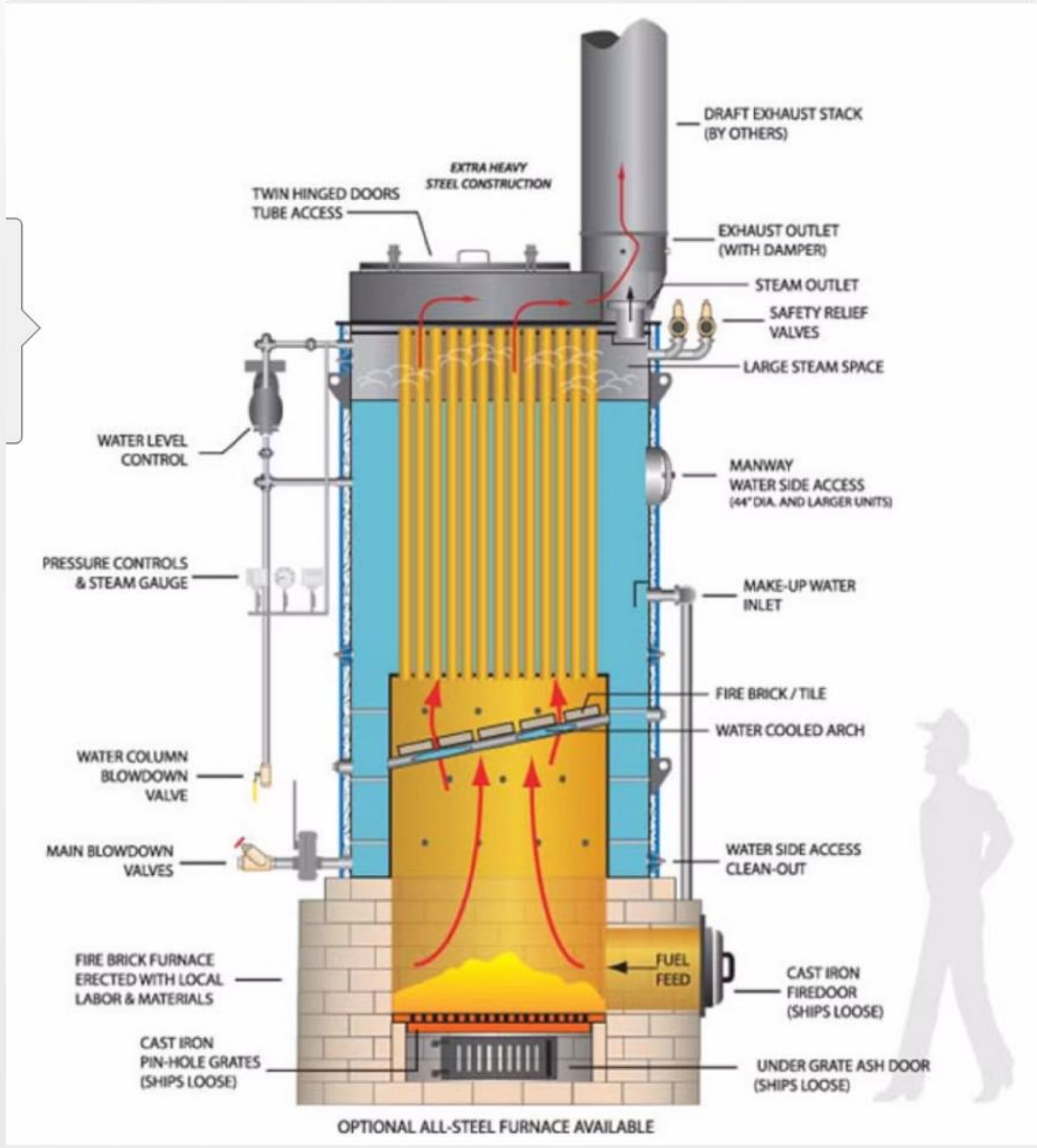
In the past, boilers and their associated components were obtained piece-by-piece and were assembled and tested at the job site. Originally, these were cast-iron sectional boilers that were often massive in size and very heavy once assembled.

Packaged Boilers

Since the post-war 1940s, most boilers for residential and small commercial use come completely assembled and tested from the factory. Packaged boilers can be made of cast iron, copper tube, steel tube, or stainless steel.

Modern Systems

Today's boilers feature advanced controls, high efficiency designs, and simplified installation requirements.



Packaged Boiler Connections

Water Make-up

Connection to the building's water supply system

External Electrical Controls

Thermostat and other control connections

Supply and Return Distribution Piping

Connections to the building's hydronic distribution system

Gas Supply

Connection to the building's gas supply

Venting System

Connection to remove combustion products

Air Supply

Connection to provide combustion air

Cast-Iron Sectional Boilers

Characteristics

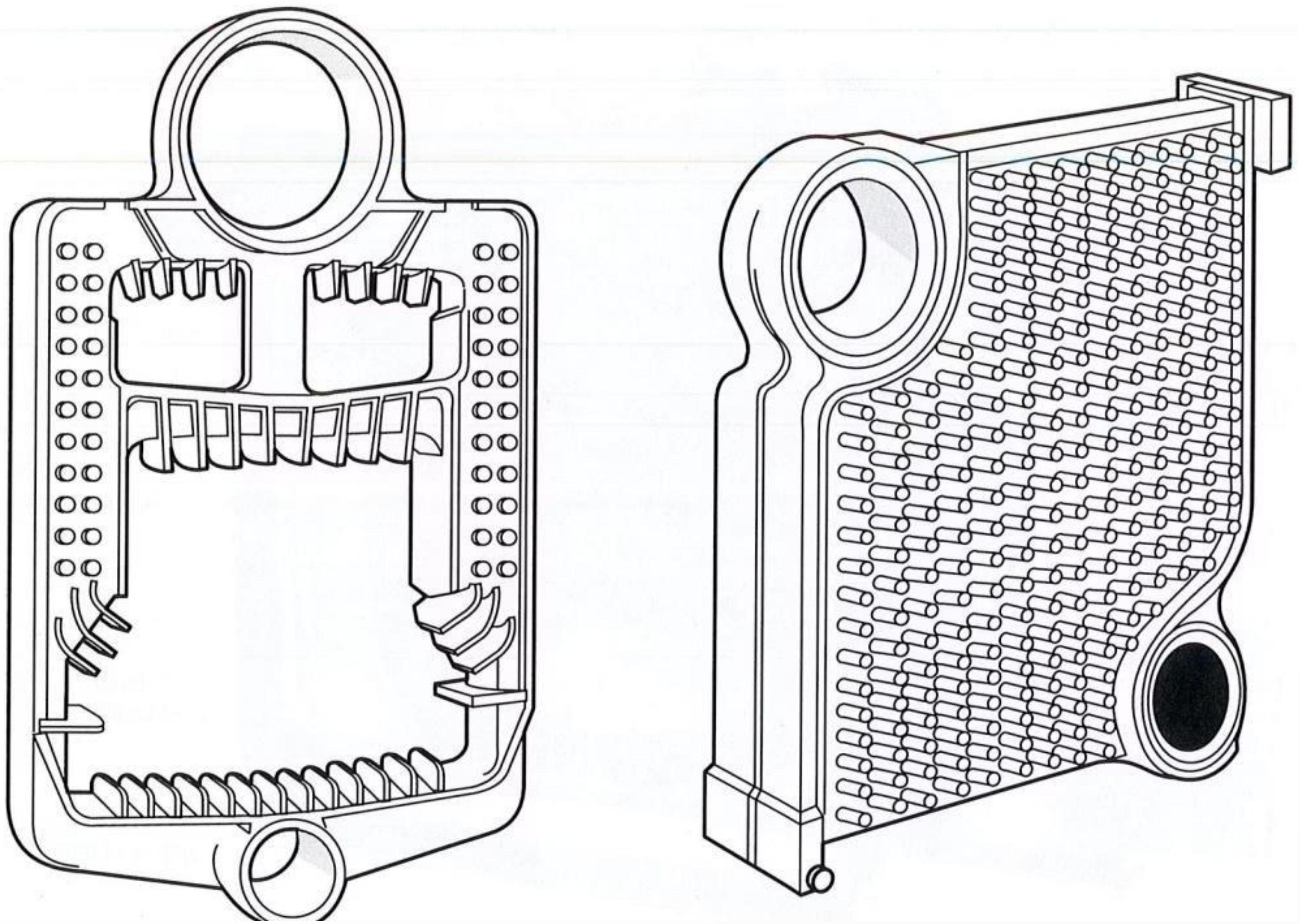
- Heats water in hollow cast-iron chambers (sections)
- Multiple sections are connected together with tapered push-nipples into a boiler block assembly
- Cavities between the sections allow the passage of hot combustion gases to heat the water
- The more sections there are, the greater the heat output of the boiler

Major Styles

Type	Description
Wet-base sectional boiler	Combustion chamber is formed by the bottom of the boiler sections
Dry-base sectional boiler	Combustion chamber is entirely below the boiler sections

Cast-Iron Sectional Boiler Sections

Figure 1-2
Wet-base and dry-base cast-iron boiler sections
Courtesy of Vaillant Corporation



Closed-Loop Systems

Cast-iron sectional boilers are only used in closed-loop hydronic

Thermal Mass

A cast-iron sectional boiler is relatively heavy due to the amount of

Best Applications

Cast-iron boilers are best for applications where the load is

Steel Fire-Tube Boilers

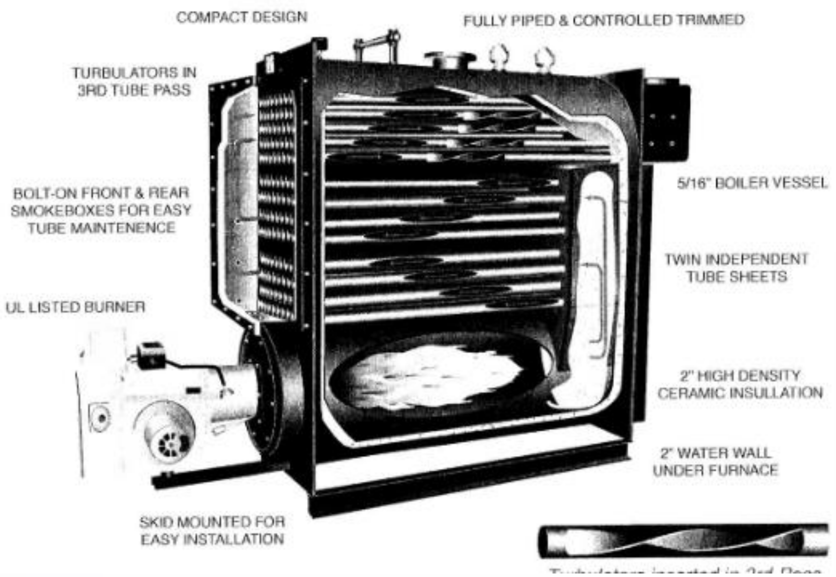
Construction

Steel fire-tube boilers consist of a group of steel tubes that pass through a chamber full of water. Hot flue gases from the combustion chamber flow through the steel fire tubes, which transfer their heat to the water surrounding them.

Applications

Steel fire-tube boilers are limited in use to closed-loop hydronic heating systems for the same reasons as cast-iron sectional boilers - to prevent corrosion from exposure to air.

Figure 1-3
Steel fire-tube boiler
Courtesy of Hurst Boiler & Welding Co., Inc. © 2019



Steel Water-Tube Boilers

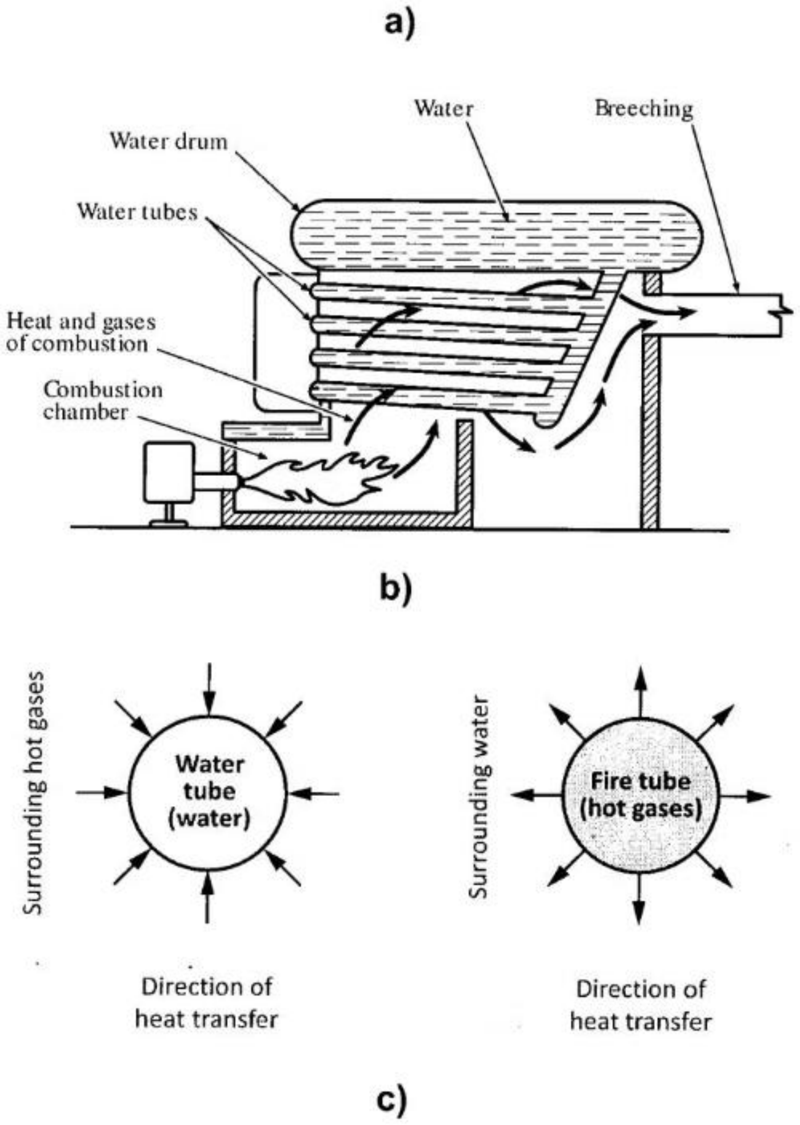
Construction

A conventional high-pressure water-tube boiler consists of one or more header drums connected by multiple tubes. Steel water-tube boilers can produce either hot water or steam.

Applications

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.

Figure 1-4
Water-tube boilers



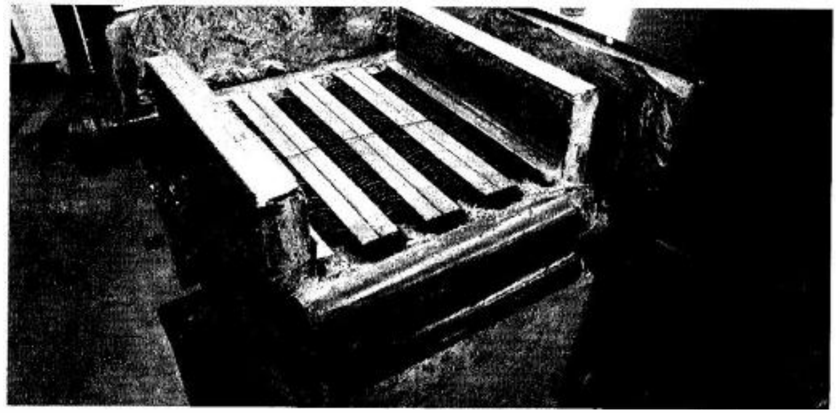
Fire-Tube vs. Water-Tube Boilers

Key Difference

The major difference between a fire-tube boiler and a water-tube boiler is the direction of heat transfer. The two designs are complete opposites in terms of the location of the water relative to the hot flue gasses.

Heat Transfer Efficiency

Water-tube boilers tend to have a higher overall heat transfer coefficient when compared to a fire-tube boiler of the same size and material.



Copper Fin-Tube Boilers

Design Features

Copper water-tube boilers typically have fins attached to them to greatly increase their surface area, which boosts heat transfer. The higher thermal conductivity of copper tubing compared to cast-iron or steel requires significantly less surface area to produce an equal rate of heat transfer.

Applications

These boilers can also be useful for direct heating of domestic water and for swimming pools because of their high corrosion resistance.

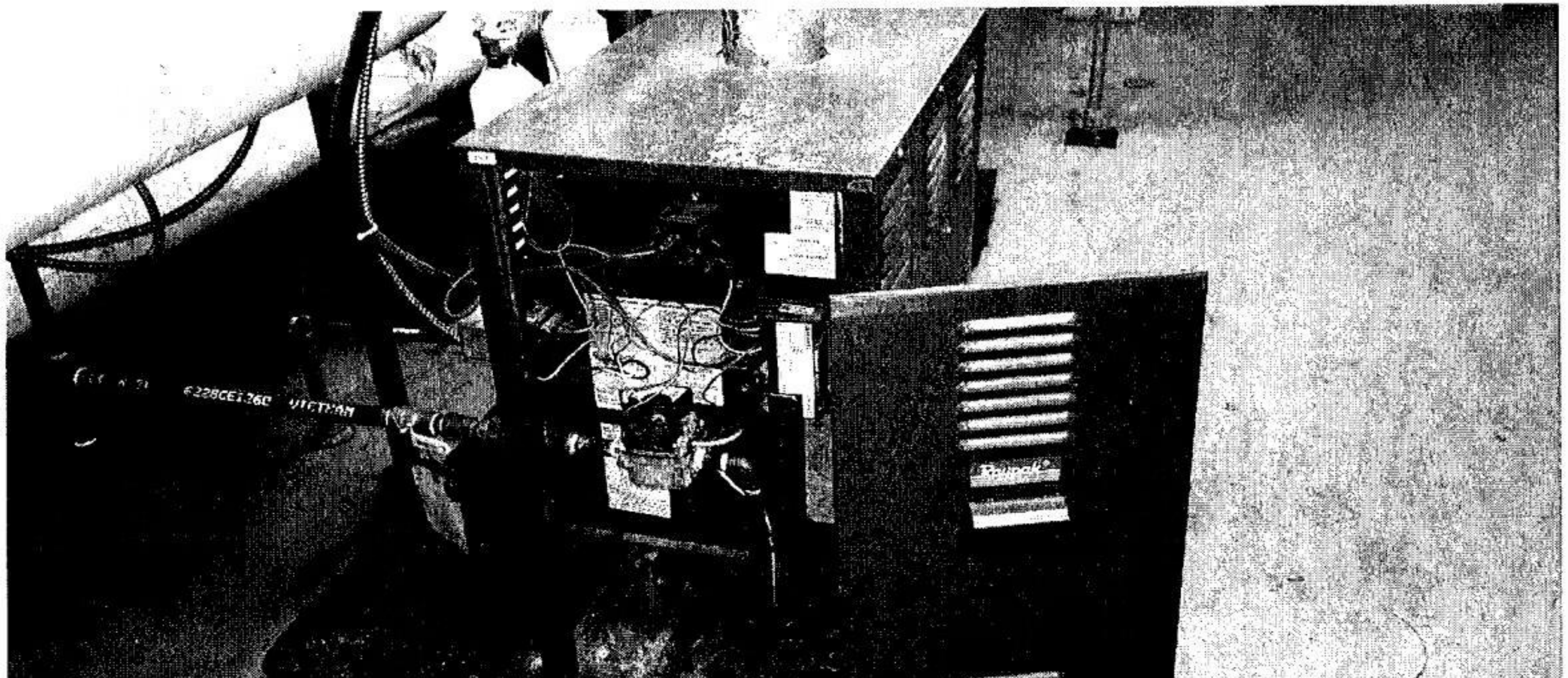
Operation Requirements

To prevent thermal stress damage, this type of boiler requires constant water circulation during firing. A flow switch or flow sensor helps prove flow prior to burner fire up.

Maintenance

Their low thermal mass and light construction allows fast warm-up on demand for heat. Tight construction and narrow flue passes improve efficiency but make annual maintenance critical.

Figure 1-5
Copper fin-tube boiler
Courtesy of Camosun College



Condensing vs. Non-Condensing Boilers

Non-Condensing Boilers

In a non-condensing boiler, the water vapour produced from combustion does not condense within the boiler or the flue passages. While this venting of water vapour prevents corrosion of boiler components exposed to the flue gases, the residual latent "hidden" heat in the water vapour is lost to atmosphere.

Condensing Boilers

A condensing boiler employs a secondary heat exchanger to condense the flue gas water vapour. This allows for more heat to be removed from the water and thereby achieves an increase in efficiency, but the boiler construction must be able to resist the corrosion caused by the acidic condensate.

Non-Condensing Boilers

Temperature Requirements

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).

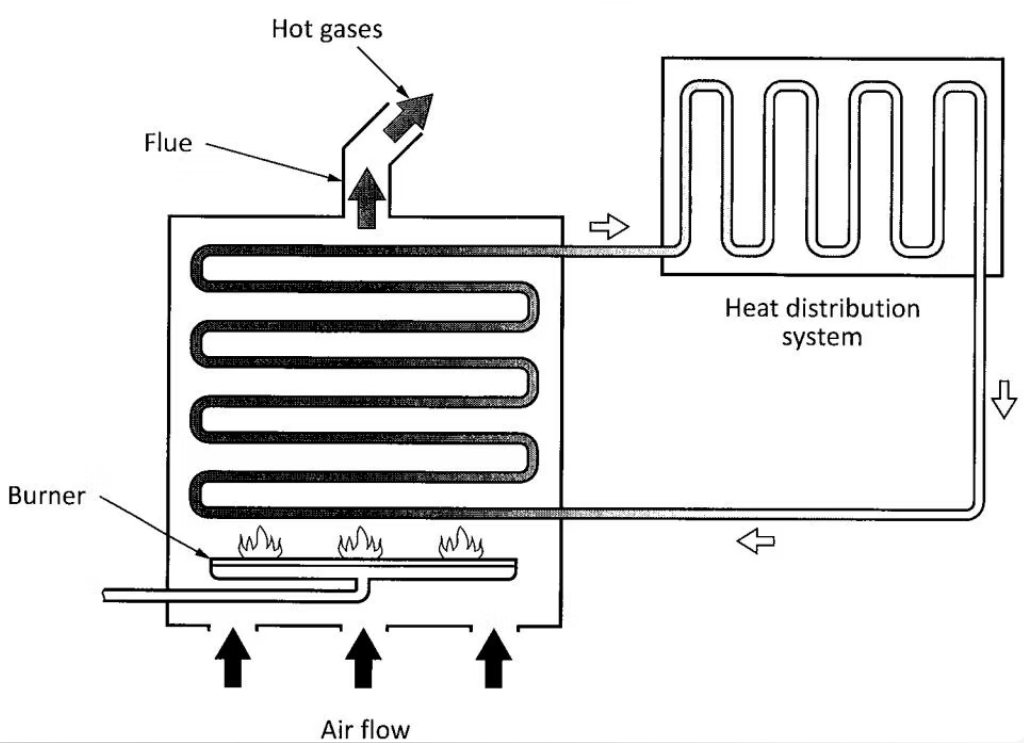
Condensation Issues

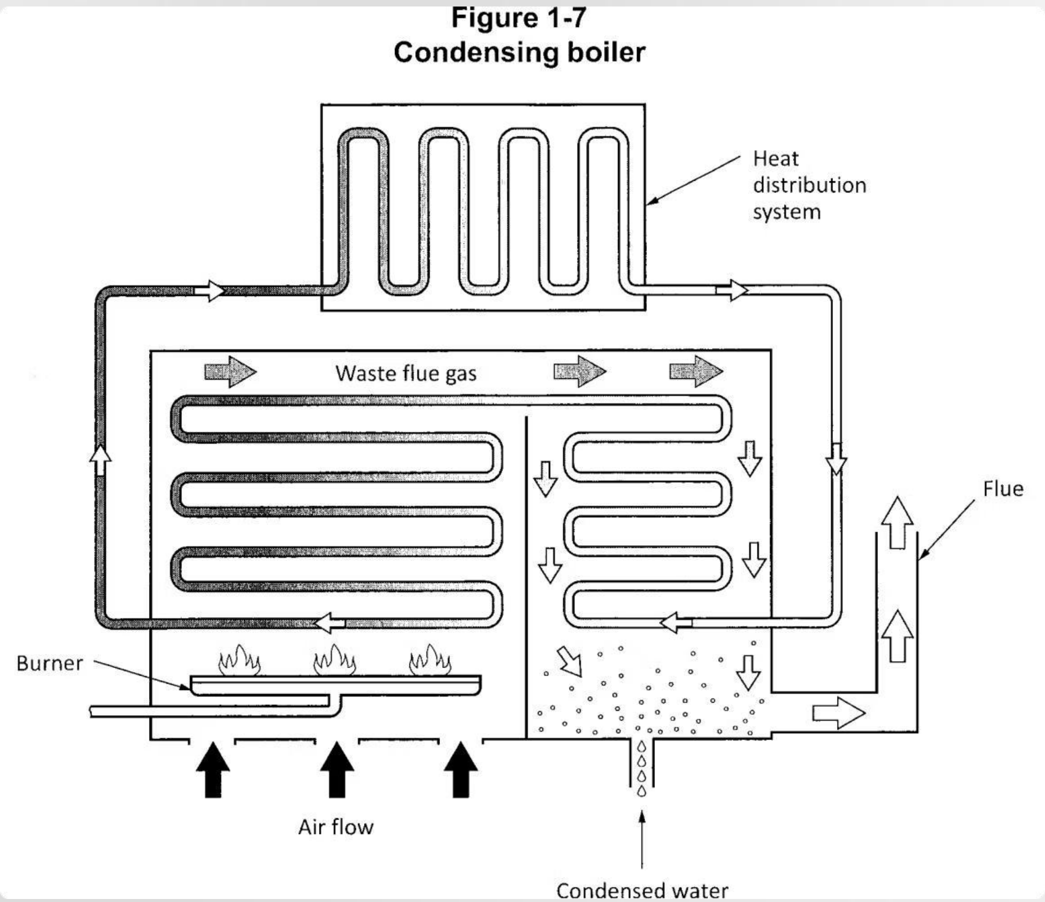
Fluid returned to a boiler below this temperature will cause the vapourized water in the flue gases to condense. Because non-condensing boilers are not equipped to withstand this condensate, which is slightly acidic, the heat exchanger and other parts of the boiler will start to deteriorate.

Energy Loss

In a non-condensing gas-fired boiler, the heat loss is typically 10% of the original energy content of the natural gas or propane.

Figure 1-6
Non-condensing boiler





Condensing Boilers

Heat Recovery

Extracting significant amounts of latent "hidden" heat from flue gases and transferring them to the water being heated

Improved Efficiency

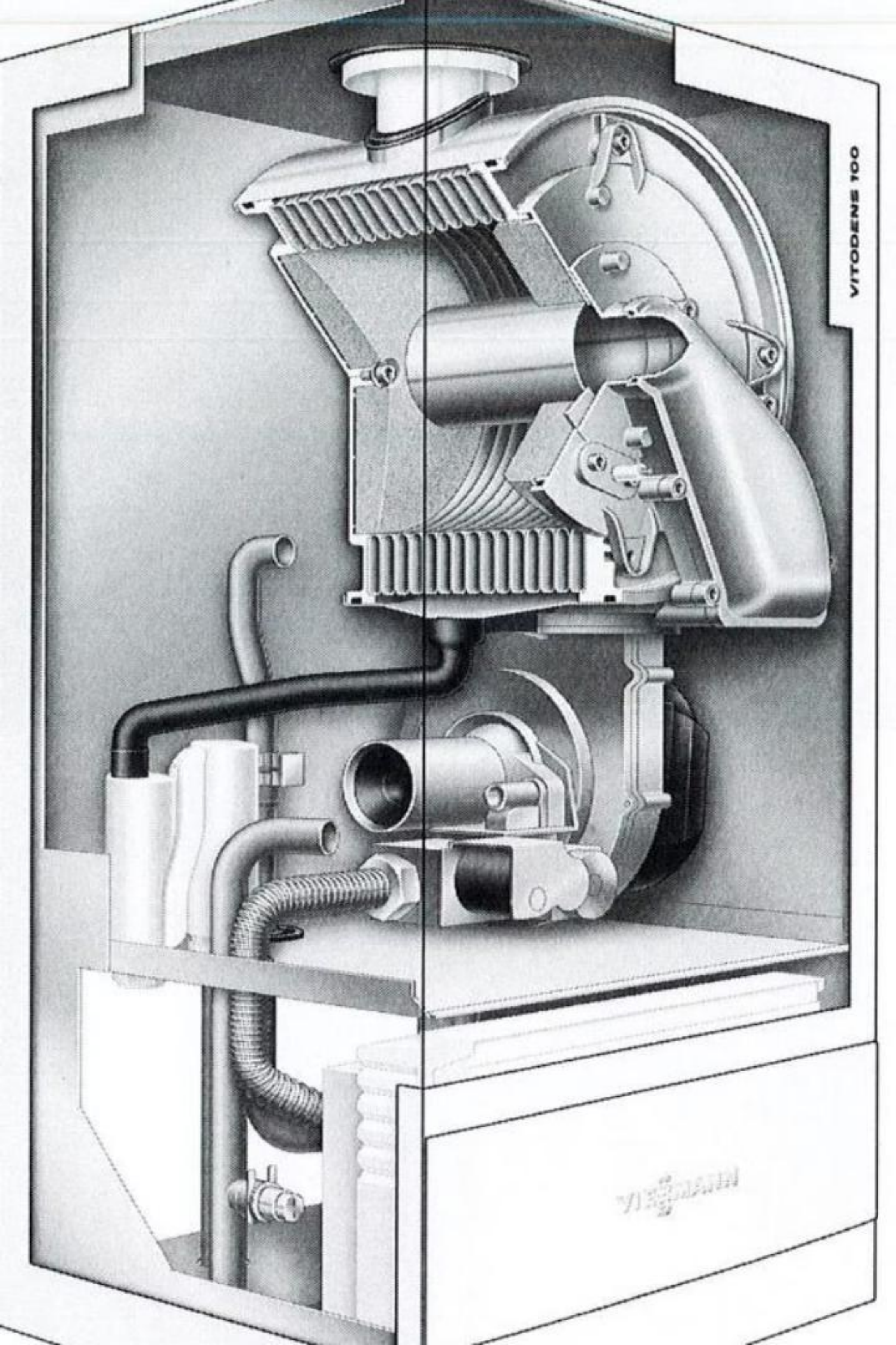
Modern conventional boilers now exceed 80% efficiency, and condensing boilers can exceed 90% efficiency

Forced Venting

Because the flue gases have now lost most of their heat and natural buoyancy, they must be forced out with a fan or blower

Corrosion-Resistant Materials

Typically constructed of corrosion-resistant material such as stainless steel and titanium alloys



Modulating/Condensing (Mod/Con) Boilers

Variable Output

Nearly all condensing boilers can vary their output from their maximum rate down to approximately 20% of that maximum output.

Turndown Ratio

The ability of a mod/con boiler to modulate is expressed by what is called its "turndown ratio." This is the ratio of the lowest possible percentage of full heat output rate the boiler can maintain.

Example

If a boiler can maintain stable operation down to 20% of its maximum heat output rate, it would have a turndown ratio of 5:1.

Condensing Boiler Designs

Wall-Mounted Design

Space-saving design that can be mounted directly to a wall, ideal for residential and light commercial applications.

Floor-Mounted Design

Larger capacity units designed for commercial applications with higher heating demands.

Input Range

Condensing boilers are available with inputs that range from as small as 50,000 Btu/h (14.65 kW) to well over 1,000,000 Btu/h (293 kW).

Courtesy of Camosun College

Pulse Combustion Boilers

Unique Technology

One unique style of condensing boiler is the pulse combustion boiler. Pulse-combustion technology is recognized as one of the most efficient ways to burn fuel.

Pulse Definition

A "pulse" is defined as one cycle of ignition and combustion of a gas/air mixture in a specially designed chamber.

Energy Efficiency

An assisting fan is used for pre- and post-purge only and turns off once combustion is established. Pulse boilers require electricity only for purge cycles, powering fuel valves, control, and other safety features. The pulse-combustion process itself does not require electricity.

Boiler Temperature and Pressure Ranges

Type	Temperature Range	Pressures
Low-pressure boilers	Operate at temperatures not exceeding 250°F (121 °C)	Operate at pressures not exceeding 160 psig (207 kPa)
High-pressure boilers	Operate at temperatures exceeding 250°F (121 °C)	Operate at pressures exceeding 160 psig (1103.2 kPa)

The American Society of Mechanical Engineers (ASME) classify hot water heating boilers according to their operating temperature range or the pressure required to maintain the water they contain in its liquid state.

Hydronic System Boiler Operating Parameters

250°F

Maximum Temperature

Commercial and industrial hydronic space heating systems usually operate at temperatures under 250°F (121 °C)

160 psig

Maximum Pressure

Commercial and industrial systems typically operate at pressures of 160 psig (1103.2 kPa) or less

180°F

Residential Temperature

Residential hot water boilers traditionally operate at temperatures of approximately 180°F (82 °C)

30 psig

Residential Pressure

Residential systems typically operate at pressures of 30 psig (210 kPa) or less

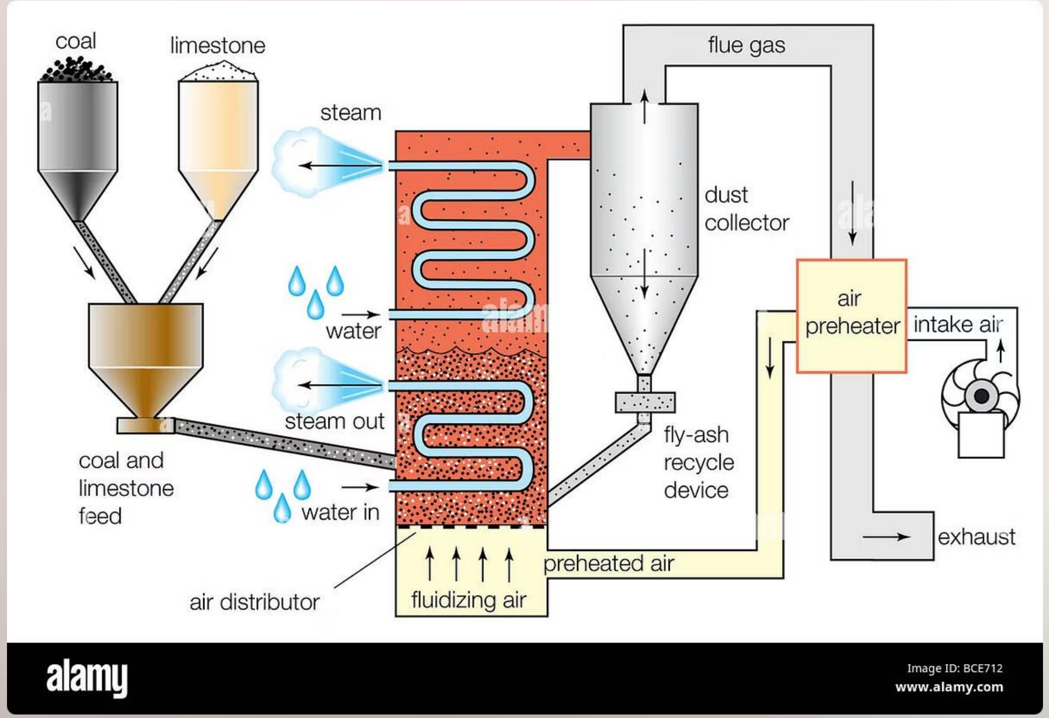
Modern Low-Temperature Systems

Radiant Floor Systems

Many newer residential systems (e.g., radiant floor systems) are designed for lower supply water temperatures (approximately 120°F/49 °C).

Design Considerations

Supply water temperature is a major factor influencing the design and installation of a hydronic heating system.



Boiler Components Overview

Burner Assembly

Supplies the proper mixture of air and gas for combustion

Combustion Chamber

Where the fuel is burned to generate heat

Flue Gas Passages

Carry the heat from combustion to the water-filled portion of the boiler

Draft Control Device

Controls the flow of combustion gases (if supplied)

Burner Assembly

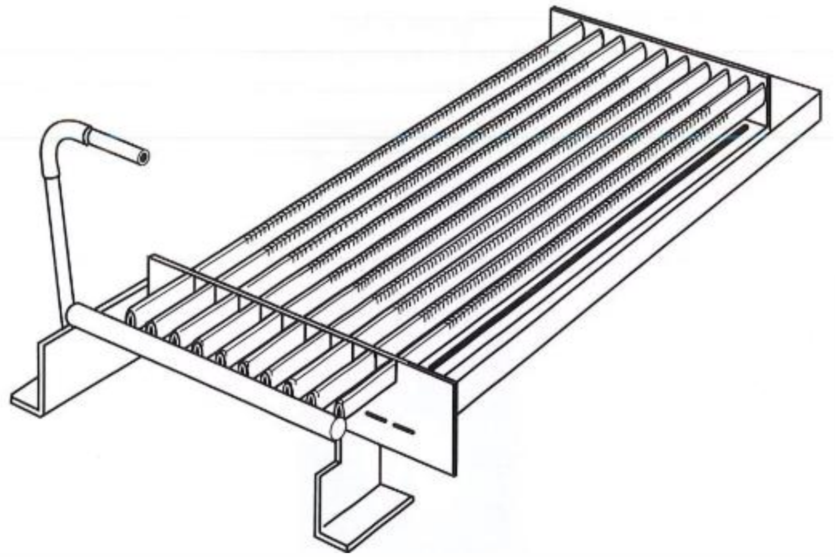
Purpose

In gas-fired boilers, the burners supply the proper mixture of air and gas in order to achieve complete combustion.

Atmospheric Multi-Port Burner

A typical atmospheric multi-port burner assembly consists of drilled or slotted tubes mounted side-by-side in an array. A gas orifice meters fuel to each burner, which mixes the fuel with a supply of primary combustion air.

Figure 1-11
Atmospheric burner assembly



Modulating Radiant Burners

Increased Efficiency

Many mod/con boilers utilize a fully modulating, radiant style burner. These mechanical burners increase the combustion efficiency by providing the optimal ratio of air and fuel.

Variable Speed Blower

A variable speed blower controls the airflow rate entering the sealed combustion chamber.

Proportional Fuel Metering

Fuel gas is metered into the air stream in proportion to the airflow rate.

Burner Head

The slightly pressurized mixture of air and fuel is forced into the burner head (stainless steel or ceramic) and ignited.

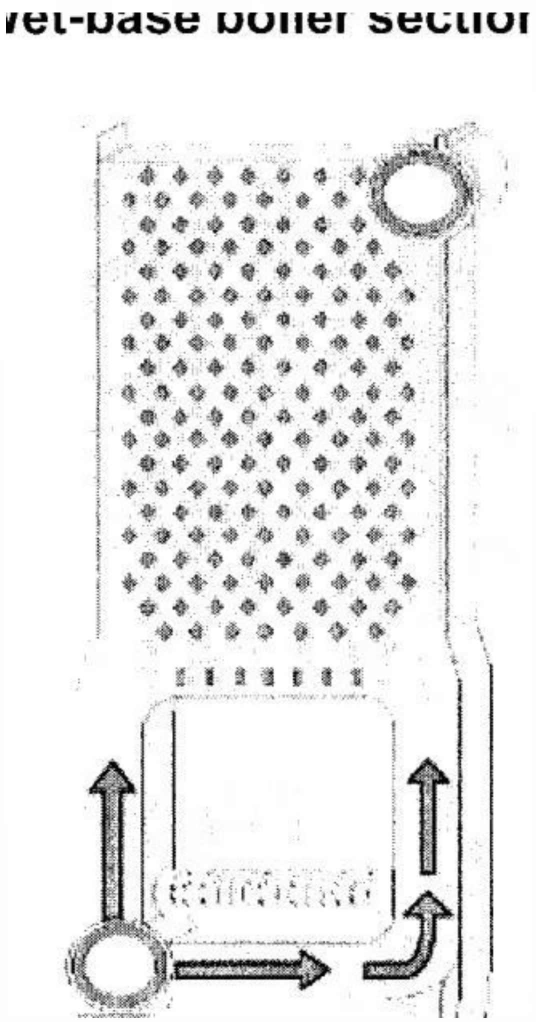
Combustion Chamber

Definition

The combustion chamber is that part of the boiler where the fuel is burned. Temperatures inside the combustion chamber can reach several hundred degrees very quickly.

Types

The combustion chamber may be enclosed by part of the water-filled portion of the boiler ("wet-base"), or separate from it, as in a "dry-base" boiler.



Fire Brick and Refractory

Materials

Fire brick and refractory are cement-like, heat-resistant materials.

Purpose

They are used to protect the metal enclosing the combustion chamber and retain heat in the chamber.

Application

They form the "dry" sections of combustion chambers.

Flue Gas Passages

Function

The flue gas passages form the heat exchanger. They carry the heat from the combustion process to the water-filled portion of the boiler.

Design Variations

Some boilers have vertical flue passages while others have horizontal flue passages. Generally speaking, the greater the number of flue passes, the greater the heat transfer to the boiler water.

Turbulators

Some boiler flue passes may include spiral-shaped baffles or "turbulators" that act to increase heat transfer by inducing turbulence and slowing the passage of the exhaust gasses.

Vertical Flue Passages

Operation

In a boiler with vertical passages, the hot flue gas rises from the combustion chamber, transferring heat to the water-filled tubes or boiler sections as it passes around them once before exiting out the flue.

Applications

This is a common style for atmospheric or natural draft-style boilers where flue passes allow the buoyancy venting of the hot products of combustion.

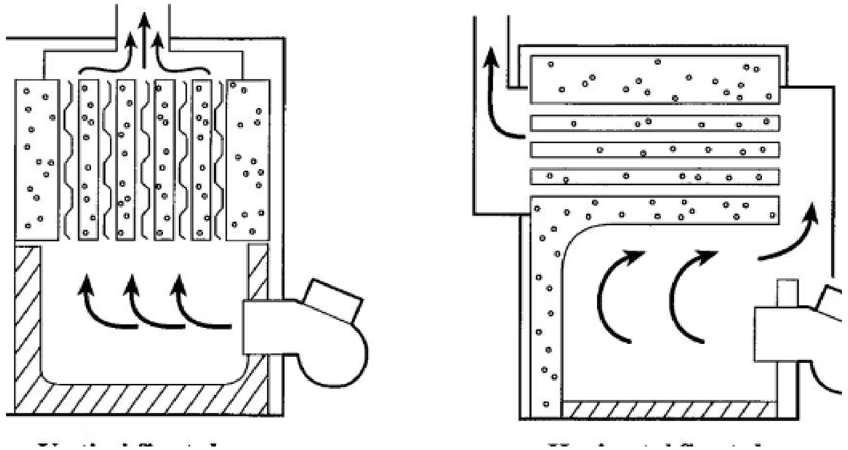
Horizontal Flue Passages

Operation

In a boiler with horizontal passages, the hot flue gas is directed through horizontal openings between the water-filled sections or the boiler. This increases the travel time for the flue gases, allowing more efficient heat transfer.

Multiple Passes

In some boilers, the flue gas must make several passes in each direction before exiting out the flue.



Draft Control Devices

Purpose

Achieving combustion efficiency requires the control of the amount and force of the draft. Boilers use various methods to control the rate of draft.

Too Strong a Draft

Will draw in too much combustion air and the time for heat transfer will be reduced.

A Weak Draft

Will smother the flame and reduce combustion efficiency.

Types

Draft hoods (draft diverters) and barometric dampers are common draft control devices.

Draft Hood (Draft Diverter)

Purpose

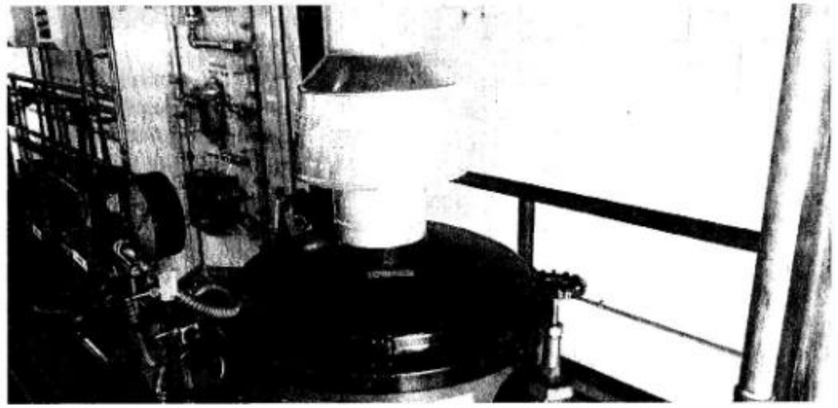
Some domestic gas boilers are of the atmospheric type and require a neutral over-fire draft in the combustion chamber. The draft hood (draft diverter) maintains this neutral pressure over the fire.

Operation

By allowing dilution air into the venting system, the draft hood lowers the temperature of the flue gases, which also prevents the hot gases from inducing a negative pressure.

When there is no draft, a backdraft, or a blockage beyond the flue gases exit the draft-hood, instead of entering the appliance. This is called spillage.

Figure 1-15
Boiler draft hood
Courtesy of Camosun College



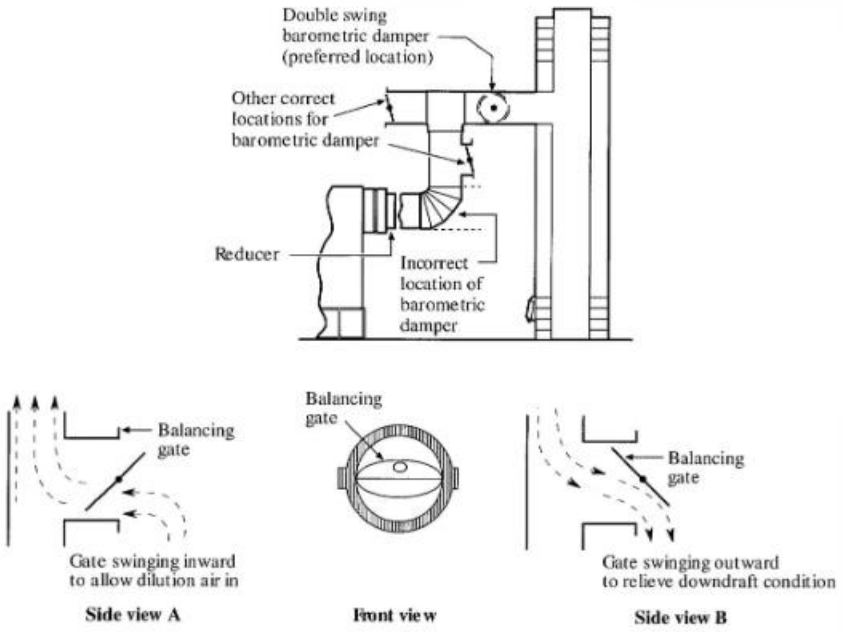
Barometric Dampers

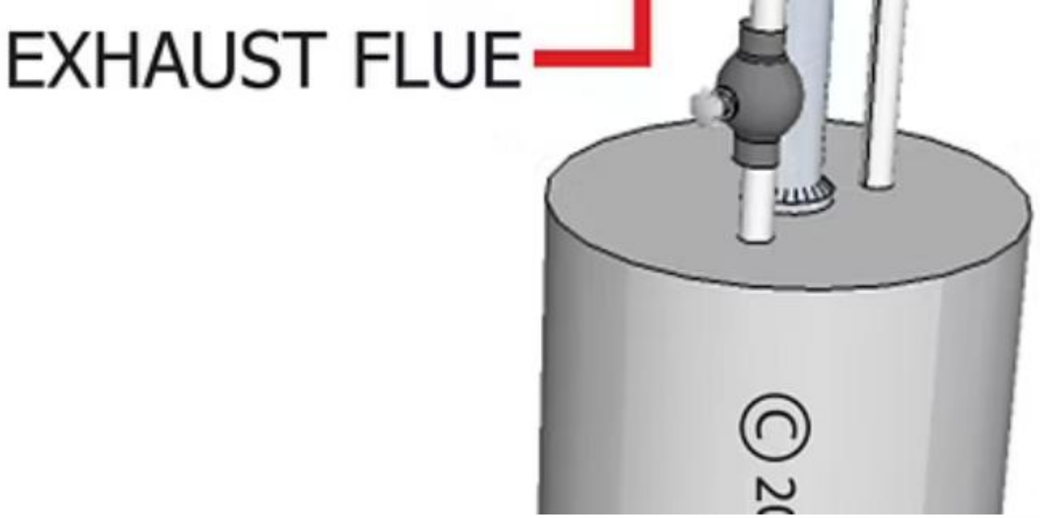
Purpose

Barometric dampers (also referred to as draft regulators) are used on appliances that operate with a controlled negative over-fire draff in the combustion chamber. This type of draft control is used when the venting system provides a negative draw on the combustion chamber to remove flue gases.

Double-Acting Design

A double-acting barometric damper can open both inward and outward. It opens inward to regulate the dilution air and opens outward to relieve down-draft and spillage.





Barometric Damper Operation

Dilution Air

When the vent draw increases, the atmospheric pressure on the outside of the damper pushes against the gate, allowing extra dilution air in to reduce the draft draw.

Down-Draft

If the pressure increases inside the venting system, the gate swings out to relieve a down-draft.

Spillage

In the event of a blockage in the venting system, the gate swings out to allow spillage.

Vent and Flue Dampers

Purpose

Dampers control the flow of flue gases. They may be useful for preventing the escape of heat through the venting system.

Common Types

- Automatic vent dampers
- Thermally actuated vent dampers
- Flue dampers

Automatic Vent Dampers

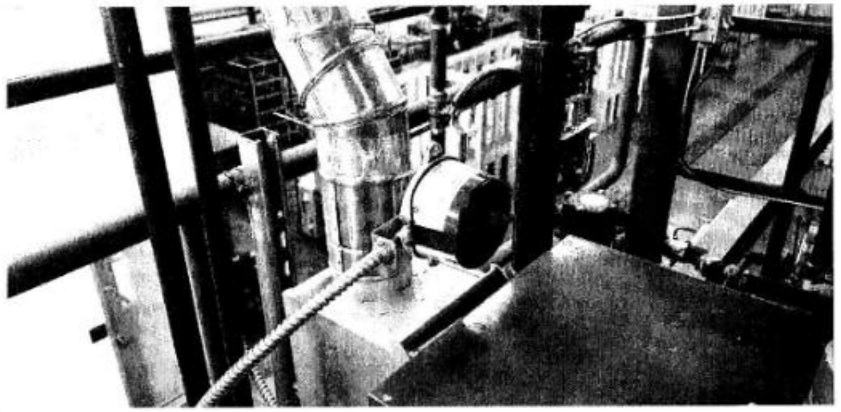
Purpose

Electrically activated automatic vent dampers prevent heat from escaping through the boiler's venting system when the boiler is not being fired.

Components

- A tubular casing
- A damper blade
- An electric motor-driven actuator

Figure 1-17
Electrically activated vent damper
Courtesy of Camosun College



Automatic Vent Damper Operation

Normal Position

The damper blade is normally in the closed position, blocking the vent.

Call for Heat

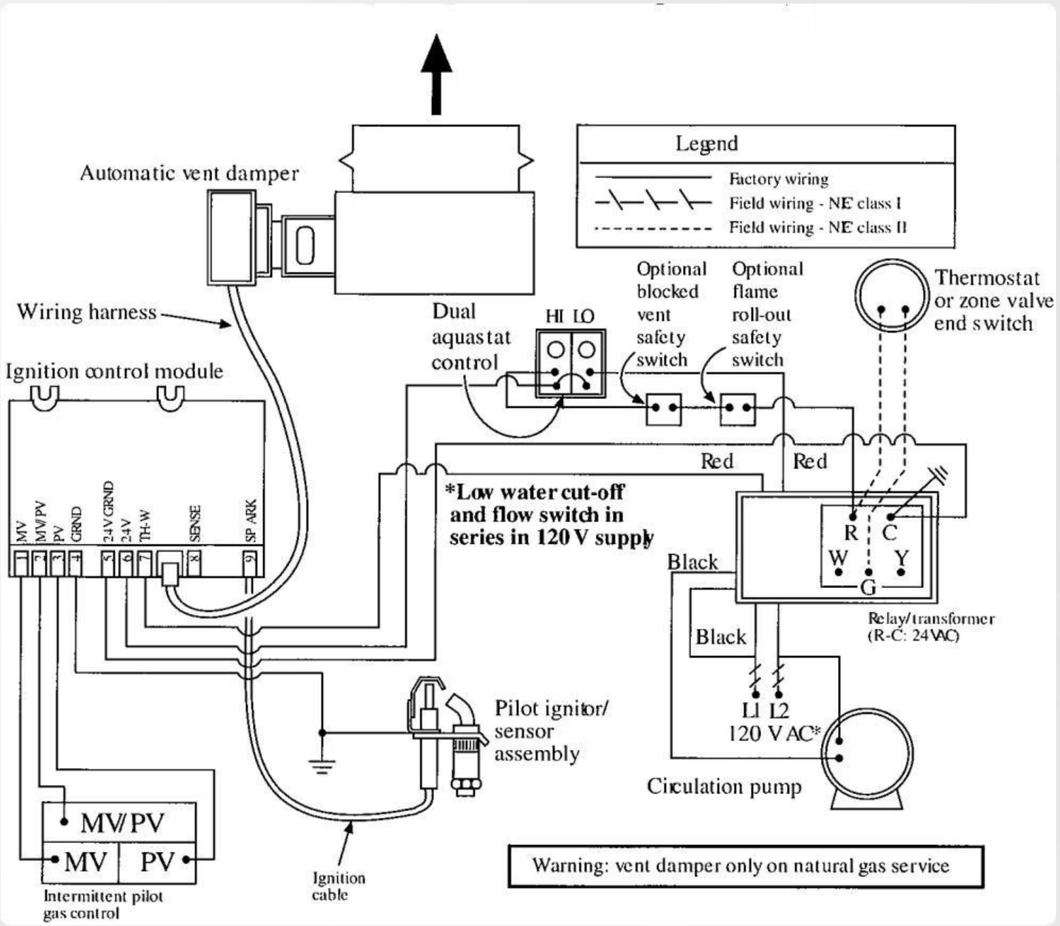
The vent damper actuator has a proving switch interlocked with the thermostat controlling the boiler burner. When there is a call for heat, the vent damper will open automatically to ensure the passage of flue gases.

Safety Feature

The burner will not operate until the vent is fully open. The vent will remain open until the burner shuts down.

Installation Location

Automatic vent dampers are located downstream of the draft hood relief openings.

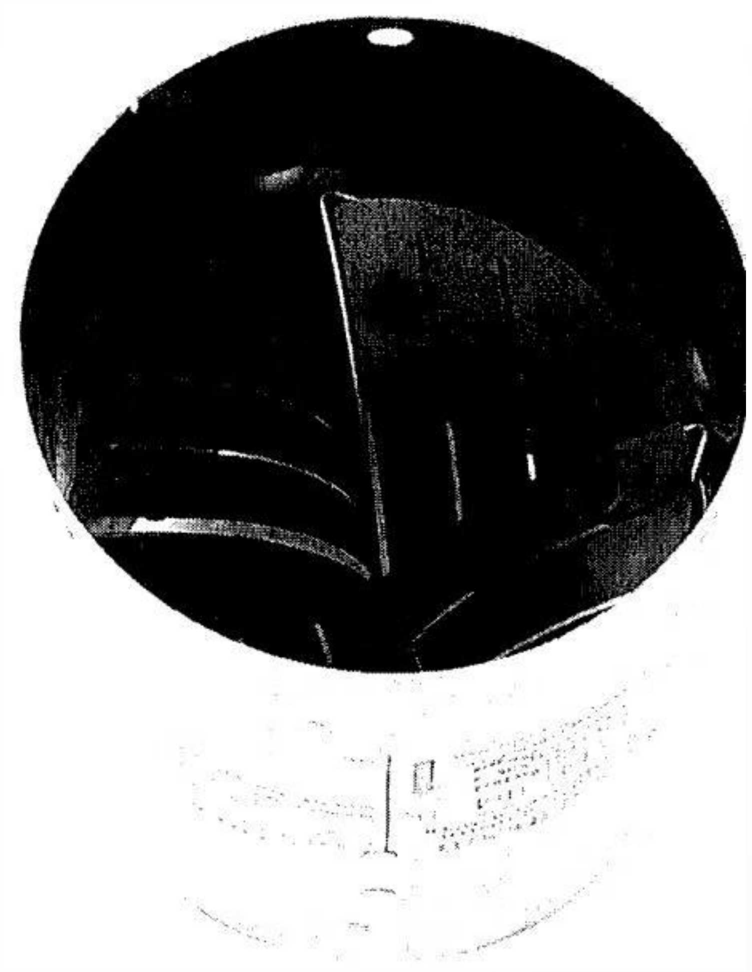


Thermally Actuated Vent Dampers

Operation

Thermally actuated vent dampers operate in response to the temperature of the flue gases.

When the flue gas temperature rises, the damper blades (bimetal leafs) open to allow passage of the flue gases out the venting system.



Cooling Response

After the burner has shut down and the temperature of the flue decreases, the damper blades close. The blades come with small slots that allow a minimum airflow through the vent to permit safe start-up.

Installation Location

Thermally actuated vent dampers are located downstream of the draft hood relief openings.

Flue Dampers

Definition

A flue damper is a movable plate designed to regulate the amount of flow or draft that can pass through the boiler's flue.

Types

Flue dampers can either be manually adjusted or automatically opened and closed.

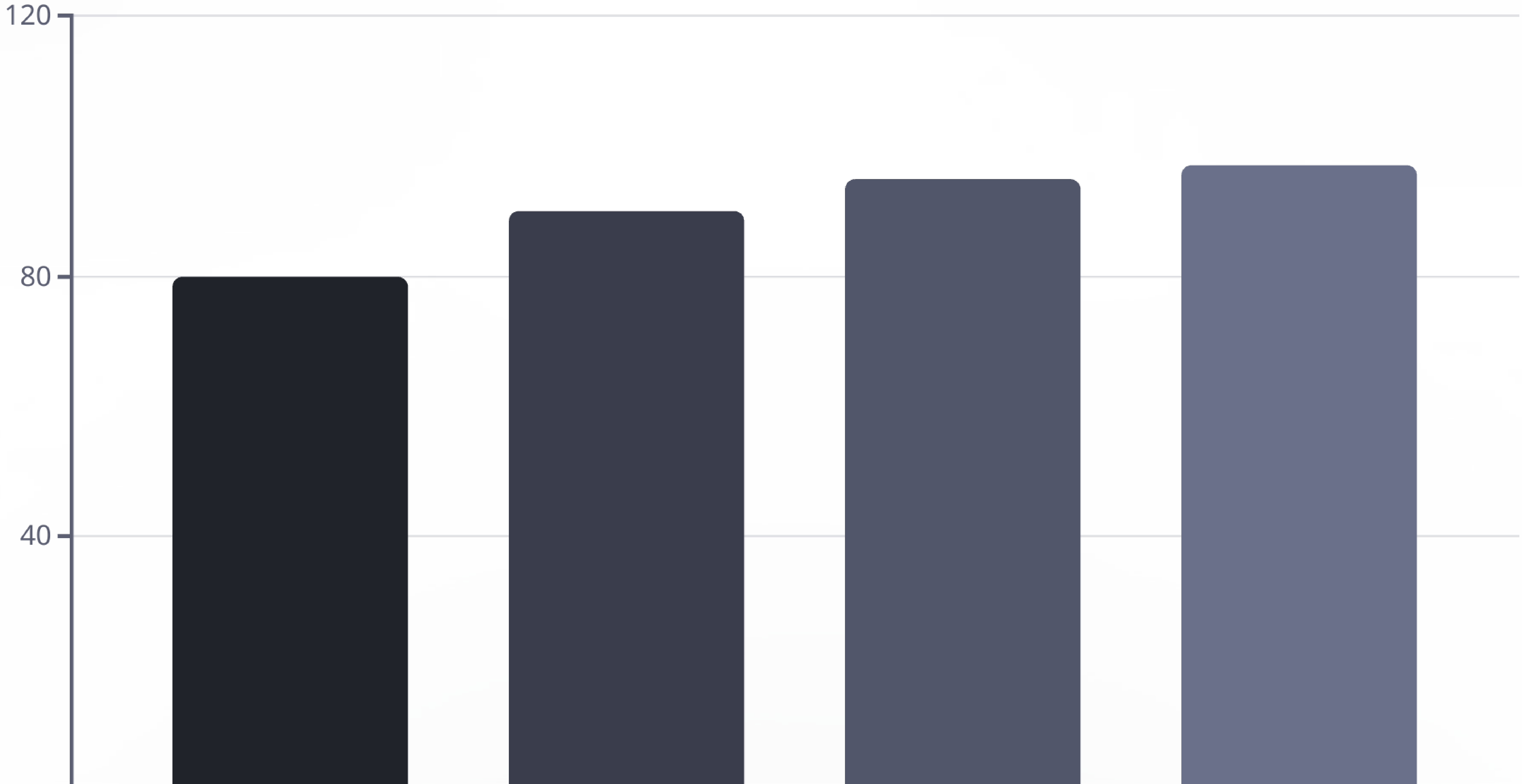
Safety Requirements

Automatic flue dampers must either be interlocked to automatically close off the supply of gas to the appliance or be provided with a means to ensure that the damper will fail fully open in the event of motor failure.

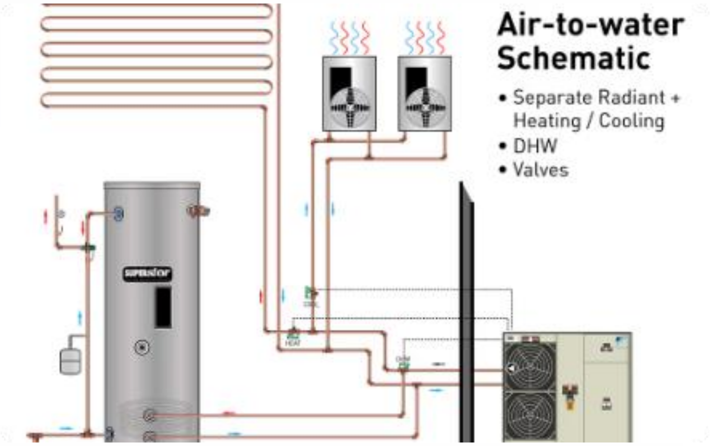
Installation Location

Flue dampers are located upstream of any draft hood relief openings.

Hydronic Heating System Efficiency



Hydronic System Applications



Residential

Hydronic systems provide comfortable, efficient heating for homes of all sizes. They can be designed with multiple zones for individualized comfort control.

Commercial

Office buildings, schools, and other commercial spaces benefit from the flexibility and efficiency of hydronic heating systems, especially in colder climates.

Industrial

Large industrial facilities can utilize high-capacity hydronic systems for space heating, process heating, and other applications requiring reliable heat transfer.

Heat Emitter Options






Hydronic systems offer a variety of heat emitter options to suit different applications and aesthetic preferences. These include traditional baseboard convectors, modern wall-mounted radiators, invisible radiant floor systems, decorative towel warmers, fan coil units, and designer radiators with custom covers.

Boiler Maintenance Requirements

Regular Inspection

Visually inspect the boiler, venting system, and associated components for signs of wear, corrosion, or damage. Check for proper operation of all safety devices.

Annual Service

Have a qualified technician perform a comprehensive service including combustion analysis, cleaning of heat exchanger surfaces, and verification of all control functions.

Water Treatment

Maintain proper water chemistry to prevent scale buildup and corrosion. This may include water testing, filtration, and chemical treatment as needed.

Component Replacement

Replace worn or damaged components promptly to maintain efficiency and prevent system failures. This includes gaskets, seals, and control devices.

Future Trends in Hydronic Heating

Higher Efficiency

Continued improvements in boiler design and materials to achieve even greater energy efficiency and reduced emissions.

Smart Controls

Integration with home automation systems, remote monitoring, and predictive maintenance capabilities.

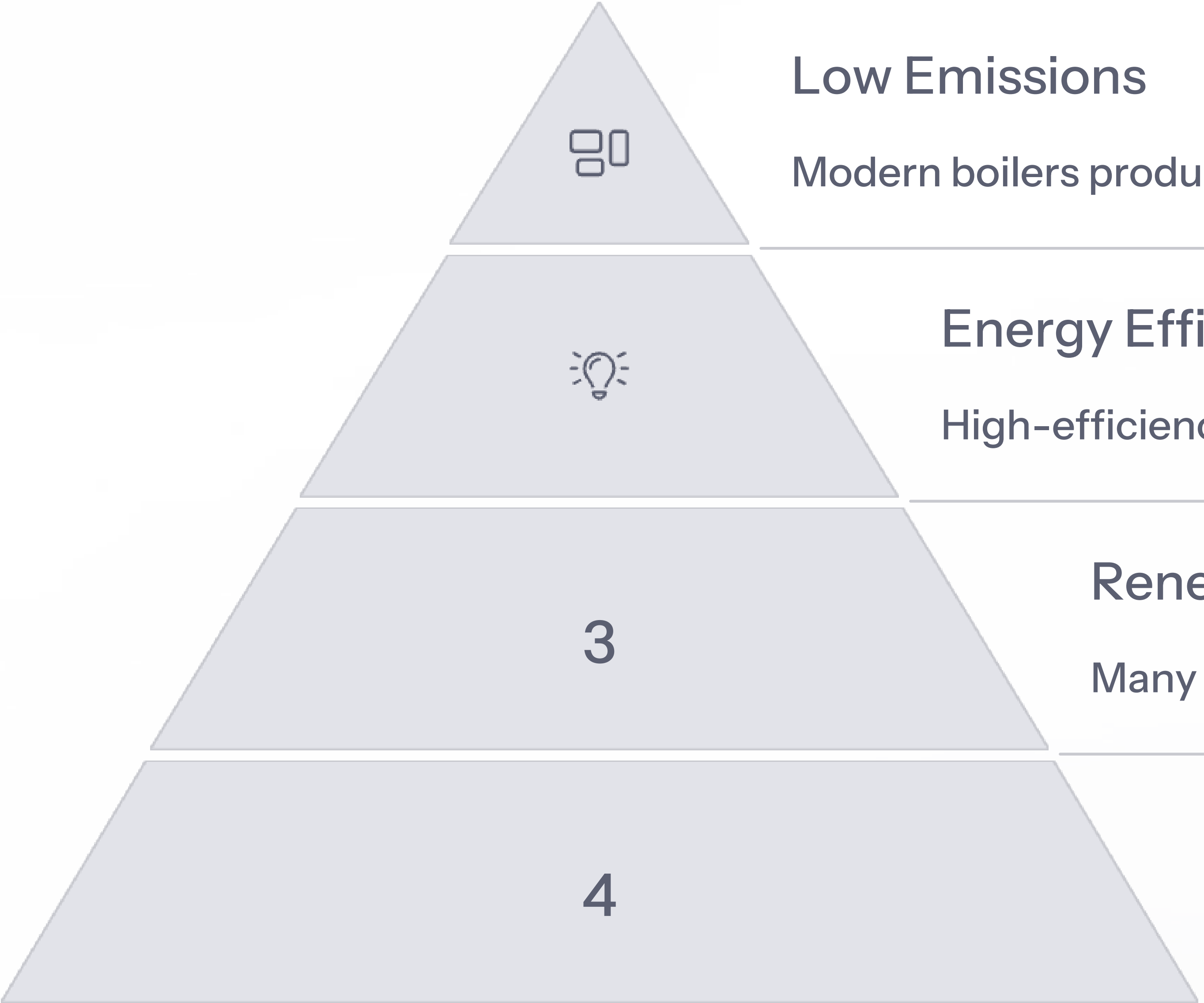
Renewable Integration

Hybrid systems that combine traditional boilers with renewable energy sources like solar thermal and heat pumps.

Compact Design

Smaller, more powerful units that require less installation space while delivering the same or better performance.

Environmental Considerations



Low Emissions

Modern boilers produce significantly fewer emissions than older models

Energy Efficiency

High-efficiency designs reduce overall energy consumption

Renewable Compatibility

Many systems can work with renewable energy sources

Lifecycle Benefits

Durable components and long service life reduce waste

Summary: Boilers in Hydronic Heating Systems

1

Understanding Hydronic Systems

Hydronic heating uses water to transfer thermal energy efficiently

Boiler Selection

Choose the right boiler type based on application needs

Component Knowledge

Understand how burners, heat exchangers, and controls work together

4

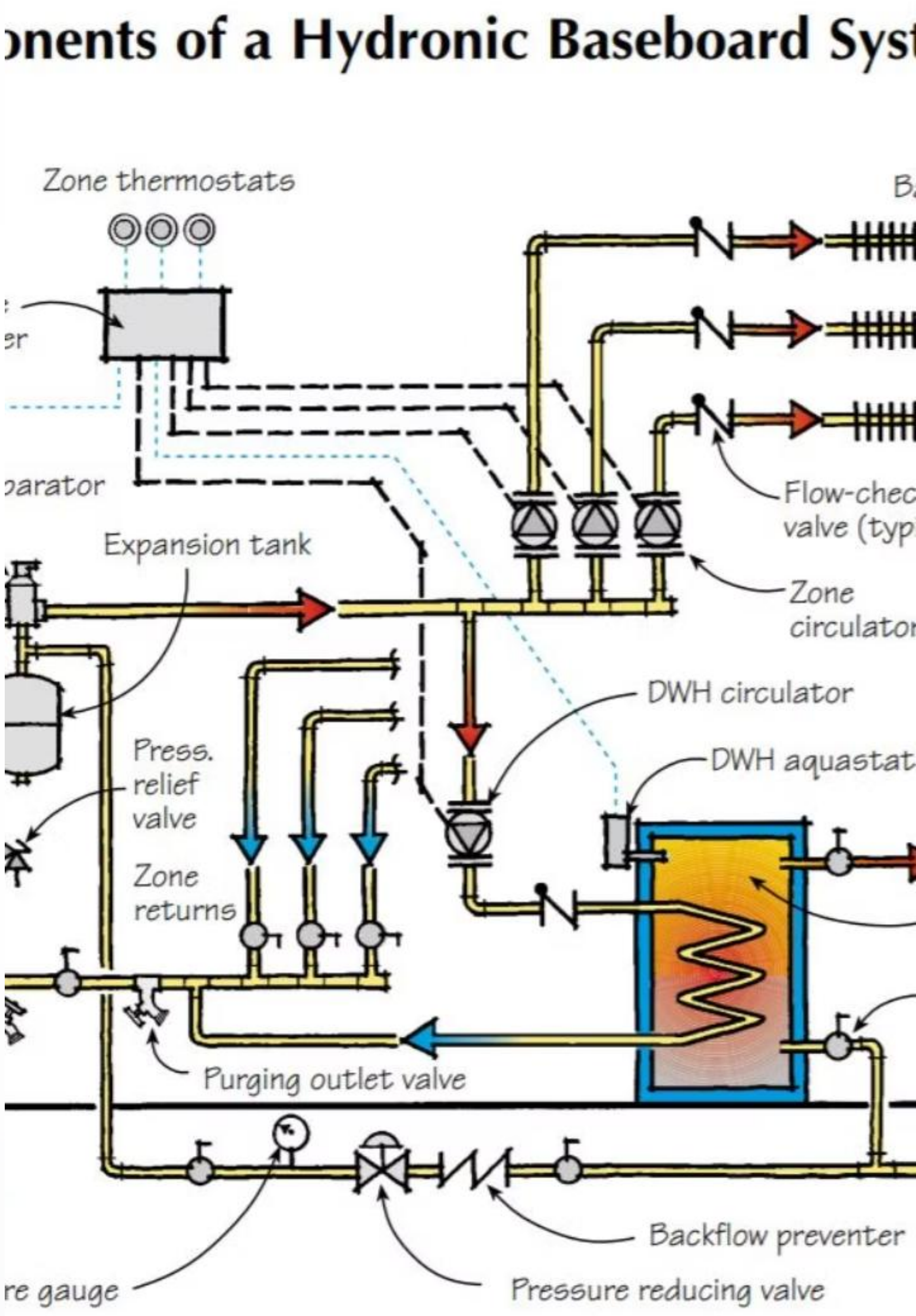
Proper Installation

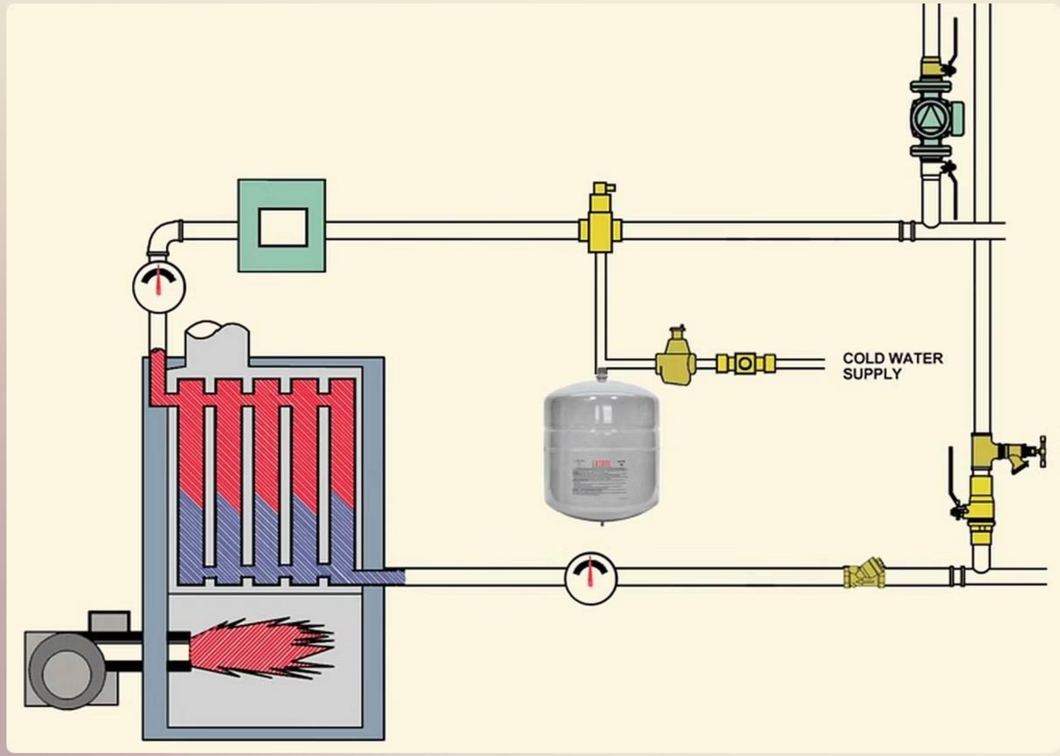
Follow codes and manufacturer guidelines for safe, efficient operation

CSA Unit 20

Chapter 2
Distribution and Control Systems in Hydronic Heating

Many different distribution systems are used in hydronic heating. This presentation describes the piping systems and controls utilized for distribution systems and includes examples of control strategies with which the gas technician/fitter must be familiar. The gas technician/fitter must also have a clear understanding of system filling and purging methods and air elimination devices since gas fitters/technicians start up boiler heated hydronic systems.





Hydronic Distribution Systems Overview

Series Loop System

The simplest hydronic distribution system where heat distributing units are connected so all water flowing through each circuit passes through each component in the circuit.

One-Pipe Systems

Uses one continuous pipe running from the boiler supply outlet back to the boiler return inlet, with diverter tees to direct flow to heating units.

Two-Pipe Systems

Features one main pipe to convey hot water from the boiler to heating units and a second pipe to return cooled water back to the boiler.

Radiant Floor Heating

Circulates warm water through tubing embedded in or secured to flooring material, radiating heat upwards into the room.

Series Loop System

How It Works

The simplest hydronic distribution system is a series loop. This type of system, which is often controlled by a single room or area thermostat, is appropriate for applications where all the rooms served experience similar heating load changes in response to changes in outdoor conditions.

A series system has the heat distributing units connected so that all the water flowing through each circuit passes through each component in the circuit.

Key Features

- A single pipe or main helps convey hot water from the boiler to the heating units
- The main directly connects each heating unit to one another in series
- A large system may be composed of two or more separate series circuits
- Each circuit runs from the boiler outlet to the boiler return

Advantages and Limitations of Series Loop Systems

Advantages

- Requires less pipe and fittings than a parallel (two-pipe) system
- Simple design and installation
- Lower initial cost

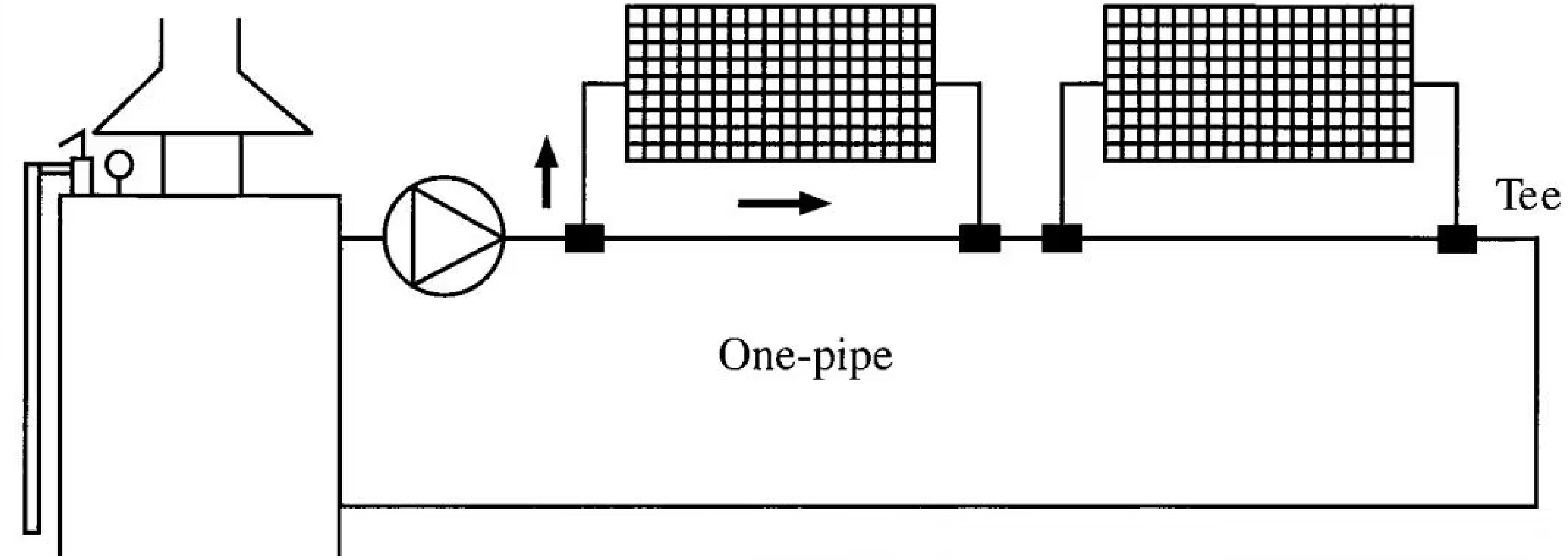
Limitations

- Critical that water flow be adequate to prevent cooling at the end of the loop
- Heat input regulated based on temperature at the location of one thermostat
- Can lead to problems of overheating rooms where the thermostat doesn't sense temperature
- Limited zone control options

Zone Control Options

- Limited to adjusting control devices on individual heating units
- Closing dampers on finned-tube baseboard units reduces heat output by about 40%
- Fan-coil units can reduce blower speed to limit heat output
- Requires manual adjustments to individual units in response to changing heat load conditions

One-Pipe (Single Main) Monoflo® System



System Design

A one-pipe mono-flow hydronic system has one continuous pipe or main running from the boiler supply outlet(s) back to the boiler return inlet(s). Two smaller pipes, the supply and return branches, connect each heating unit to the main pipe.

One-pipe diverter tee fittings are installed in the main where the branches connect to it. These special fittings (often called "Monoflo" tees) divert a portion of the main water flow into the heating unit supply pipes.

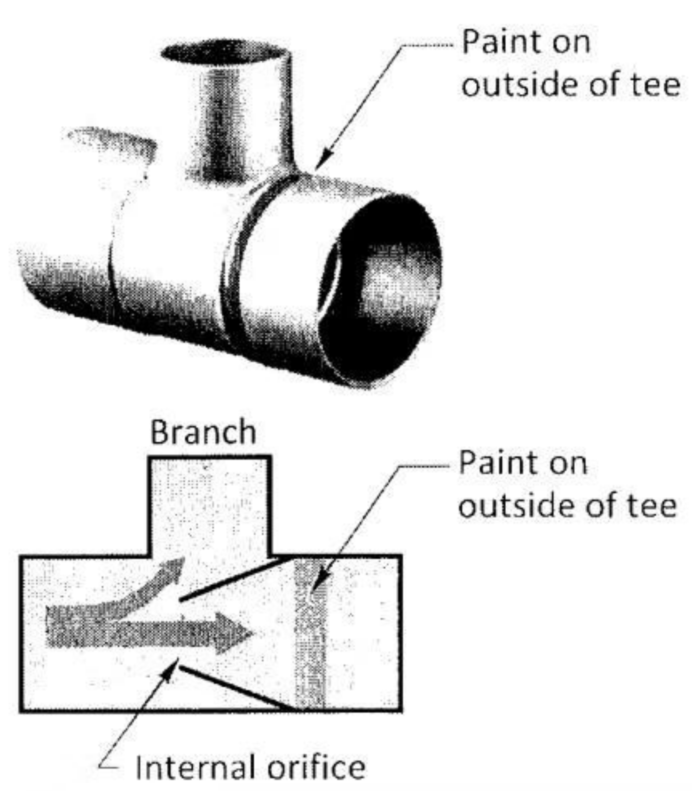
Advantages

- Piping requirements are less
- Use of valves and diverter tees can control the flow to each heating unit

Disadvantages

- Not suitable for high head-loss heat transfer units
- Total heat load is typically limited to 50,000-60,000 Btu/h per circuit

Diverter Tee Applications



1

Function

Diverter tees divert some of the water from the main piping through a heating unit on a branch circuit.

2

Installation Options

Installation of diverter tees can be individual or in pairs. With the use of two diverter tees, the greater pressure difference created across the branch circuit induces a higher flow rate in the branch.

3

Application Guidelines

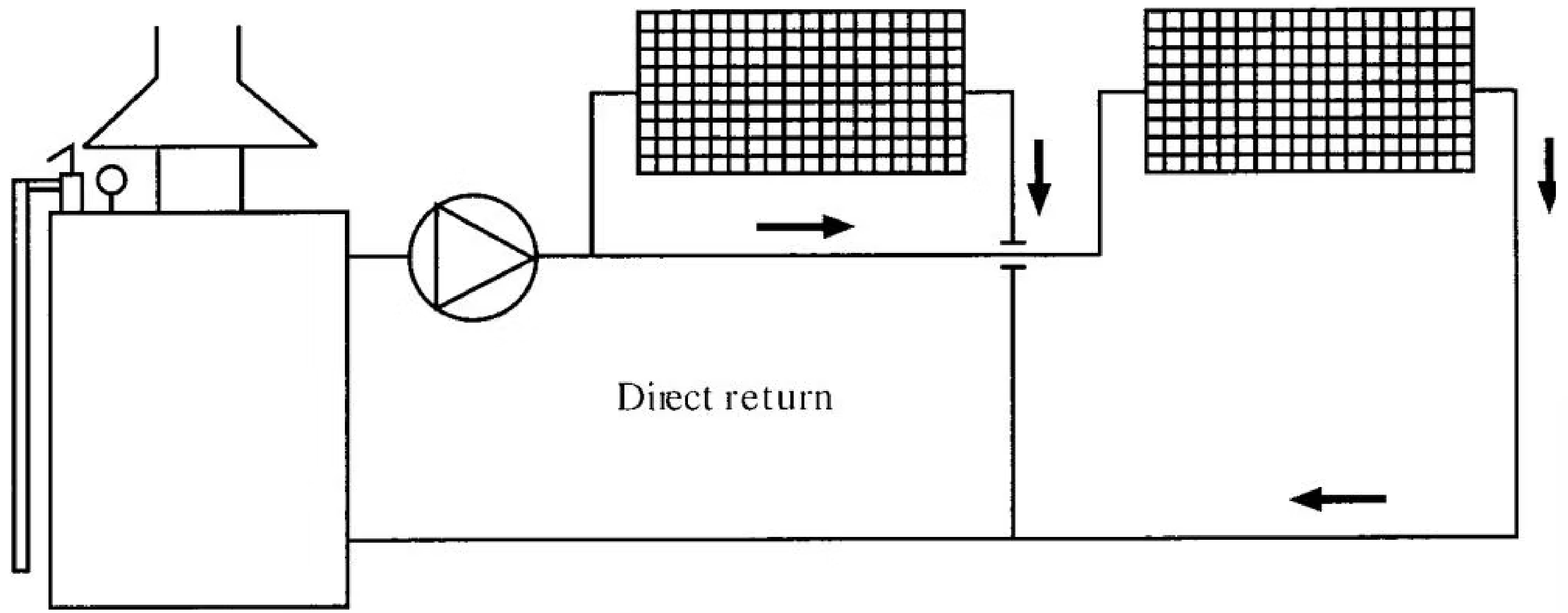
Single diverter tee installations are often adequate for low-resistance heating units, such as short runs of finned-tube baseboard or a panel radiator. A pair of diverter tees may be required for fan coils or other units with higher flow resistances.

4

Installation Best Practices

In a dual diverter-tee installation, there should be at least one foot of pipe between the tees. This piping arrangement allows partial dissipation of any flow turbulence created by the first tee before entering the second

Two-Pipe Systems: Direct-Return



System Design

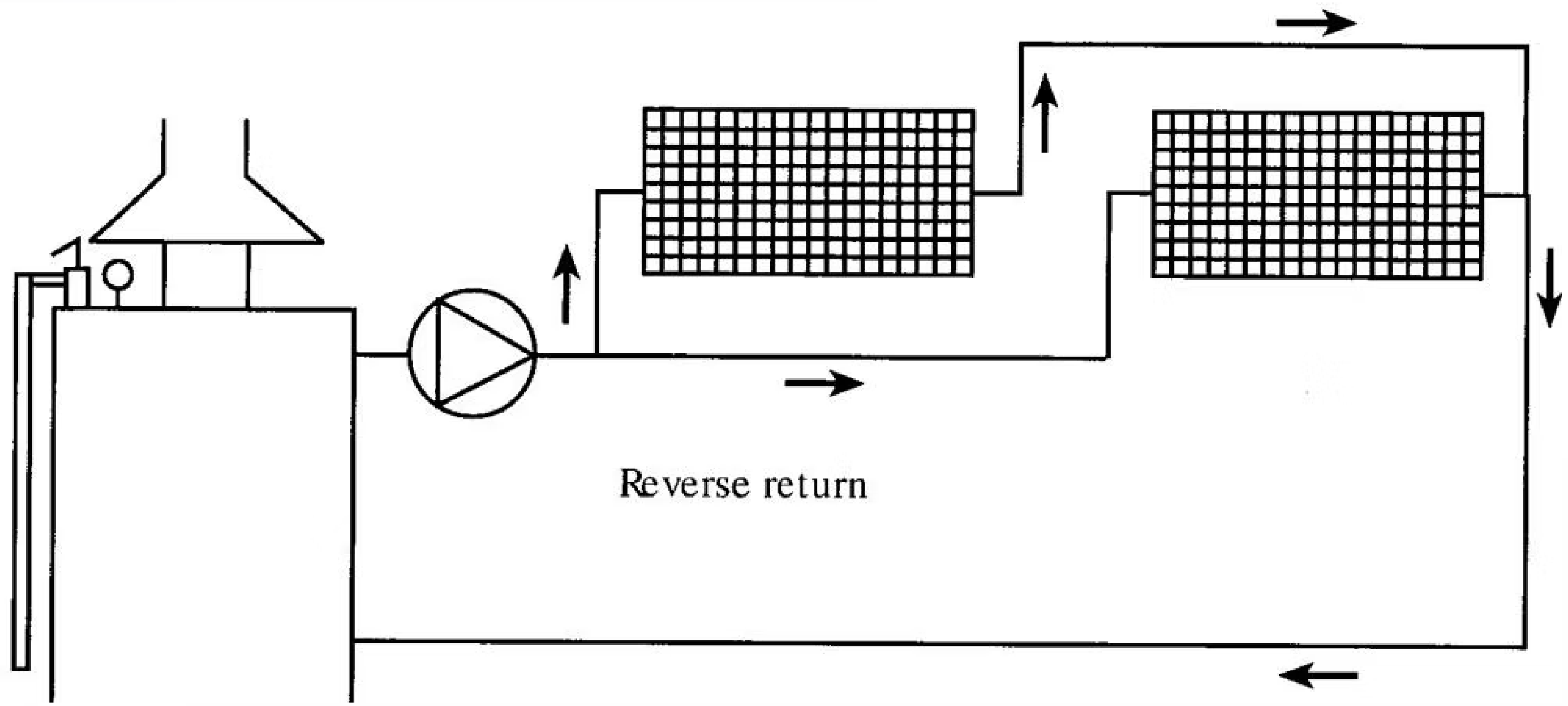
A direct-return two-pipe hydronic system is one in which water from the heating units returns to the boiler through the shortest practical path (known as "first-return").

A two-pipe hydronic system has one main pipe to convey hot water from the boiler to the heating units and a second pipe to return the cooled water from the heating units back to the boiler.

Key Characteristics

- The length of the circuit and the resistance to flow through units close to the boiler are significantly less than for units farther away
- Can cause uneven system flow rates
- Requires system balancing valves to create additional friction in the shorter circuits
- Balancing is essential for proper operation

Two-Pipe Systems: Reverse-Return



System Design

A reverse-return two-pipe hydronic system is one in which the heating units are connected to the return main in the reverse order that they are connected to the supply main.

In this system, the heating unit closest to the heat source (on the supply main) is also the farthest from the heat source on the return main. The farthest heating unit from the heat source on the supply main is also the closest on the return (known as "first-fed, last-return").

Key Advantages

- Ensures that circuit length and flow resistance through each heating unit is approximately equal
- Helps reduce system balancing problems
- Overcomes most of the flow balancing problems associated with parallel direct-return systems
- Particularly effective when all heating units have similar flow resistances

Reverse-Return System Design Considerations

Pipe Sizing

A two-pipe system requires different sizes of pipe in certain parts of the system. The size of the supply main piping is progressively smaller, the farther away from the heat source it is. The return main piping is progressively larger, the closer to the heat source it is.

Optimal Layout

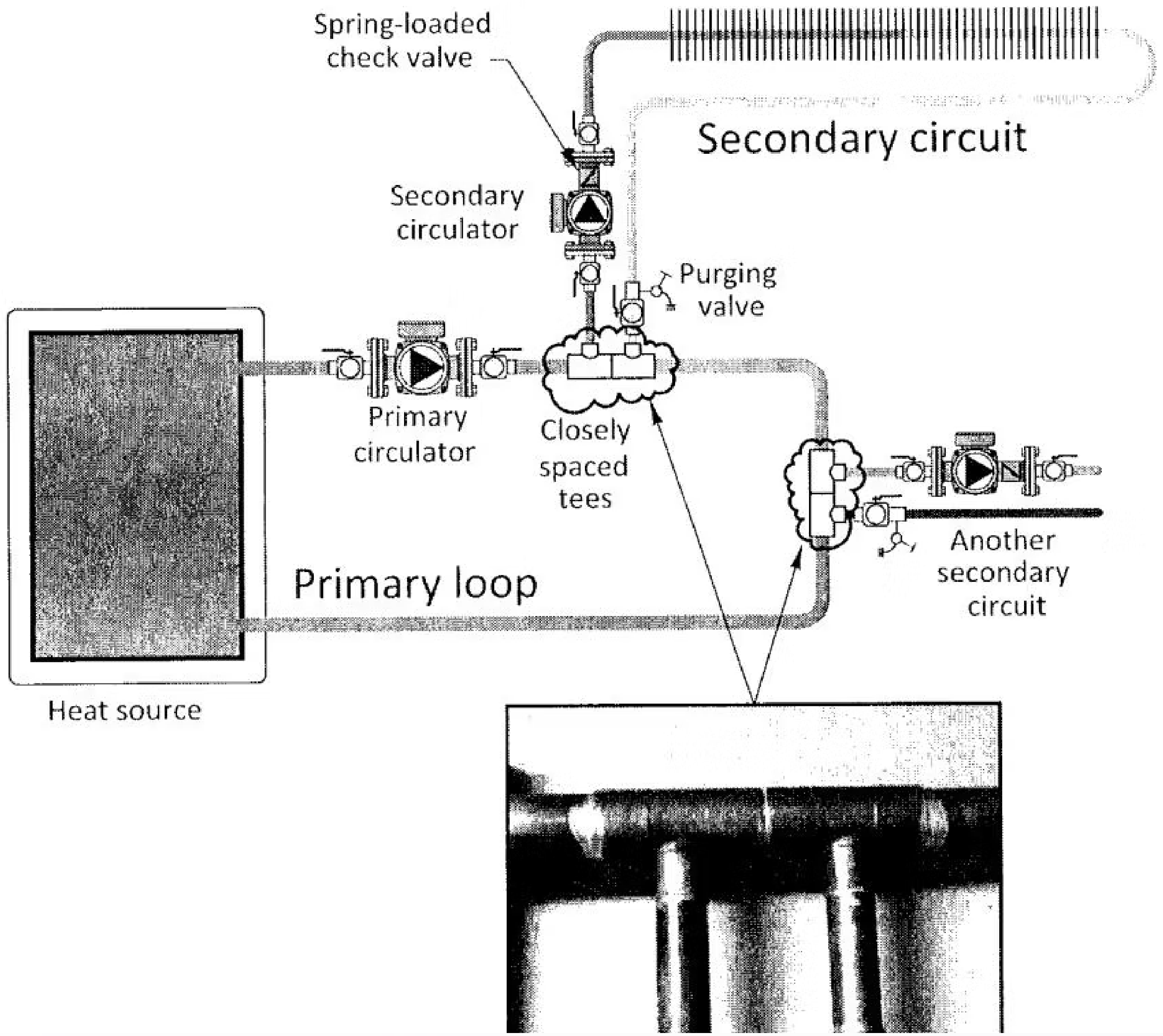
The optimum arrangement for a parallel reverse-return system is to route the supply and return mains around the perimeter of the zone that is being heated.

Balancing Requirements

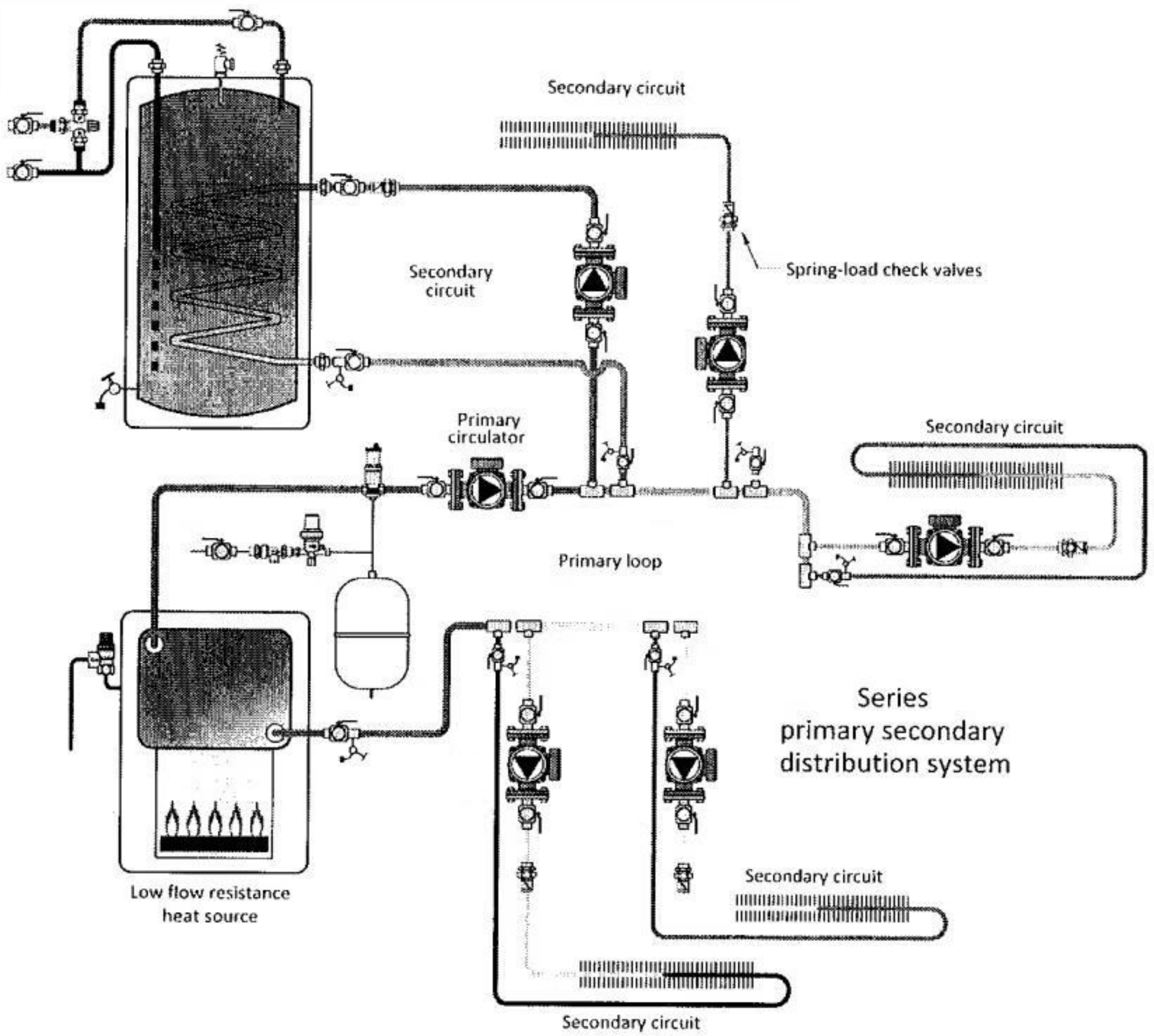
If a reverse-return hydronic system has been designed and sized correctly, it is significantly easier to balance than a direct-return system. However, these systems are not "self-balancing". Every system requires flow balancing to ensure that each circuit within the distribution system is achieving its design flow rates.

Primary/Secondary Systems

Figure 2-7
Primary/Secondary system showing closely spaced tees
Courtesy of idronics™ 15: Separation in Hydronic Systems, ©Caleffi North America, Inc.



Primary/Secondary System Configurations



Low Resistance Boiler Configuration

If the heat source has low flow resistance, it is usually piped as part of the primary loop.

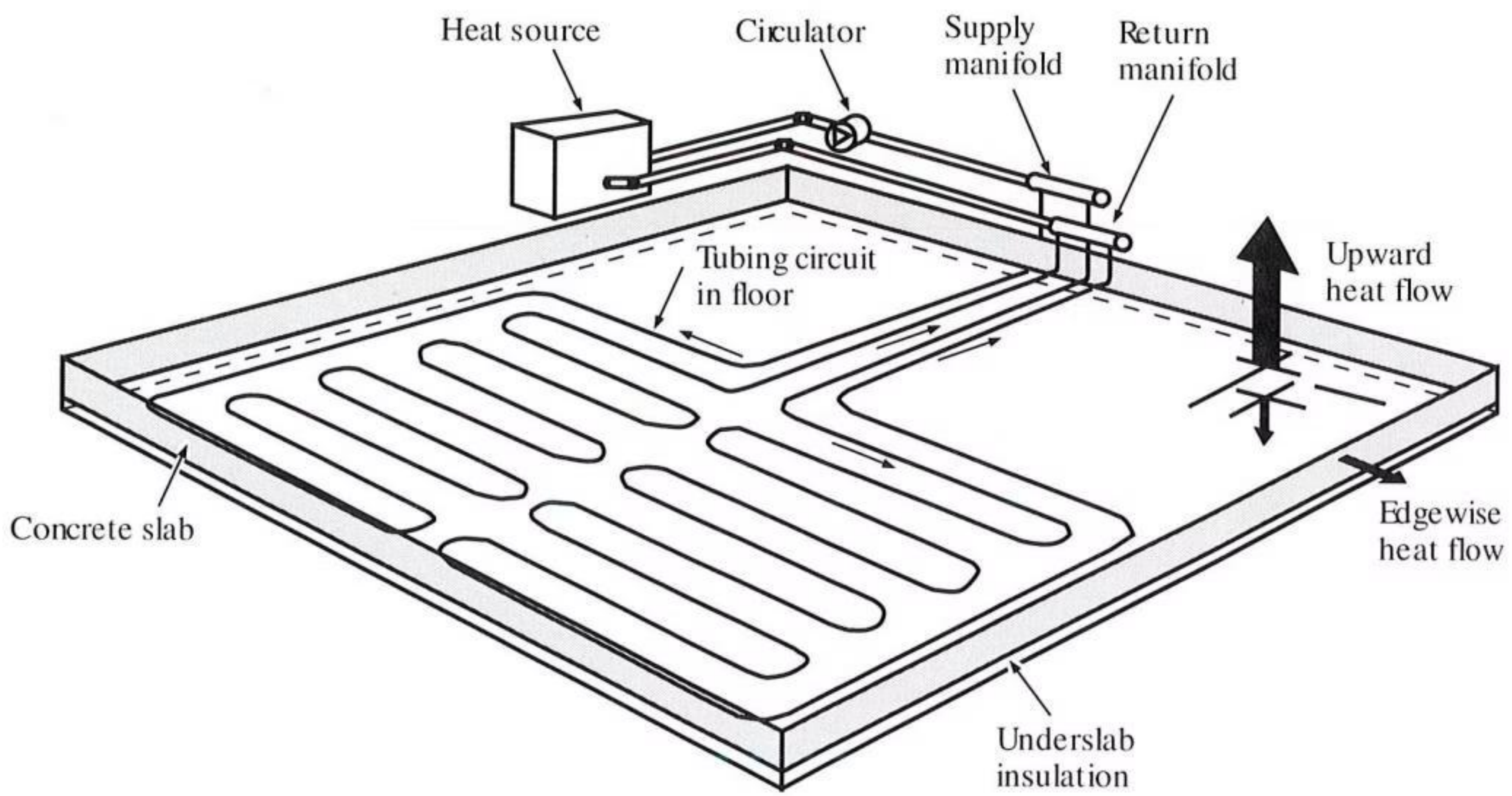
This configuration simplifies the system design and reduces the number of components needed.

High Resistance Boiler Configuration

If the heat source has higher flow resistance, it is usually provided with its own circulator and connected to the primary loop using a set of closely spaced tees.

This configuration helps maintain proper flow through the boiler while minimizing its impact on

Radiant Heating: Radiant Panels



System Design

In a hydronic radiant floor heating system, warm water circulates through tubing embedded in or secured to the flooring material. Most of the heat transferred to the flooring from the warm water radiates upwards into the room. A small portion of the heat is lost through the bottom and edges of the floor.

Installation Methods

- Attached to the underside of wood subflooring
- Embedded in a thin layer of gypcrete topping poured over a subfloor
- Installed in walls and ceilings
- Embedded in concrete structural slab

When the slab is placed directly on grade, the underside and edges of the slab must be well insulated.

Radiant Tubing Layout Patterns

Tubing Materials

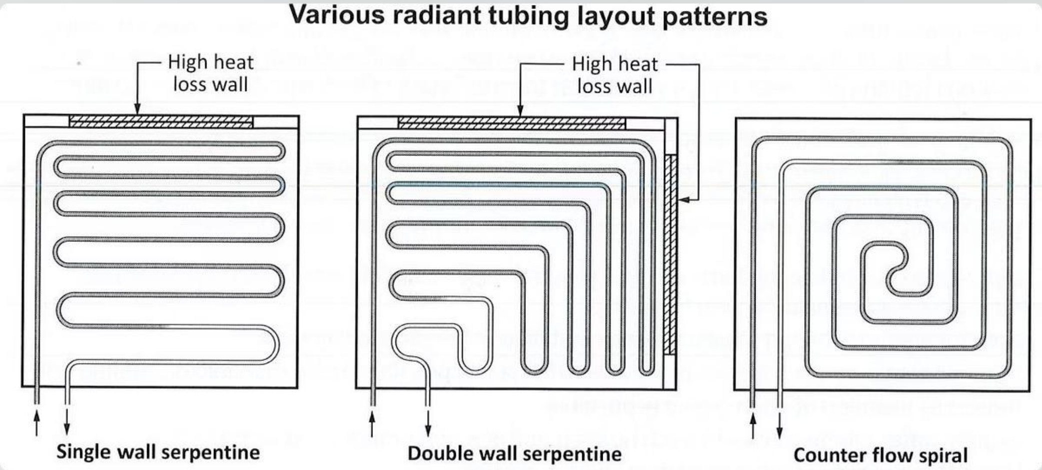
The most common tubing used for hydronic in-floor heating systems is cross-linked polyethylene (PEX) with oxygen barrier or cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX/AL/PEX).

Layout Considerations

Various layout patterns are acceptable depending on the floor material used and the heat loss of the room. The hydronic system tubing is typically attached to the metal bars or wire mesh that is installed in the slab for reinforcement.

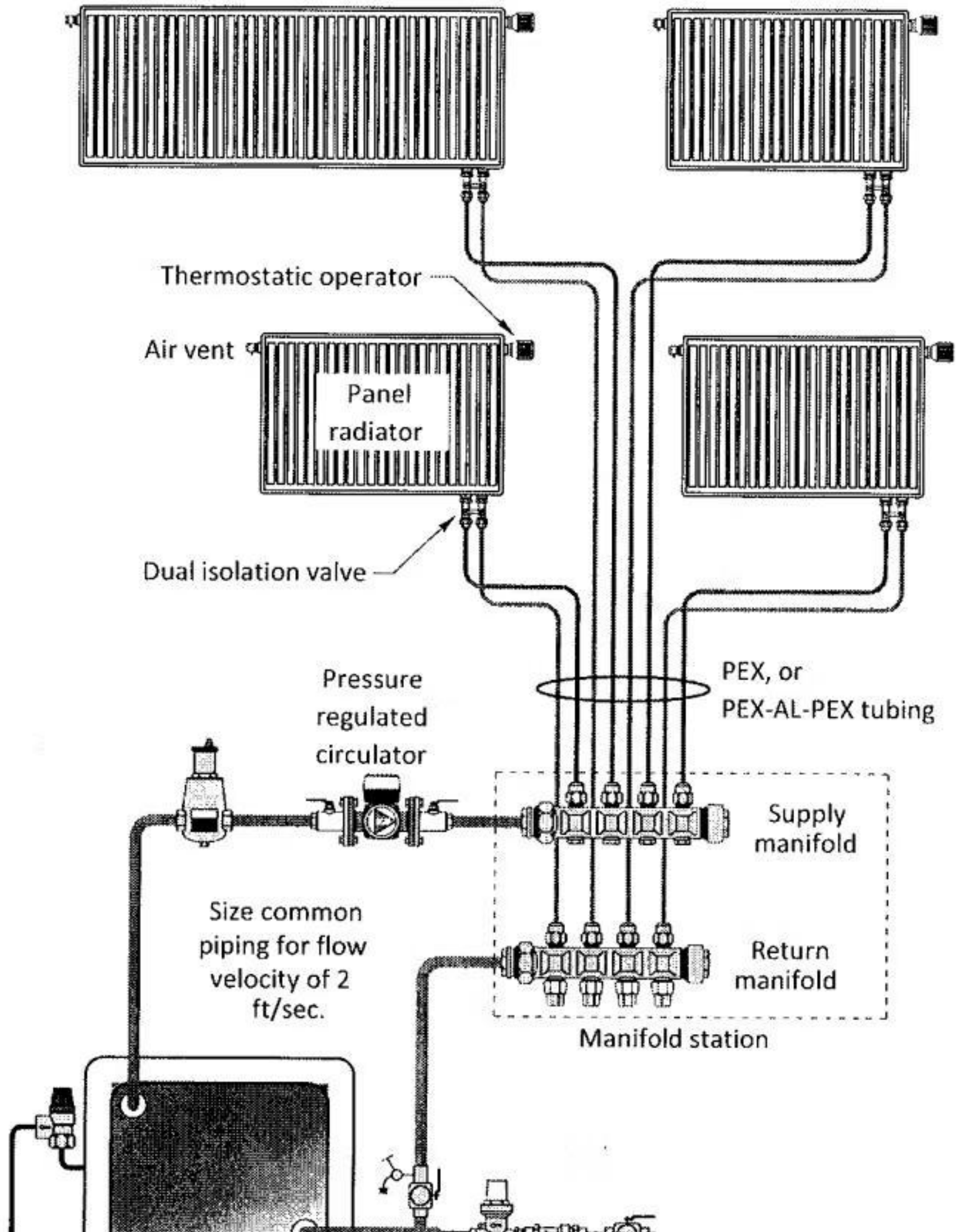
Material Selection

Gas fitters/technicians have tried various other piping materials in the past, but most of these have had issues with oxygen diffusion, leading to system failures.

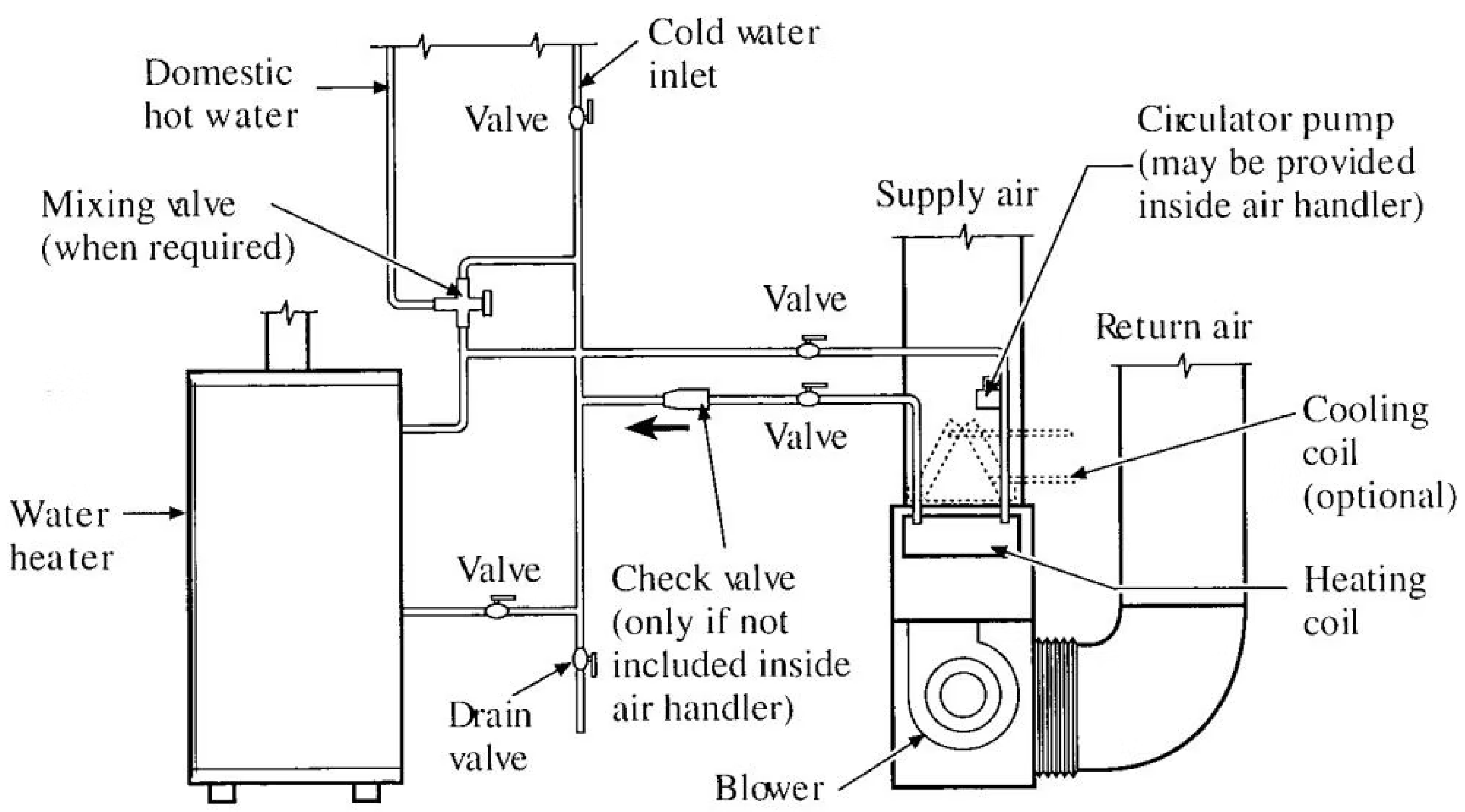


Manifold Distribution Systems

Figure 2-12
Manifold distribution system
Courtesy of idronics™ 12: Hydronic Fundamentals, ©Caleffi North America, Inc.



Combination Hydronic Heating System with Domestic Hot Water



System Design

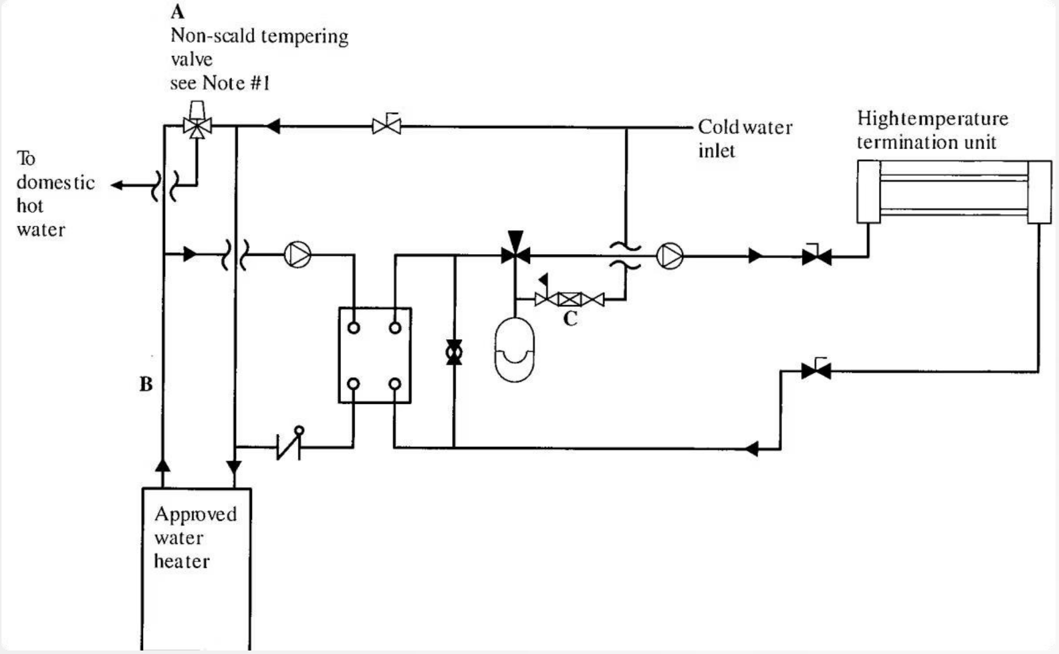
Combination systems combine hydronic space heating with domestic water heating. A water heater used for domestic water is combined with a space-heating unit.

On a call for heat from a thermostat, domestic hot water circulates through a heating coil. A blower distributes the heated air to the conditioned space through a ducted system.

Key Considerations

- Chemical additives may not be introduced into open-type combination systems
- Where additives are added to closed systems, provisions must be implemented to avoid cross-contamination
- May require a double wall heat exchanger with a visible leak path separating the two systems
- When the heating system requires water at temperatures higher than needed for domestic purposes, a thermostatic mixing valve must be installed

Combination Hydronic Baseboard System



Potable Water Components

All components used on the domestic water side of the combination water heater must be suitable for use in potable water systems.

Temperature Control

When the heating system requires water at temperatures higher than needed for domestic purposes, a thermostatic mixing valve must be installed.

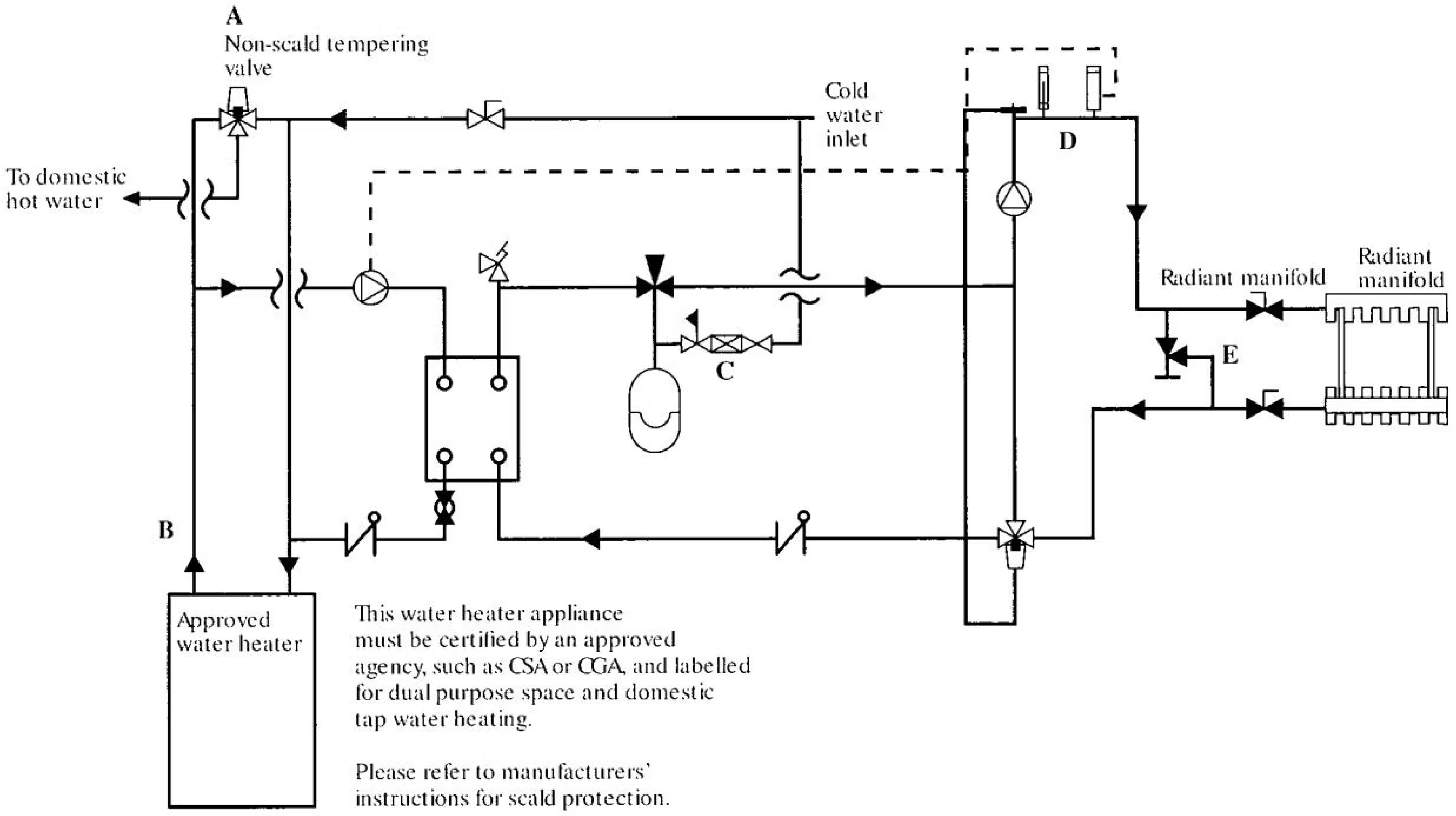
Chemical Additives

Chemical additives may not be introduced into open-type combination systems. Where they are added to closed systems, provisions must be implemented to avoid cross-contamination, as required by the authority having jurisdiction.

Heat Exchanger Requirements

May require a double wall heat exchanger with a visible leak path separating the two systems.

Combination Hydronic Radiant Floor System



Note: This diagram illustrates a general arrangement and may not show all the accessories that can be utilized or required by local codes. Consult manufacturers' installation instructions

Temperature Control

Use a suitable thermostatic mixing valve to regulate the domestic water outlet temperature.

Potable Water Components

All components used on the water heater side of the isolation heat exchanger must be suitable for use in potable water systems.

Open Loop vs. Closed Loop Systems

Open System

According to CSA B214, an open system is a piping system, conveying potable water or a hydronic solution that is open at any point to atmosphere.

- Air contains oxygen, which allows oxidization of ferrous components
- When systems communicate with the atmosphere or have continuous renewal of fresh domestic water, eliminating the air (and oxygen) content becomes impossible
- This prohibits the use of ferrous components within the system

Closed System

A closed system is a piping system that is sealed at all points from the atmosphere and contains a non-potable solution.

- Properly designed and installed closed systems have air elimination devices that remove most of the air contained within the system fluid
- The fluid is less capable of allowing oxidization of ferrous components
- Components within the system may be ferrous (cheaper cost)
- Potential increase to the lifespan of the system

Closed System Requirements

System Separation

For a system to be considered a "closed system", there must be no contact to atmosphere at any point. This includes complete separation of the space heating fluid from the domestic water supply using a hydronic (water-to-water) heat exchanger.

Backflow Prevention

In some cases, reducing the possibility of system fluid backflowing into the potable supply may require a double-walled heat exchanger (with or without a visible leak path). Check with local jurisdiction for more information regarding backflow prevention in your area.

Heat Transfer Fluid

Closed-loop systems do not maintain the heat transfer fluid in a potable state. This allows for the use of antifreeze solutions and other additives that would not be permitted in potable water systems.

Thermal Expansion Devices

Purpose

Whenever liquid undergoes heating, it expands volumetrically. Since a hydronic system undergoes temperature changes that will cause changes in system fluid volume, every system containing liquid must have provision for this expansion and contraction.

Therefore, in a hydronic heating system, thermal expansion devices must be installed to allow for the expansion and contraction of the heat transfer fluid.

Evolution of Expansion Devices

The styles/types of expansion devices used historically have varied; however, their designs have been improved over the years.

Modern systems typically use one of three types of expansion devices:

- Open expansion tanks
- Air cushion tanks
- Bladder or diaphragm expansion tanks

Open Expansion Tank

Figure 2-18
Gravity hydronic heating system with natural circulation and open expansion tank

Historical Design

Prior to the 1930s, hydronic systems used to have an expansion device located at the highest point in the system (usually the attic). This tank had a vent that was open to atmosphere and was therefore termed an "open" expansion tank.

Any excess volume of water created by expansion in the system flows freely into the tank. When the system cools, the volume of the water in the tank and the level in the tank drop.

Components and Limitations

- Includes a sight gauge that indicates the water level
- Has an overflow pipe that allows excess water to drain from the tank
- Because the tank was open, water and oxygen could access the metal in these systems, leading to high rates of corrosion
- Maintaining the water levels of these systems requires caution

Most gravity systems (that do not use forced circulation) are open systems.

Evolution of Hydronic Systems

Gravity Systems

Early hydronic systems relied on gravity circulation with open expansion tanks, leading to high corrosion rates.

Introduction of Circulating Pumps

The introduction of circulating pumps in the late 1920s overcame all the obstacles of the gravity systems, while retaining all the advantages of heating with water.

Improved Flow and Smaller Components

Forced circulation greatly improved the flow of water such that smaller radiation could be used, supplied with much smaller piping.

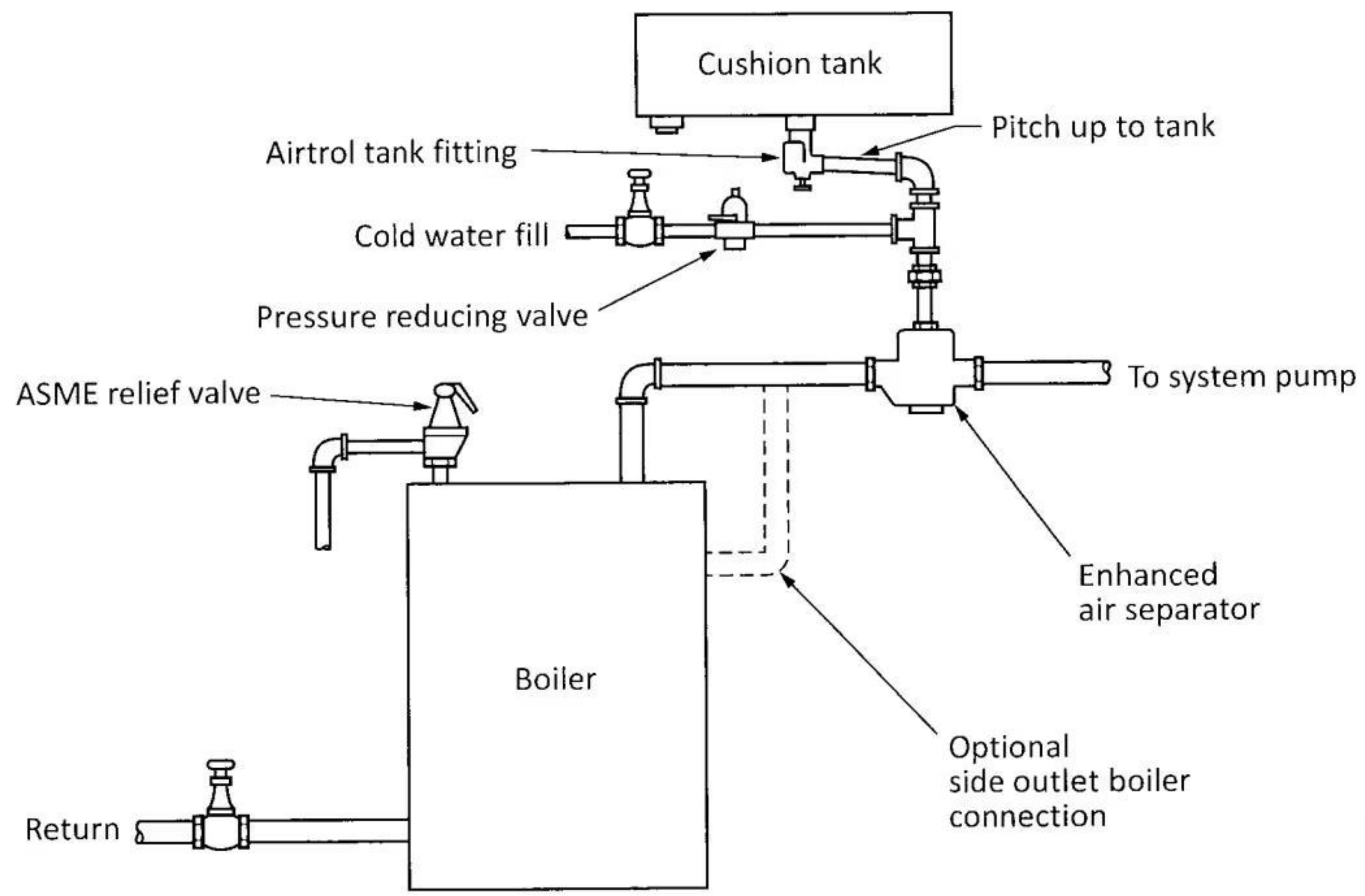
Higher Temperature Operation

Forced water systems also allowed design using higher water temperatures, resulting in higher emission rates.

Closed System Benefits

Controlling the closing of the system allowed for increased static pressures and elimination of air (as well as oxygen) is now possible.

Air Cushion Tank



Design and Function

Air cushion tanks (or sometimes referred to as conventional compression tanks) are a closed tank that is not open to atmosphere.

Air, in contrast to water or other heat transfer liquids, is capable of being compressed. Therefore, the intent is that this type of tank would be sized and monitored to maintain a volume of air that acts as a cushion, accepting the expansion of system fluid whilst simultaneously compressing the air.

Operation Considerations

- When system fluid that is in direct contact with the air portion of these tanks cools, it absorbs air
- This air can thereafter be communicated throughout the system
- Air removal devices must be selected and installed in a manner that returns this air to the air cushion tank
- Systems that utilize air cushion tanks are treated as closed-loop systems despite the continuous

Air Cushion Tank Requirements

Proper Sizing and Selection

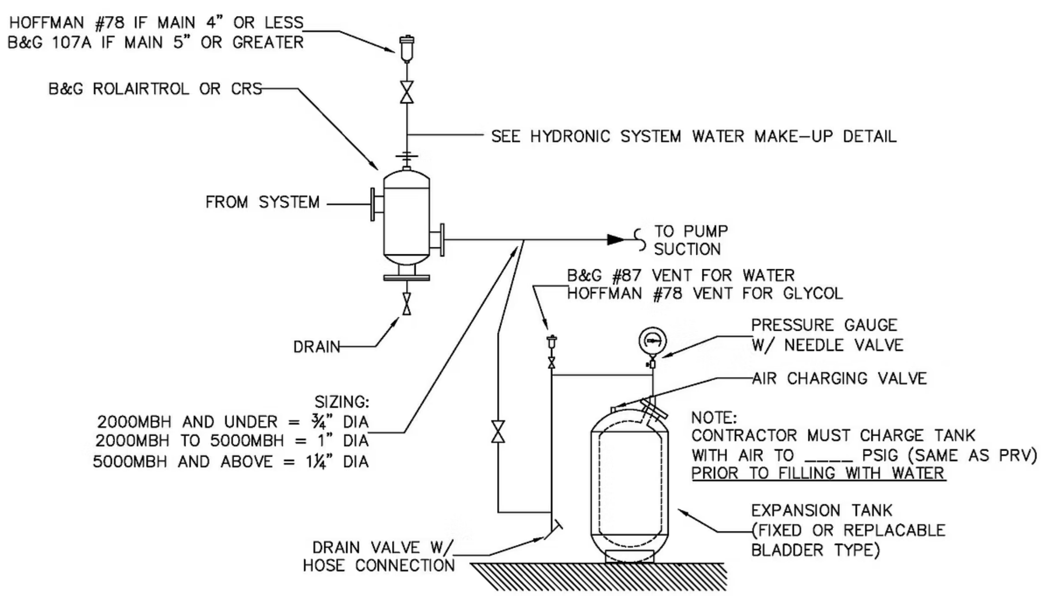
The tank must be correctly sized to accommodate the expected volume changes in the system fluid.

Air Management

Air removal devices should be installed in a manner that returns any air removed from the system to the air cushion tank. Removing air from the system completely will cause the air cushion tank to become water-logged (filled with water) leaving no provision for the volumetric expansion for system fluid.

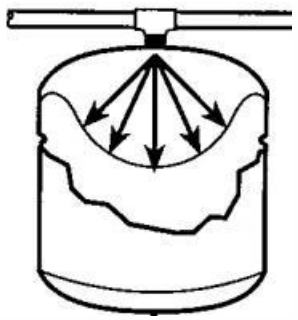
Supporting Components

Proper selection and assembly of components that support the functionality of the air cushion tank is essential for system operation.



VERTICAL BLADDER TANK INSTALLATION DETAIL

Bladder or Diaphragm Expansion Tanks



Design and Function

The most commonly used expansion tank types are bladder or diaphragm types, which utilize an elastomer membrane in different formations to separate the system heat transfer fluid from a precharged volume of captive air.

It is important that the diaphragm tank is pre-charged to the system design pressure (typically 12-18 psig) before it is installed onto the system.

Operation Cycle

1. When the system temperature is increased, the system fluid expands into the expansion device
2. As the system fluid volume within the tank increases, it pushes against the diaphragm or bladder that separates the air side within the device
3. The air side is compressed, reduced in volume and pressurized to design parameters
4. Upon a reduction in system temperature, the total system fluid contracts and the volume of the system fluid within the water side of the tank is reduced
5. Simultaneously, the pressurized air side of the device expands

Advantages of Bladder/Diaphragm Expansion Tanks

Air Separation

This captive design is the most effective of the previously discussed expansion devices at enabling a properly designed system to minimize air content.

Reliability

Since these expansion devices have little risk (unless improperly undersized or if the membrane ruptures) of becoming waterlogged, they are considered effective options for expansion provision.

Pressure Considerations

If the pre-charge pressure is too low, the tank volume will drop immediately once it is connected to the system fluid, due to pressure equalization. If the pressure is too high, the system will experience wide variations in pressures during operation.

Safety

If the pressure increase (due to thermal expansion of the system fluid) is excessive, the boiler's relief valve will actuate.

Converting Open Systems to Closed Systems

1. ### Expansion Device Replacement

   Remove and replace an open expansion tank with a closed style expansion device with associated components.

2. ### Make-up Water Assembly

   Install a make-up water assembly including, but not limited to, an approved backflow preventer, fast-fill bypass and pressure reducing valve (or glycol pre-mix feed assembly).

3. ### Pressure Relief Valve

   Install a properly sized, certified pressure relief valve on the boiler.

4. ### Air Elimination

   Install properly designed air elimination devices.

5. ### Heat Exchanger

   Install an approved heat exchanger to separate domestic system water from hydronic system heat transfer fluid.

Filling and Bleeding: Importance of Air Removal

Why Remove Air?

When a hydronic system is filled with water at start-up or partially refilled after repairs or servicing, you must remove any air that has accumulated or bleed it out of the system. The air removal process is also called purging.

You must purge the system of air to prevent:

- Insulating effect of air in the system from reducing heat transfer
- Noise in the system
- Air locks from blocking water flow in the system
- Oxidation and gaseous corrosion of the system

Sources of Air

Heat transfer only occurs in a hydronic heating system that is filled with water or glycol/water mixture (the heat transfer medium). Because air is a good insulator, any air in the heating system slows down or prevents the heat transfer process.

Air can enter a hydronic heating system in many ways, such as:

- With the boiler makeup water
- Through leaky gaskets
- Present in the system during the initial installation since each component is filled with air

System Filling and Purging Methods

Gravity Purging

Gravity purging is simply expelling the air in the system by:

- Opening the feed-water valve to fill the system
- Letting the trapped air escape out the high point vents

During this process, air pockets will probably form at all high points in the system. If all high points are not vented, the remaining air pockets will disrupt flow through the system when the circulator starts operating.

Gravity purging can be time consuming, especially if low capacity manual and automatic vents are used.

Forced-Water Purging

Forced-water purging can significantly reduce the time and effort required to fill a hydronic system and purge it of air.

The success of this method is due to the fact that water flowing at sufficient velocity will entrain air bubbles - the faster the system is filled from a high-pressure source of water, the faster air will be expelled from the system.

Air Elimination Devices

Manual Air Vents

Small, economical vents installed at accessible locations for occasional venting. Can be installed horizontally or vertically. Common at point-of-use locations like baseboard heating units.

Automatic Air Vents

Automatically eliminate air from the system as it collects. Two common types are washer type (hygroscopic) and float type vents.

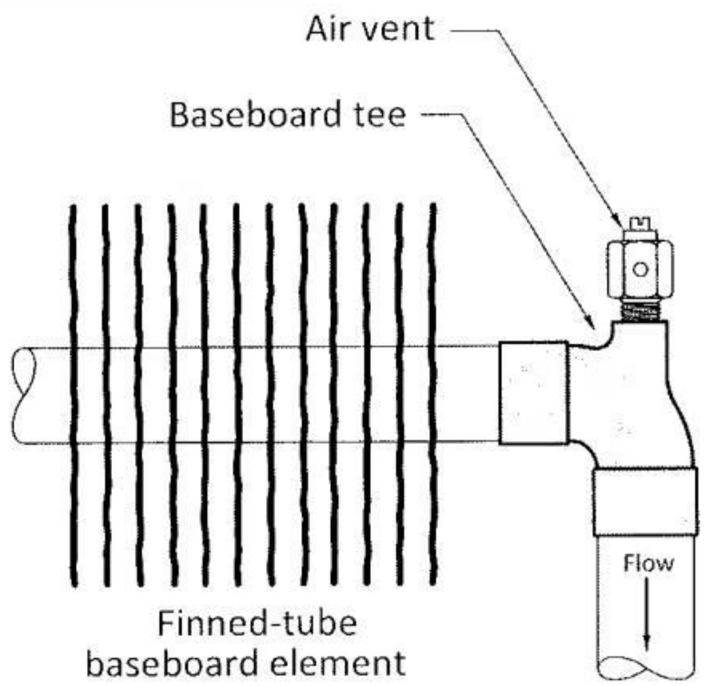
Air Purgers/Air Scoops

Metal chambers with internal baffles that help separate air bubbles from the heat transfer fluid. Usually installed horizontally in the main supply piping, close to the boiler.

Microbubblers

High-capacity air separators (deaerators) that are highly effective at removing air from hydronic heating systems, including microbubbles.

Manual Air Vent



Design and Function

Manual wheel vents or coin vents are small and economical. They are installed at accessible locations for occasional venting and can be installed horizontally or vertically.

They are common at point-of-use locations like baseboard heating units.

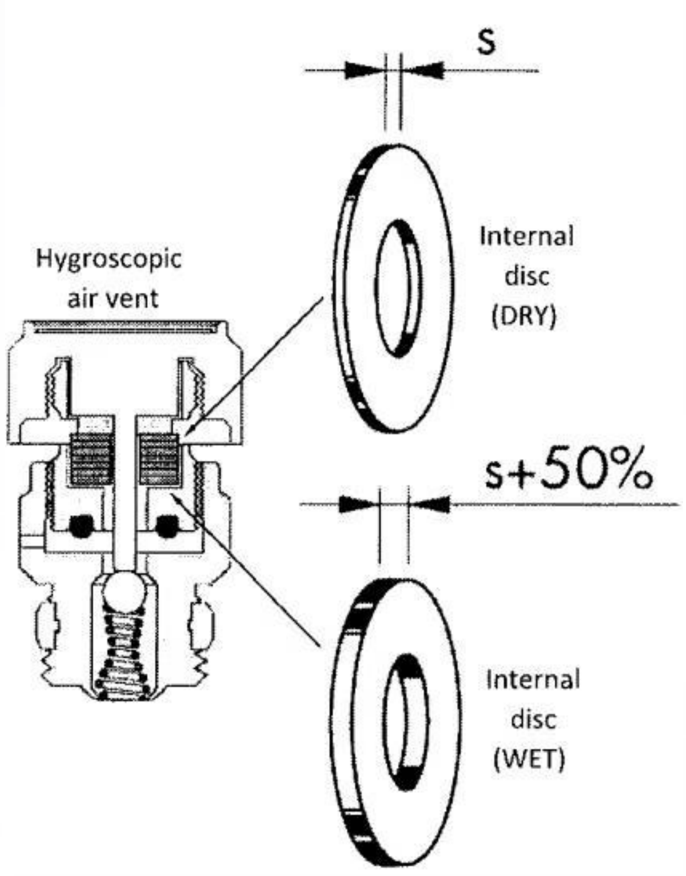
Operation

To operate a manual air vent:

1. Locate the vent at a high point in the system
2. Use a screwdriver or special key to open the vent slightly
3. Allow air to escape until water begins to flow
4. Close the vent immediately once water appears

This process may need to be repeated periodically as air accumulates in the system.

Automatic Air Vents



Washer-Type (Hygroscopic) Vent

Washer-type automatic air vents (also known as hygroscopic vents) are nearly as small as coin vents.

Hygroscopic air vents contain a special cellulose fibre disc that, when dry, allows air to pass through it and exit the vent. When moisture reaches the disc, it expands quickly to stop further flow from the device.

- When the washer comes in contact with water: The valve expands and closes
- When the washer comes in contact with air: The valve shrinks, opens, and lets the air escape

Float-Type Vent

A float-type automatic vent consists of:

- Air collection chamber
- Float assembly
- Vent valve

The collection chamber is full of water, and the float seals the venting valve shut when no air is present.

- When air enters the chamber: It displaces the water and the float drops, opening the valve to let the air escape

Air Purger/Air Scoop

Figure 2-25
Air purger/scoop

Design and Function

An air purger or air scoop is a metal chamber with two flow paths divided by baffles. Its internal shape and baffles help, under ideal design conditions, to separate air bubbles that are entrained within the heat transfer fluid.

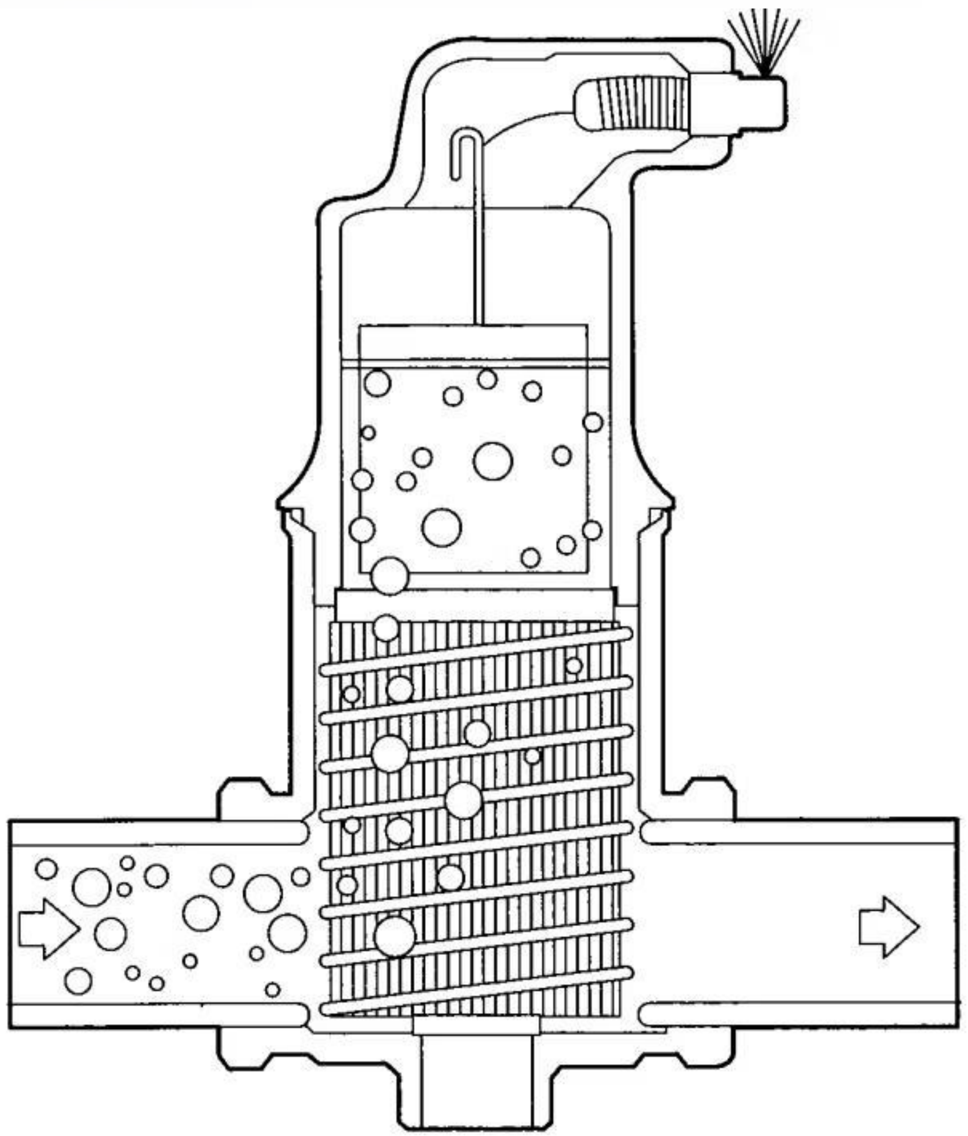
The air bubbles collect at the top of the air purger/scoop where an attached automatic air removal device discharges accumulation intermittently.

Installation

Air purgers are usually installed horizontally, as per manufacturer's instructions. They are located in the main supply piping, as close to the boiler as possible.

This location is ideal for separating air from system fluid. High fluid temperature and low fluid velocity are ideal conditions for air separation.

Air Separators



1

Design

A high-capacity air separator, also known as a deaerator or "microbubble resorber," is highly effective at removing air from hydronic heating systems. Many manufacturers offer a version of this device.

2

Internal Components

This device contains a bundle of small wires that project into the water flowing through the body. The wire bundle acts as a fine mesh strainer, creating an area of reduced flow pressure on its downstream side.

3

Microbubble Separation

This effect encourages dissolved air (as microbubbles) to separate from the water. A spiral winding around the wire bundle guides the bubbles as they rise into the upper chamber of the resorber, where they merge to form a single volume of air.

Air Purging Methods: Considerations

System Factors

- Distribution system type
- Heat transfer fluid type
- Heat emitter type(s)
- Materials/piping/joining methods used

Size and Scale

- Size of system and associated piping
- Complexity of the distribution network
- Number of zones and circuits

Manufacturer Requirements

- Boiler manufacturer requirements
- Certified instructions
- Warranty considerations

Service Context

- Initial start-up vs. service refill
- Complete vs. partial system drain
- Reason for system draining

Purging Systems with Manual Air Vents

1

Preparation

Ensure that all manual air vents are closed. Ensure that the expansion tank is empty of fluid and charged to the system's anticipated fill pressure (some cases will require temporary isolation during system flushing).

2

Initial Fill

Turn on the main water supply to the system. Check all zones for hissing sounds (indicating an open air vent).

3

Fast Fill

Open the fast-fill PRV bypass valve (if provided) and continuously monitor the pressure gauge (ensure that the boiler's relief valve set pressure is not exceeded). Fill to the designated pressure of the system.

4

Valve Adjustment

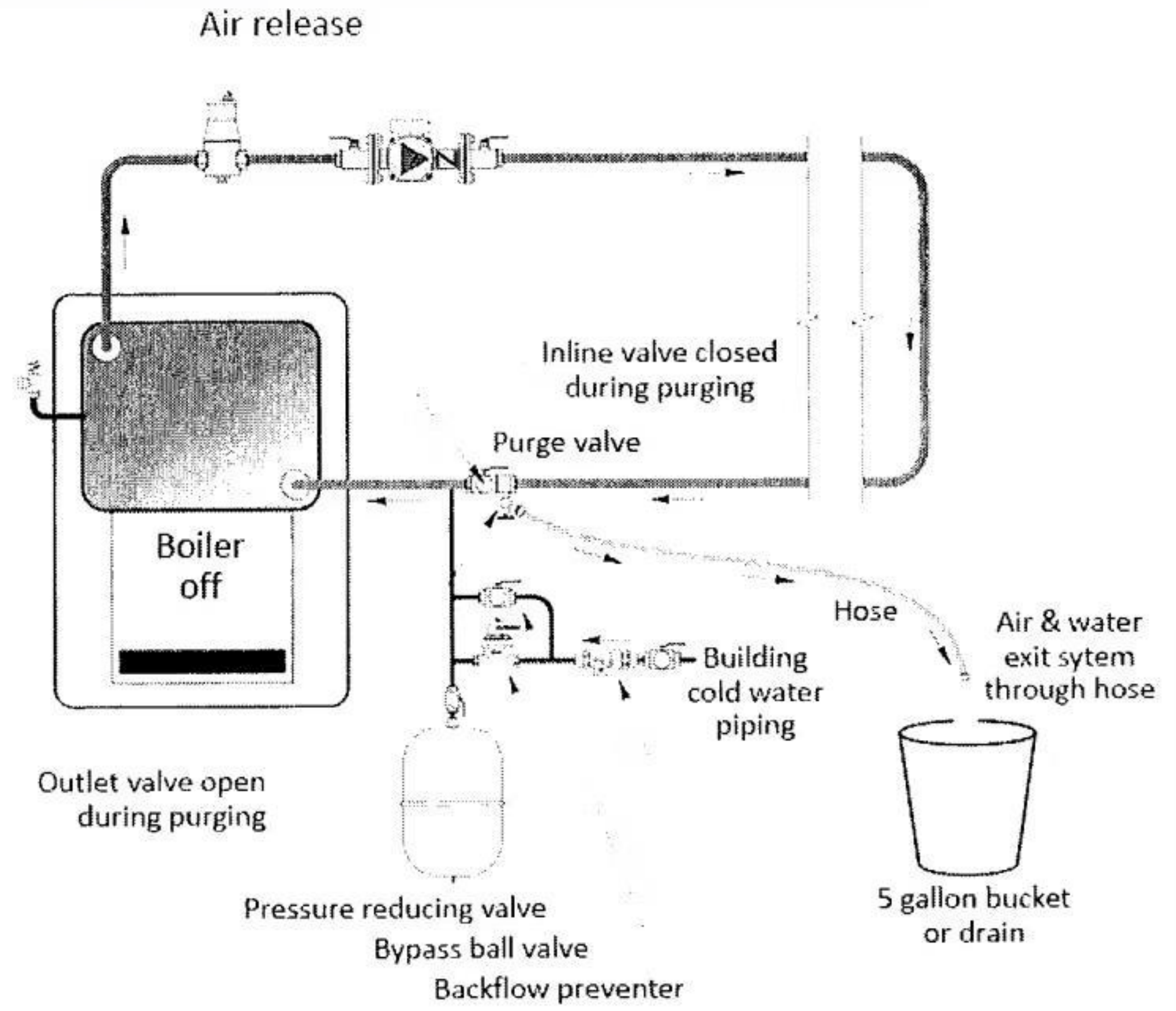
Close the fast-fill valve. The pressure reducing valve (PRV) and main shut off valve must remain open.

5

Air Removal

Bleed the air from each heating unit and every high point in the system. Make a final check of system pressure. Compensate if necessary.

Purging Systems without Air Vents at Heating Units



1

Hose Connection

Attach a garden hose at the purge valve (drain valve) at the end of the closest zone or circuit.

2

Valve Positioning

Close the manual zone return valve (immediately downstream of the purge valve). Some isolation valves will have a combined purge valve included for system filling.

3

Water Supply

Turn on the main water supply to the system. Open the fast-fill PRV bypass valve (if provided) and continuously monitor the pressure gauge (ensure that the boiler's relief valve set pressure is not exceeded).

4

Zone Purging

Hydronic System Controls Overview

Hot Water Boiler Valves and Controls

- Pressure reducing valves
- Bypass feed valves
- Operating aquastats
- High limit aquastats

Flow Control Devices

- Circulators
- Zone valves
- Balancing valves
- Check valves

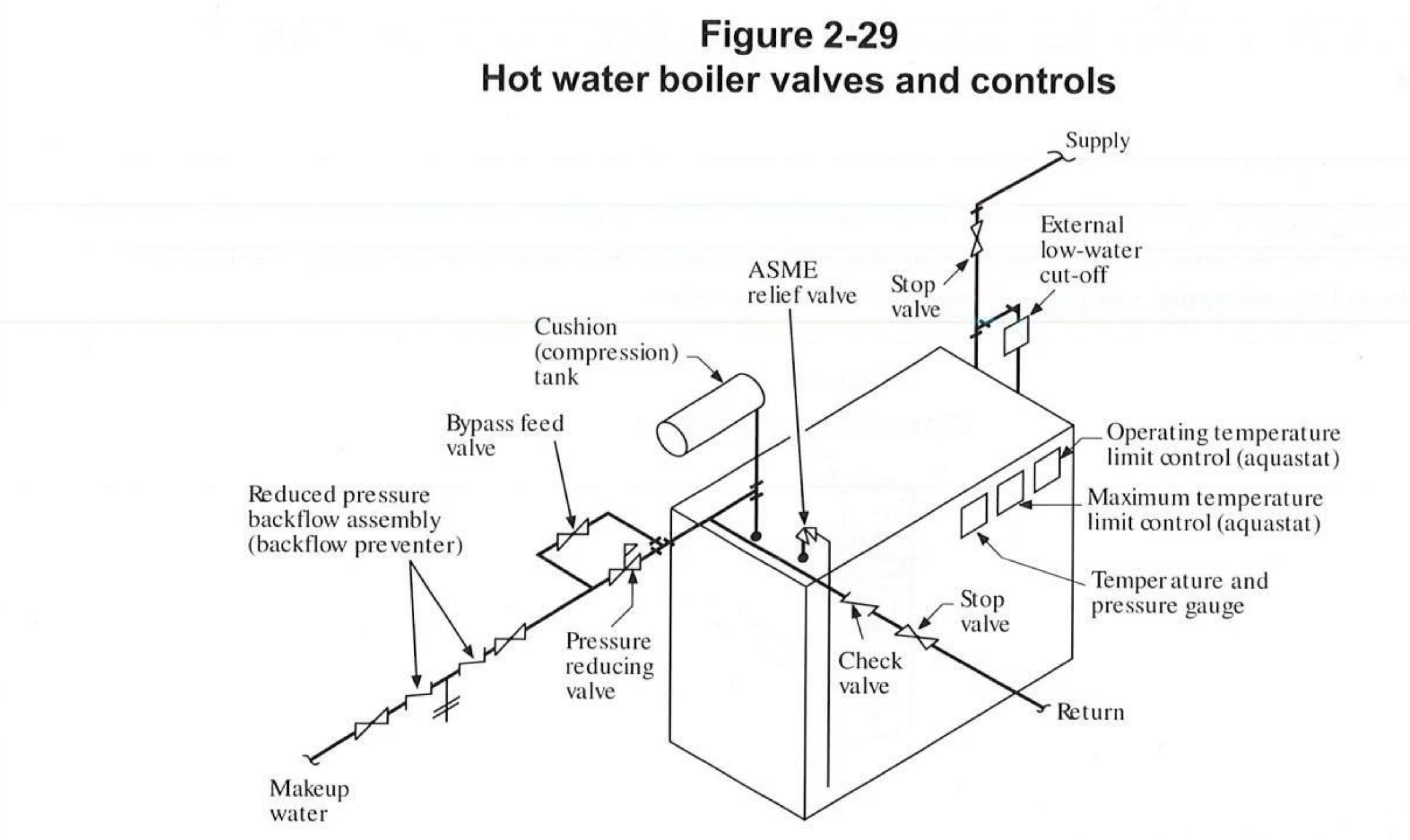
Temperature Control Devices

- Thermostats
- Mixing valves
- Reset controllers
- Temperature sensors

Differential Pressure Devices

- Pressure bypass valves
- Differential pressure regulators
- Pressure relief valves

Hot Water Heating System Valves and Controls



Common Components

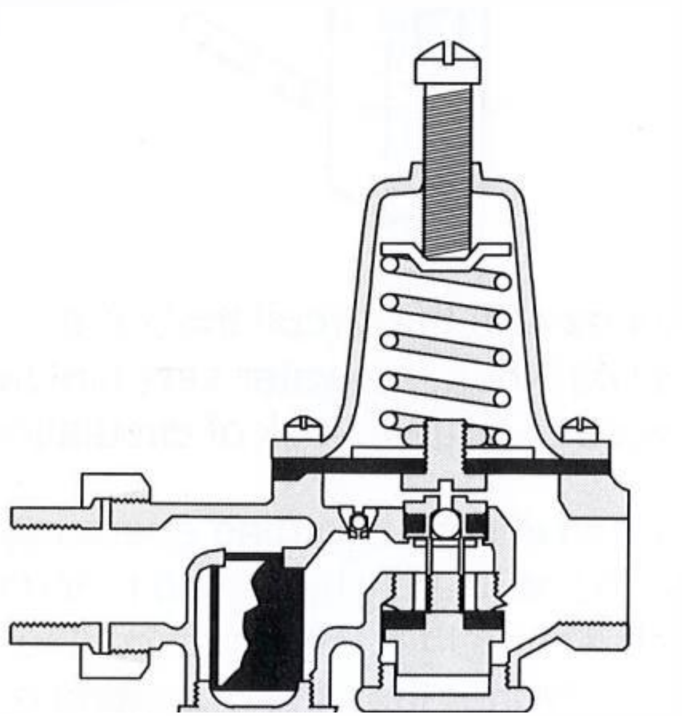
The image shows the valves and controls commonly found on a hot water boiler used to supply a hydronic heating system.

These components work together to ensure safe and efficient operation of the hydronic heating system, providing proper temperature control, pressure regulation, and safety protection.

Key Controls

- Pressure reducing valve - maintains proper system pressure
- Bypass feed valve - allows manual filling of the system
- Operating aquastat - controls water temperature at the desired level
- High limit aquastat - safety device that prevents overheating

Pressure Reducing Valve



Function

The pressure reducing valve is adjusted to open when the boiler pressure reaches a point below which it must not drop. The valve allows make-up water to enter the boiler to bring the boiler pressure up to the proper level.

This automatic function helps maintain the system at the correct operating pressure without manual intervention.

Installation Considerations

- Typically installed on the cold water make-up line
- Should be preceded by a backflow preventer to protect the potable water supply
- Usually set to maintain 12-15 psi in residential systems
- Higher settings may be required for taller buildings (add approximately 0.5 psi per foot of height)

Bypass Feed Valve/Fast-Fill Bypass

Function

A bypass feed valve helps fill a boiler with water manually. This valve is located in a parallel piping loop that bypasses the system's pressure reducing valve on the boiler's make-up water supply.

Important Safety Note

You should never install a bypass around the make-up water supply's backflow preventer.

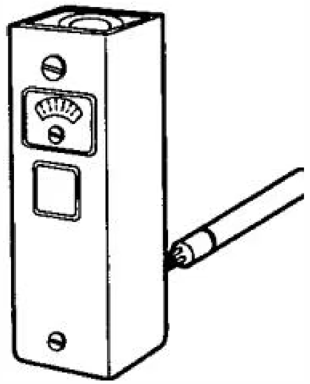
Usage

The bypass valve allows for faster filling of the system during initial setup or after service, significantly reducing the time required compared to filling through the pressure reducing valve alone.

Operation

When using the fast-fill bypass, continuously monitor the system pressure gauge to prevent exceeding the relief valve setting.

Operating Aquastat



Function

The operating aquastat, or low limit, is interlocked with the burner to control water temperature at the desired level. It senses water temperature and opens a switch to shut off the burner when the aquastat set point temperature is reached.

Operation

The operating aquastat functions as the primary temperature control for the boiler:

- When water temperature drops below the set point minus the differential, the aquastat closes its contacts to allow the burner to fire
- When water temperature reaches the set point, the aquastat opens its contacts to stop the burner
- This cycling maintains the water temperature within the desired range
- Typically set between 160°F and 180°F (71°C and 82°C) for most hydronic heating applications

High Limit Aquastat

Figure 2-32
High Limit aquastat

Function

A high limit or manual reset aquastat is a control device that senses water temperature and opens a switch when the aquastat set point temperature is reached.

A high limit aquastat is wired in series with the circuit that opens the burner gas valve. The gas valve closes, and the burner shuts off when the water set point temperature is exceeded.

Safety Features

- The operating temperature may be exceeded due to lack of circulation or operating aquastat failure
- A high limit aquastat is normally wired in series with an operating aquastat so that either one can shut off the burner
- A high limit aquastat usually has a red manual reset button
- You must push the reset button to close the switch if something has caused it to open
- The high limit aquastat is normally set 20 to 30°F (11 to 17°C) higher than the operating aquastat
- Unlike the operating aquastat, a manual reset high limit aquastat does not automatically close when the water temperature drops

Hydronic System Safety Devices

Pressure Relief Valve

Opens to release pressure if it exceeds the valve's setting, typically 30 psi for residential systems. Must be properly sized and certified for the boiler's BTU rating.

Low Water Cut-Off

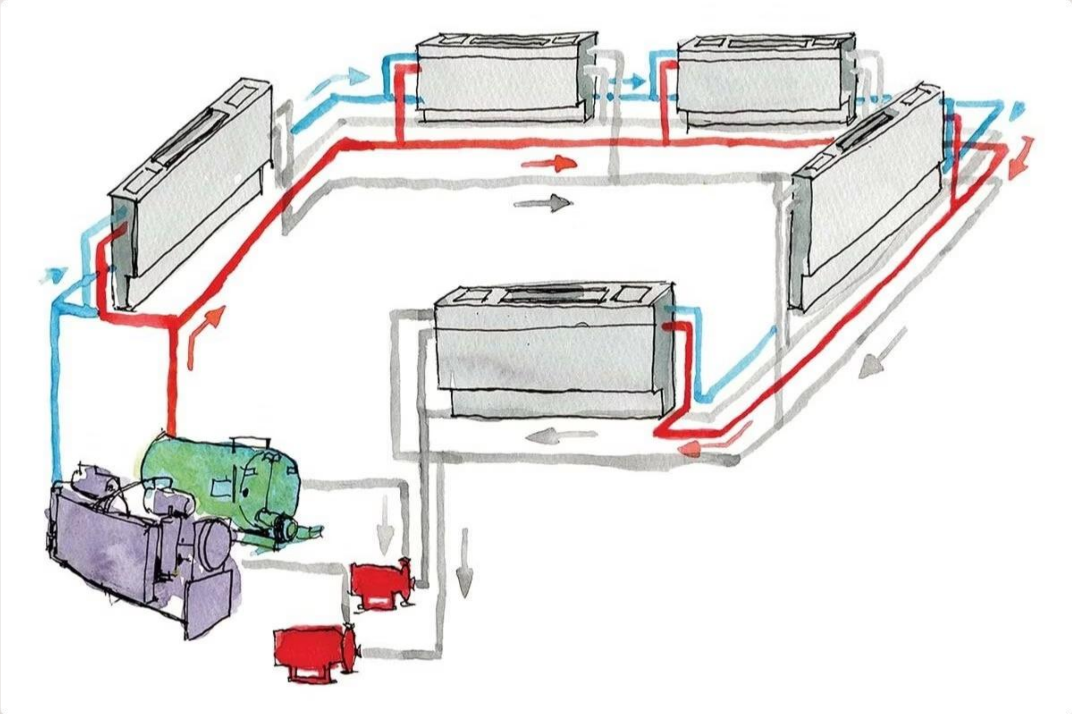
Shuts down the burner if water level drops below a safe level. Required for boilers with inputs of 400,000 BTU/h or greater.

Backflow Preventer

Protects potable water connections to a boiler from cross-contamination with non-potable boiler water or toxic substances.

High Limit Controls

Prevent the boiler from exceeding safe temperature limits. Manual reset types provide additional safety by requiring operator intervention after a high temperature event.



Hydronic System Quiz Questions

Question 1

What is installed to protect potable water connections to a boiler (make up water connections) from cross-contamination with non-potable boiler water or toxic substances?

Answer: Backflow preventer

Question 2

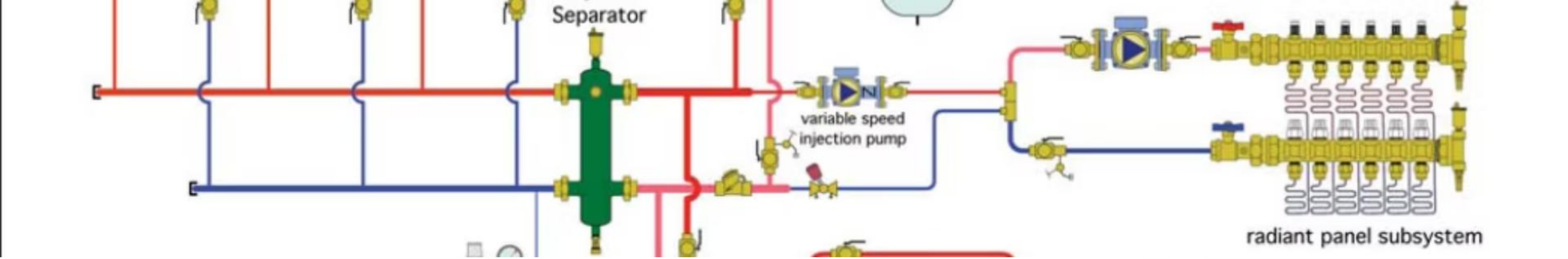
What is not an advantage of a hydronic heating system?

Answer: Fast reaction time

Question 3

What input would require a low water cut off for a hot water boiler?

Answer: 500 MBtu/h



More Hydronic System Quiz Questions

Question 4

What is used to connect multiple cast-iron boiler sections together into a boiler block assembly?

Answer: Tapered push-nipples

Question 5

Which type of boiler could be used to directly heat domestic water?

Answer: Copper fin-tube

Question 6

What is the result if flue gas combustion products are cooled below their dew point?

Answer: Condensation

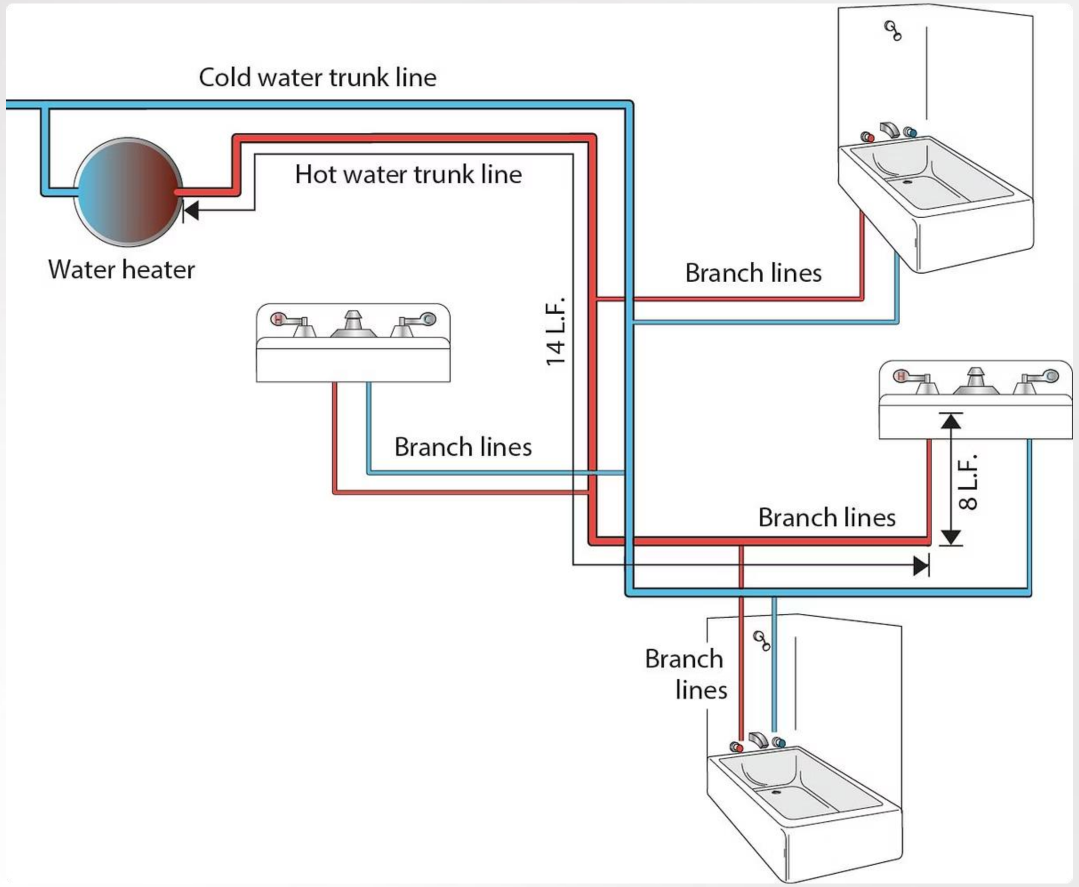
Question 7

Steel water tube boilers are commonly used for the production of hot water or steam.

Answer: True

Hydronic Distribution System Comparison

System Type	Advantages	Disadvantages	Best Applications
Series Loop	Simple design, less piping, lower cost	Limited zone control, temperature drop across system	Small spaces with similar heating needs
One-Pipe Monoflo	Less piping than two-pipe, individual unit control	Not suitable for high head-loss units, limited heat load	Medium-sized residential applications
Two-Pipe Direct Return	Individual unit control, consistent supply temperature	Requires careful balancing, more piping	Larger residential and light commercial
Two-Pipe Reverse Return	Self-balancing, consistent flow rates	Most piping required, higher cost	Commercial and larger residential systems
Primary/Secondary	Hydraulic separation, multiple temperature zones	More complex, requires multiple circulators	Mixed-use buildings, multiple temperature requirements



Hydronic System Flow Rates

500

BTU/h per GPM

For each 1°F temperature drop across a load

10,000

BTU/h per GPM

For a typical 20°F temperature drop

4

Feet per Second

Maximum recommended flow velocity in copper piping

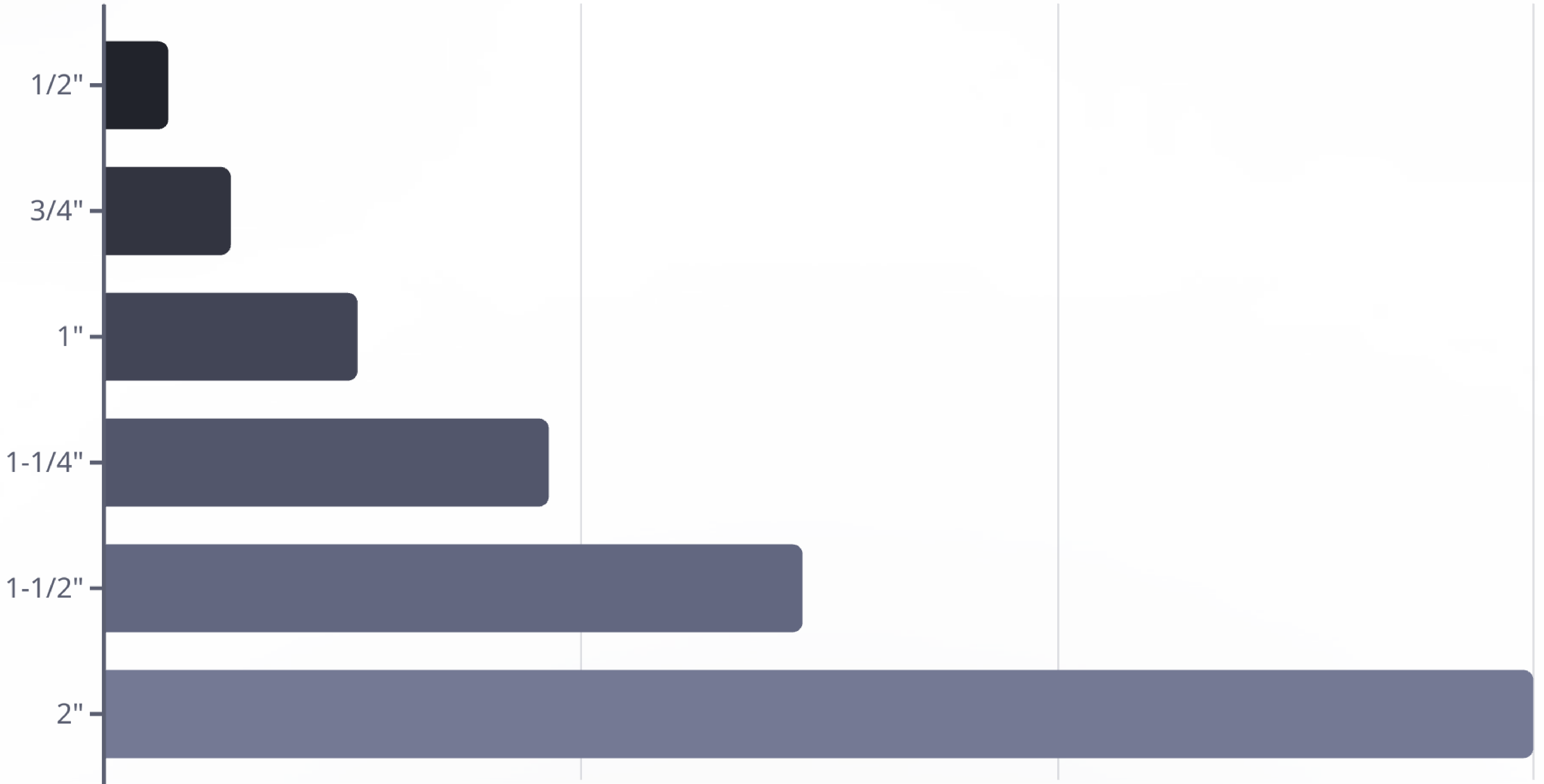
2

Feet per Second

Recommended flow velocity for quiet operation

Flow rate is a critical factor in hydronic system design. The formula $Q = 500 \times GPM \times \Delta T$ relates heat transfer (Q in BTU/h) to flow rate (GPM) and temperature difference (ΔT in °F). Proper flow rates ensure efficient heat transfer while preventing issues like erosion, noise, and excessive head loss.

Hydronic System Pipe Sizing



Hydronic System Zoning Methods

Zone Valve Method

In this approach, a single circulator pumps water through the entire system, while electrically operated zone valves control flow to individual zones.

- Advantages: Lower initial cost, less electrical consumption, simpler wiring
- Disadvantages: Single point of failure (circulator), valve noise, limited by circulator capacity
- Best for: Smaller systems with 2-4 zones of similar size

Zone Pump Method

This method uses a dedicated circulator for each zone, eliminating the need for zone valves.

- Advantages: Redundancy (if one pump fails, other zones still work), better flow control, quieter operation
- Disadvantages: Higher initial cost, more electrical consumption, more complex wiring
- Best for: Larger systems, zones with different flow requirements, critical applications

Hydronic System Temperature Control

Sensing

Temperature sensors monitor system conditions at key points

Control Logic

Controllers compare actual temperatures to setpoints and determine required actions

Mixing

Mixing valves or injection systems blend supply and return water to achieve target temperatures

Distribution

Properly tempered water is circulated to heat emitters throughout the building

Modern hydronic systems often employ outdoor reset control, which automatically adjusts water temperature based on outdoor conditions. This improves comfort and efficiency by providing only as much heat as needed for current weather conditions.

Hydronic System Pressure Control

System Pressure Requirements

Hydronic systems must maintain sufficient pressure to prevent boiling at the highest temperature point and to ensure proper circulation throughout the system. Typical residential systems operate at 12-15 psi at the fill point.

Static Height Considerations

System pressure must increase by approximately 0.5 psi for each foot of height above the pressure gauge. A three-story building might require 18-20 psi at the fill point to ensure adequate pressure at the highest point.

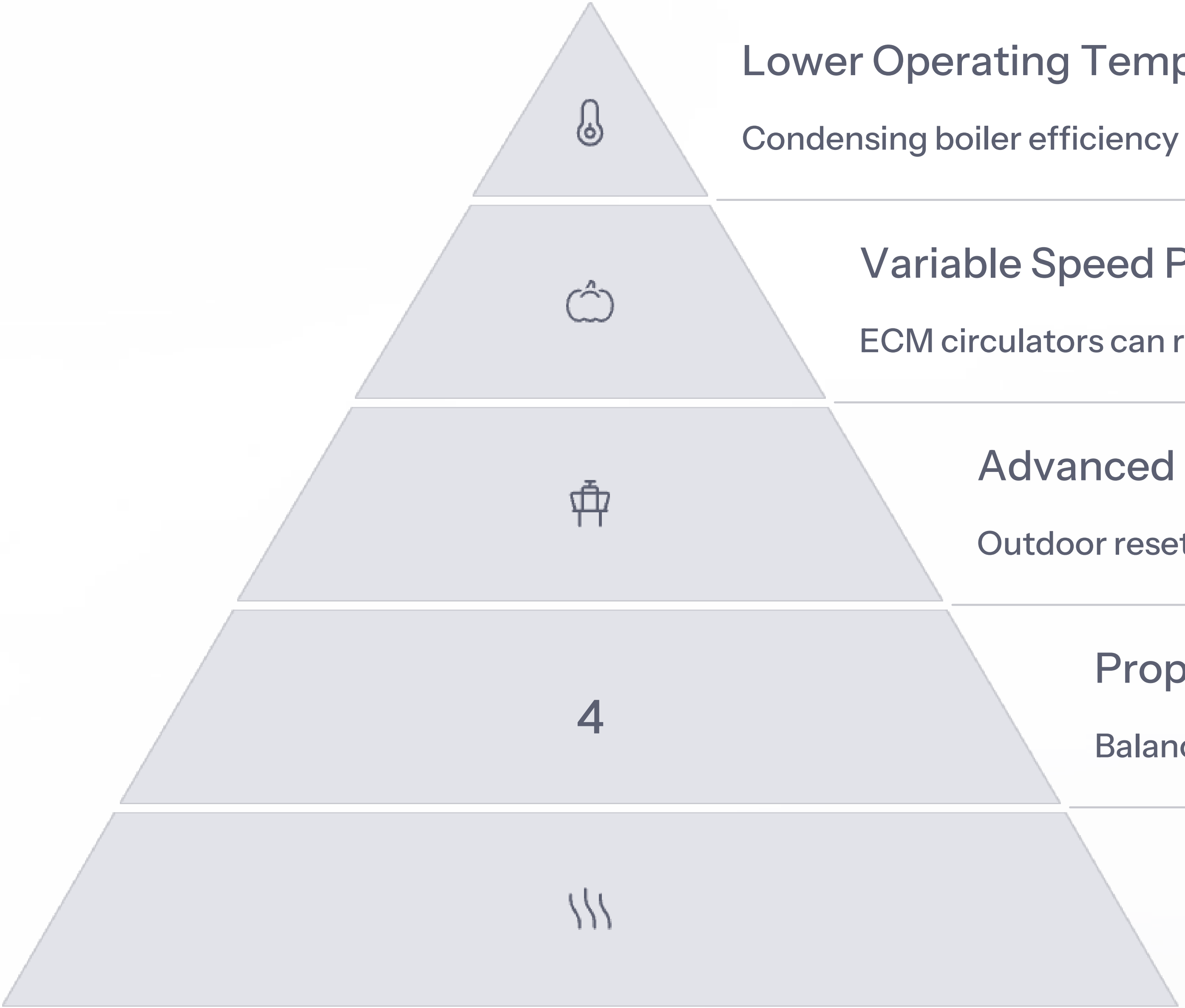
Expansion Accommodation

The expansion tank must be properly sized to accommodate the increased volume of water as it heats without exceeding the relief valve setting (typically 30 psi).

Safety Relief

A properly sized pressure relief valve provides the final safety measure against excessive pressure, protecting the system components from damage.

Hydronic System Efficiency Factors



Lower Operating Temperatures

Condensing boiler efficiency increases dramatically at lower return water temperatures

Variable Speed Pumping

ECM circulators can reduce pumping energy by 60-80%

Advanced Controls

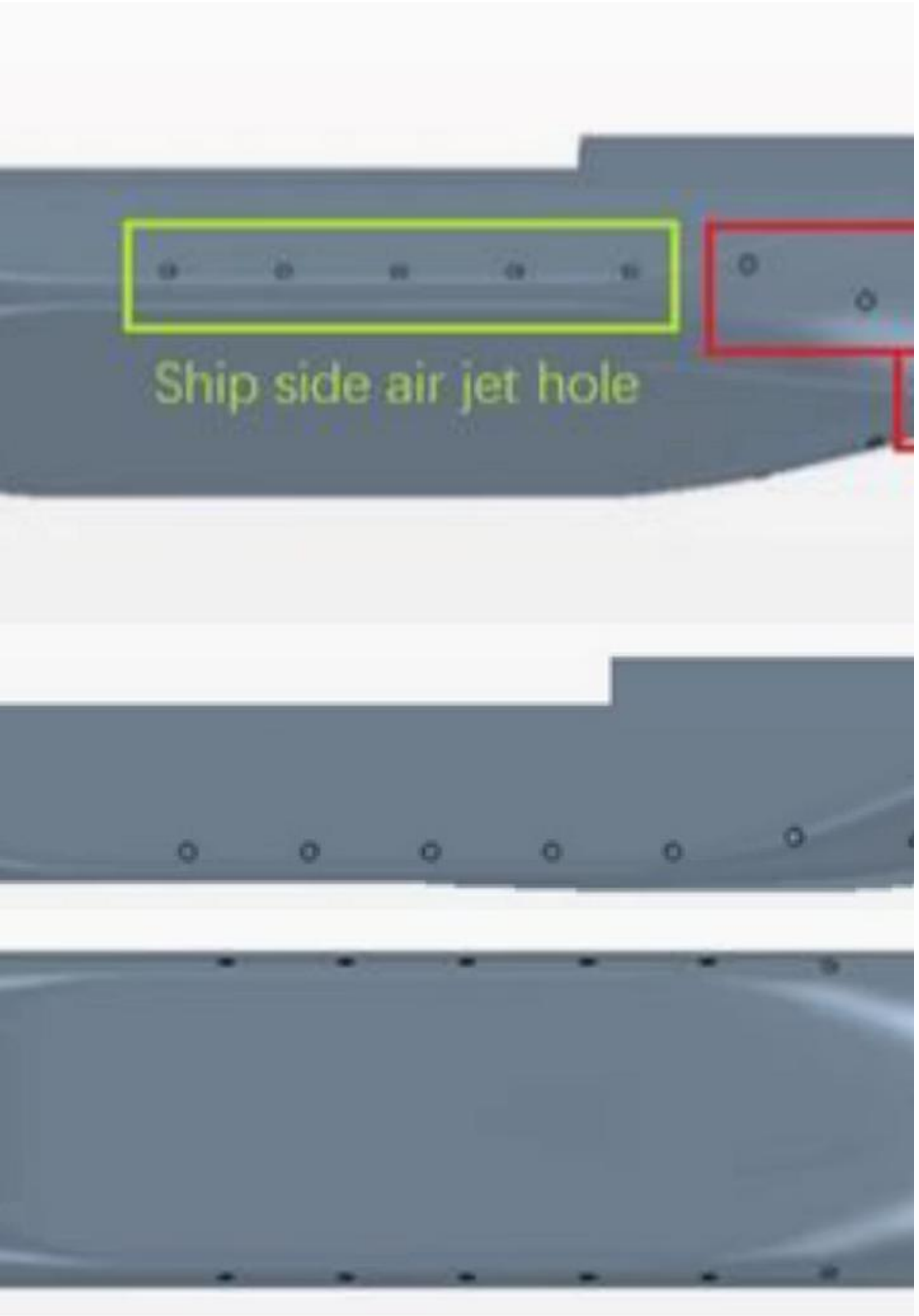
Outdoor reset, indoor feedback, and smart controls optimize operation

Proper Distribution Design

Balanced flow, hydraulic separation, and proper pipe sizing minimize waste

High-Efficiency Heat Source

Modern condensing boilers can achieve 95%+ efficiency



Hydronic System Troubleshooting: Air Problems

Symptom: Noise

Gurgling, bubbling, or water hammer sounds indicate air in the system. Noise is often most noticeable at startup or when flow rates change.

Symptom: Poor Heat Transfer

Air pockets can block or reduce flow, causing cold spots in radiators or uneven heating throughout the system.

Symptom: Circulator Issues

Air can cause circulators to lose prime, operate inefficiently, or become damaged due to cavitation.

Solution: Systematic Air Removal

Proper purging during filling, installation of effective air elimination devices, and addressing the root cause of air entry are essential for resolving air problems.

Hydronic System Troubleshooting: Flow Problems

Insufficient Flow

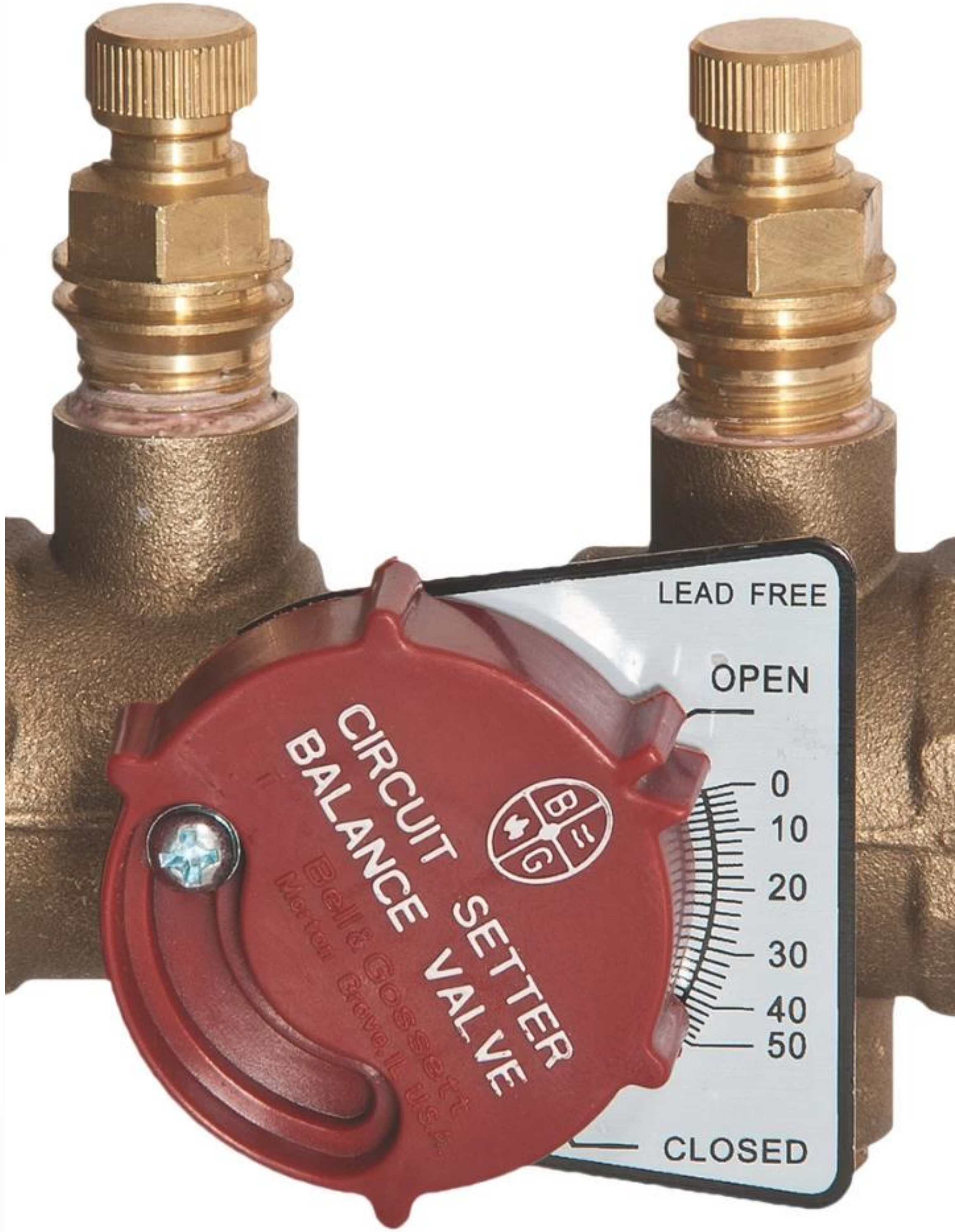
- Symptoms: Poor heat transfer, large ΔT across heat emitters
- Causes: Undersized circulator, closed/partially closed valves, clogged strainers, air locks
- Solutions: Verify valve positions, clean strainers, check circulator operation, purge air

Unbalanced Flow

- Symptoms: Some zones overheating while others remain cool
- Causes: Improper balancing, path of least resistance issues
- Solutions: Install and adjust balancing valves, verify proper system design

Velocity Noise

- Symptoms: Rushing or whistling sounds in piping
- Causes: Excessive flow velocity, typically over 4 ft/sec
- Solutions: Reduce pump speed, open balancing valves, address pipe sizing issues



Hydronic System Troubleshooting: Temperature Problems

Insufficient Heat

- Symptoms: Building doesn't reach setpoint temperature
- Causes: Boiler temperature too low, insufficient flow, undersized components
- Solutions: Check boiler operation and settings, verify proper sizing, ensure adequate flow

Overheating

- Symptoms: Building or zones too hot, frequent cycling
- Causes: Improper control settings, oversized components, control failures
- Solutions: Adjust control settings, check for stuck valves, verify proper operation of aquastats

Temperature Swings

- Symptoms: Cyclical temperature variations in the building
- Causes: Improper control settings, system oversizing, poor thermostat placement
- Solutions: Implement outdoor reset control, adjust differentials, relocate thermostats

Hydronic System Maintenance Schedule

Monthly Checks

- Visual inspection for leaks
- System pressure verification
- Check for unusual noises

Seasonal Maintenance

- Check expansion tank pressure
- Inspect air vents for proper operation
- Test zone valves and circulators
- Verify control settings and operation

Annual Service

- Clean or replace strainers
- Check water quality and treat if necessary
- Inspect and test safety devices
- Verify proper flow rates and balance if needed

Every 3-5 Years

- Inspect expansion tank for proper operation
- Consider system flush if performance has degraded
- Evaluate overall system efficiency

Hydronic System Water Quality

Common Water Issues

- Corrosion: Caused by oxygen, low pH, or galvanic reactions between dissimilar metals
- Scale: Calcium and magnesium deposits that reduce heat transfer and restrict flow
- Biological growth: Bacteria and algae that can cause fouling and odors
- Sediment: Particulate matter that can clog components and cause wear

Treatment Options

- Inhibitors: Chemicals that form protective films on metal surfaces
- pH adjusters: Maintain proper pH levels (typically 7.5-9.5 for hydronic systems)
- Oxygen scavengers: Remove dissolved oxygen to prevent corrosion
- Biocides: Prevent biological growth in the system
- Glycol solutions: Provide freeze protection and often include inhibitor packages

Note: Chemical additives may not be introduced into open-type combination systems. Where they are added to closed systems, provisions must be implemented to avoid cross-contamination.

Hydronic System Design Best Practices

Proper Load Calculation

Accurate heat loss calculation is the foundation of good system design

Appropriate Component Sizing

Right-size boilers, circulators, and piping for efficiency and performance

Hydraulic Separation

Prevent unwanted flow interactions between system components

Effective Air Management

Design for proper filling, purging, and continuous air elimination

Intelligent Control Strategies

Implement outdoor reset, variable speed pumping, and zone control

Future Trends in Hydronic Heating

Low Temperature Distribution

Systems designed to operate at lower temperatures (95-120°F) for maximum efficiency with condensing boilers and heat pumps.

Renewable Integration

Hydronic systems increasingly paired with solar thermal, air-to-water heat pumps, and geothermal sources.

Smart Controls

AI-driven predictive controls that learn building characteristics and occupant patterns to optimize comfort and efficiency.

Energy Storage

Thermal storage solutions that allow systems to shift loads and integrate with variable renewable energy sources.

The future of hydronic heating lies in its ability to efficiently distribute heat from diverse energy sources while providing superior comfort. As building envelopes improve and energy codes become more stringent, hydronic systems will continue to evolve toward lower temperatures, smarter controls, and seamless integration with renewable energy sources.

Boiler Control Systems and Components

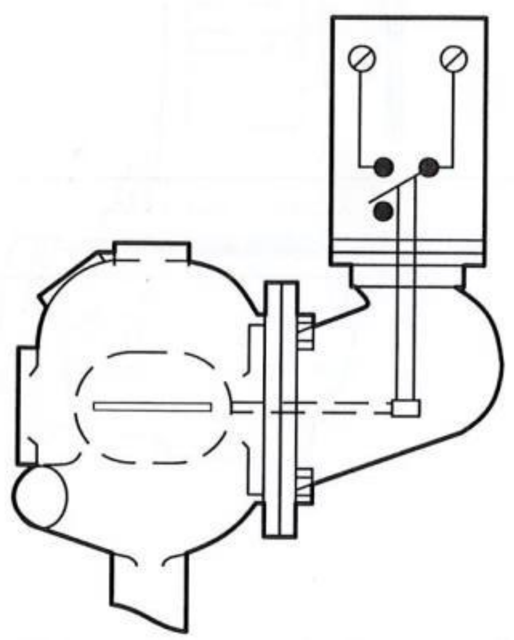
This presentation covers essential components and control systems for hydronic boilers, including safety devices, flow control mechanisms, temperature regulation, and zoning strategies. Understanding these components is crucial for proper installation, maintenance, and troubleshooting of hydronic heating systems.

Low Water Cut-Off

Function and Requirements

The low water cut-off is interlocked with the burner and will cause the burner to shut down if the water level in the boiler drops below a set level (Figure 2-33). Low water cut-offs are required on all steam boilers and typically on hot water boilers rated in excess of 400 MBH (120 kW).

Figure 2-33
Float-type low water cut off



ASME Relief Valve

Certification

Relief valves with the ASME (The American Society of Mechanical Engineers) symbol have undergone testing and received approval under the ASME Boiler and Pressure Vessel Code. They are rated by their discharge capacity in Btu/h.

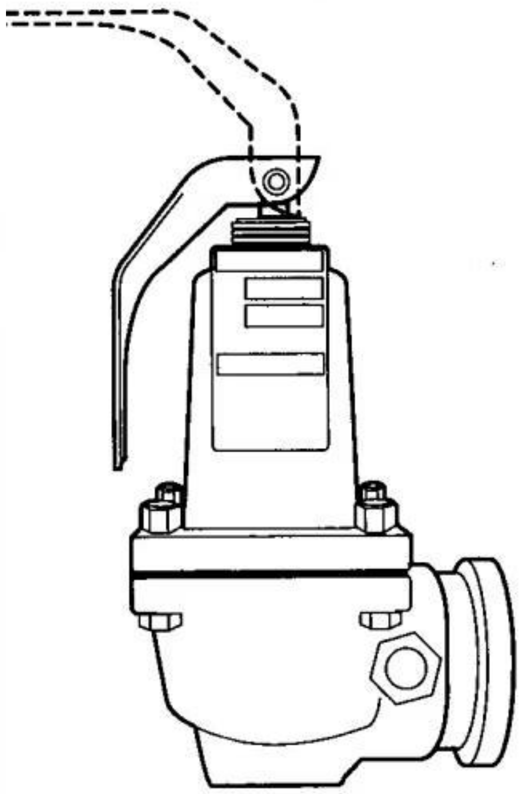
Operation

Relief valves operate on thermal expansion pressure and/or steam pressure (Figure 2-34). A relief valve that meets ASME requirements helps protect a boiler from rupturing if the boiler's working pressure is exceeded.

Installation Guidelines

You may install multiple, lower-capacity ASME relief valves to total the capacity of the boiler. Install relief valves close to or directly into the top of the boiler, at the point of no pressure change, and with no shut-off valve between them and the boiler.

Figure 2-34
Relief valve



Relief Valve Installation Requirements

Proper Sizing

Ensure that the relief valve discharge drain line has the same size as the relief valve outlet fitting.

Safety Precaution

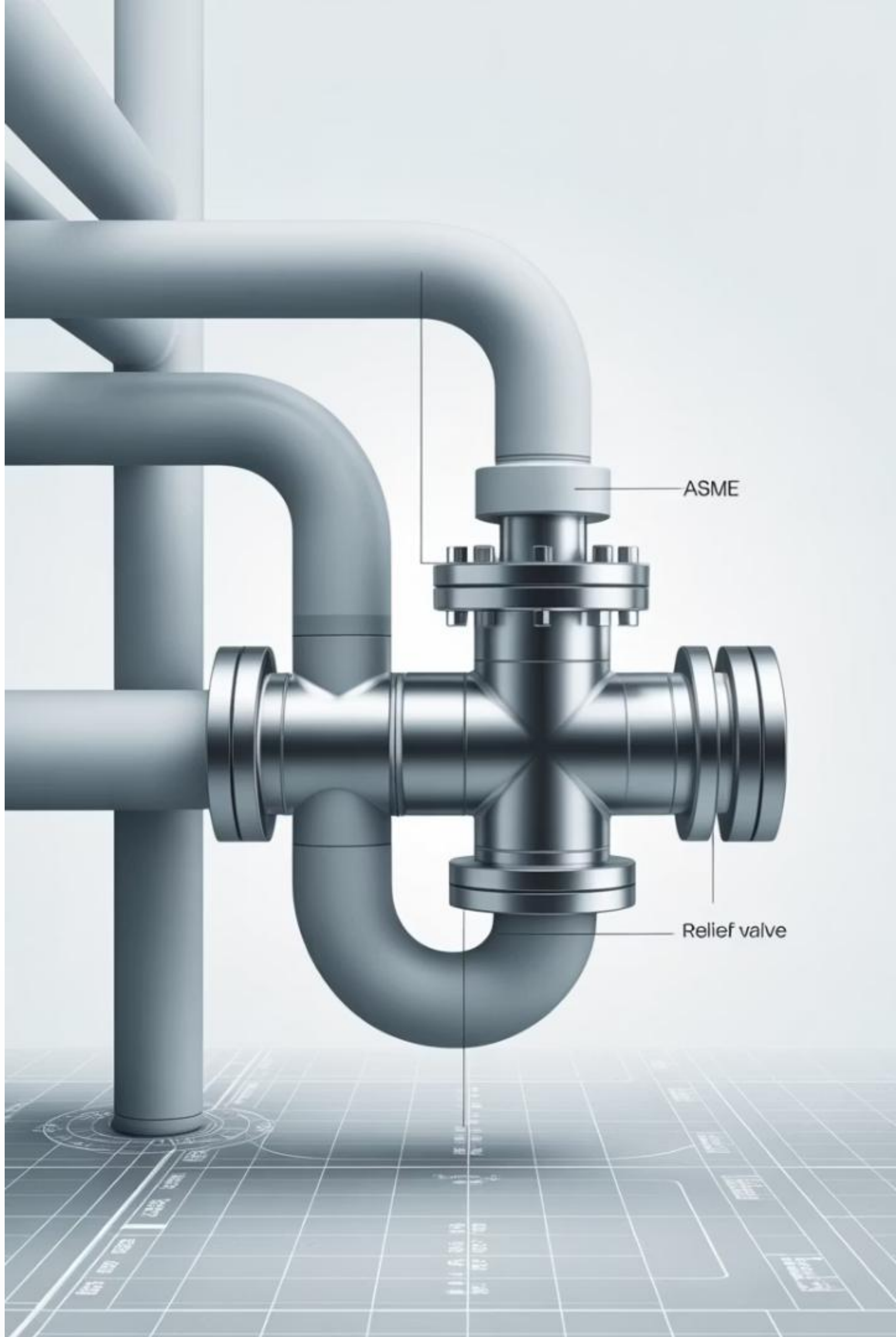
Never install a shut-off valve in a relief valve drain line.

Multiple Valves

You may install multiple, lower-capacity ASME relief valves to total the capacity of the boiler.

Positioning

Install relief valves close to or directly into the top of the boiler, at the point of no pressure change.



Backflow Preventer

Definition and Purpose

Backflow is defined as a reversal of the normal direction of flow. This can be a result of either back-siphonage or back-pressure.

The primary purpose of the device is to prevent water and or any chemicals in the heating system from flowing into the domestic water supply piping. A properly selected and installed backflow preventer only allows water to flow in one direction.

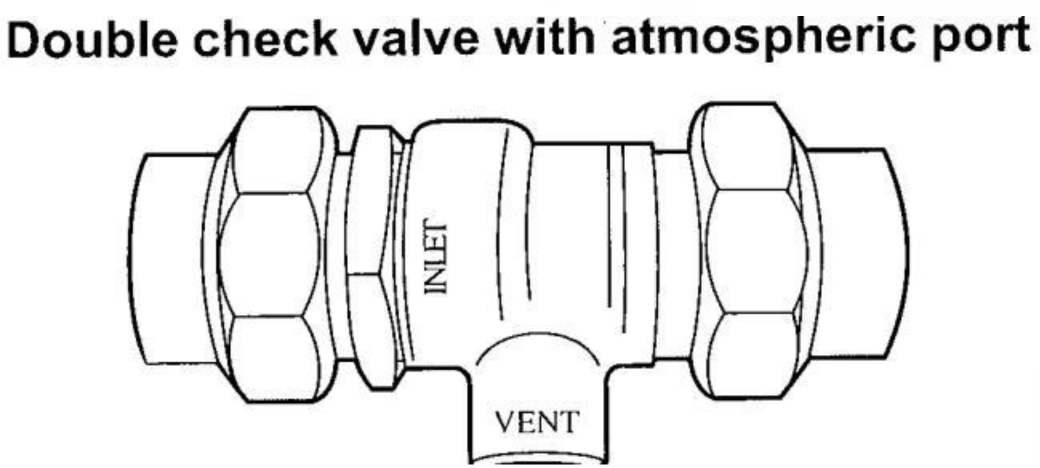
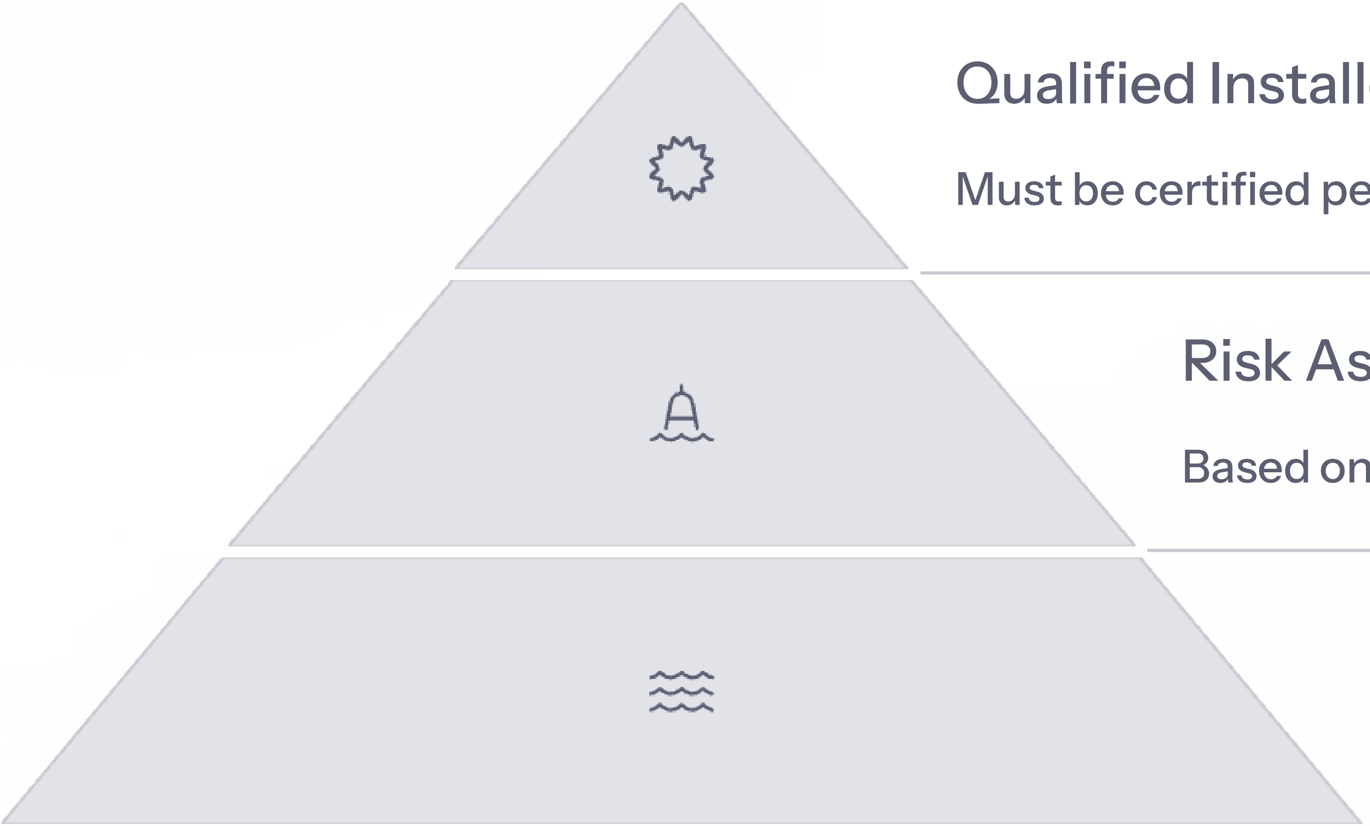


Figure 2-35

Note: The valve in Figure 2-35 is not a "testable" device. It is only used for backflow prevention where "moderate" hazards of cross-contamination exist and cannot be utilized in many other instances.

Installation Requirements for Backflow Preventers



Qualified Installer

Must be certified per Authority Having Jurisdiction

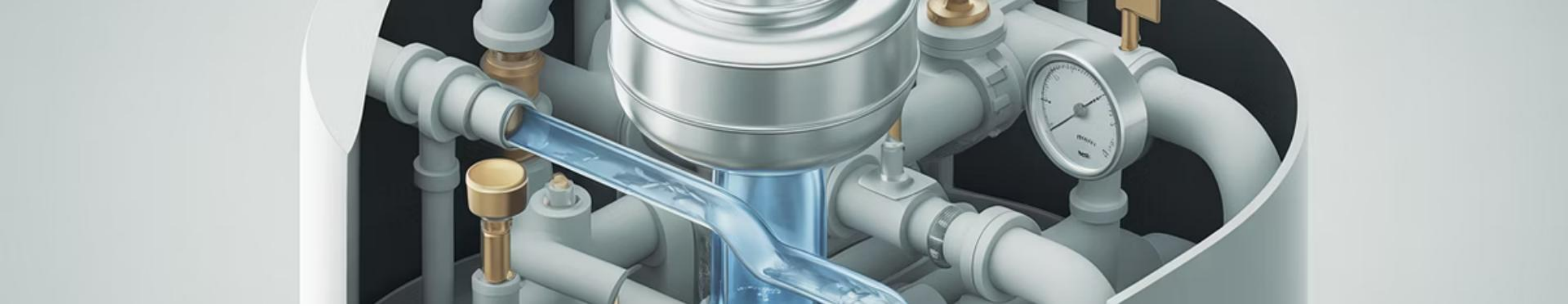
Risk Assessment

Based on potential for cross contamination

System Integration

Proper placement in hydronic system

Wherever the potential for cross contamination may occur, a qualified installer as per the Authority Having Jurisdiction must select and install a requirement to have a backflow preventer. (In Ontario, a plumber that carries a backflow prevention tester certificate is required.)



Mechanical Water Feed for Steam Boiler

Function

A mechanical water feed helps maintain the correct water level in a steam boiler.

Operation

You open or close a valve in response to the movement of a float or other sensing device located at the desired water level in the boiler.

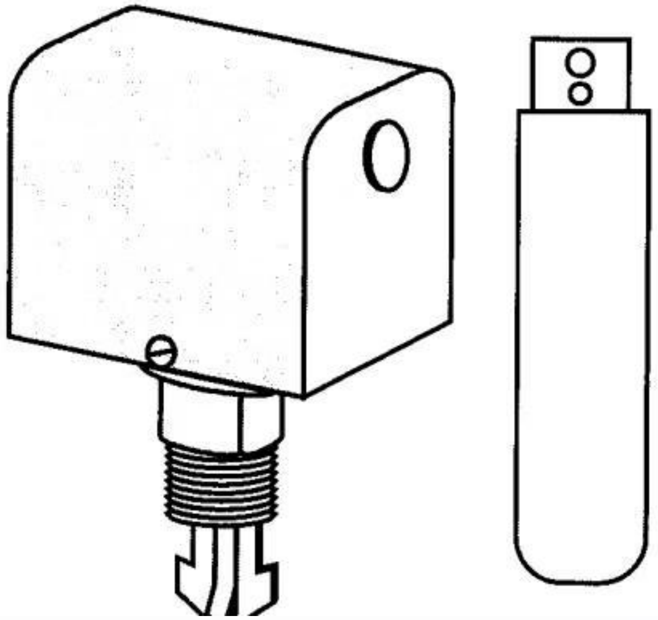
Flow (Pressure) Switch

Function

A flow (or pressure) switch (Figure 2-36) shuts off the boiler burner(s) if the water flow is too low.

This is achieved either by water flowing through the system moving a paddle that operates the switch or the sensing of water pressure with a pressure sensing switch.

Figure 2-36
Flow switch



Flame Rollout Switch

Purpose and Function

The flame rollout switch (Figure 2-37) is a device for sensing problems in the flow of combustion products.

These problems may result from blockages in the heat exchangers and flue and may be a failure of a combustion air-blower or exhaust blower to function properly, which could lead to flame rollout.

If the switch senses flame rollout, it causes the burner to shut down.

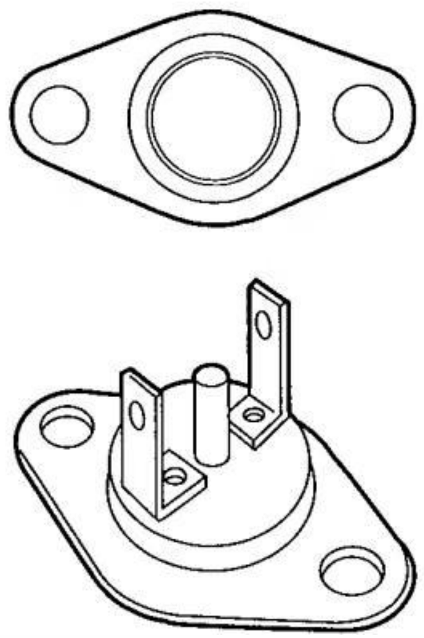


Figure 2-37 Flame rollout switch

Troubleshooting Flame Rollout Issues

Identify the Problem

If flame rollout switch has tripped, inspect for blockages in heat exchangers and flue.

Check Blower Operation

Verify that combustion air-blower and exhaust blower are functioning properly.

Remove Blockages

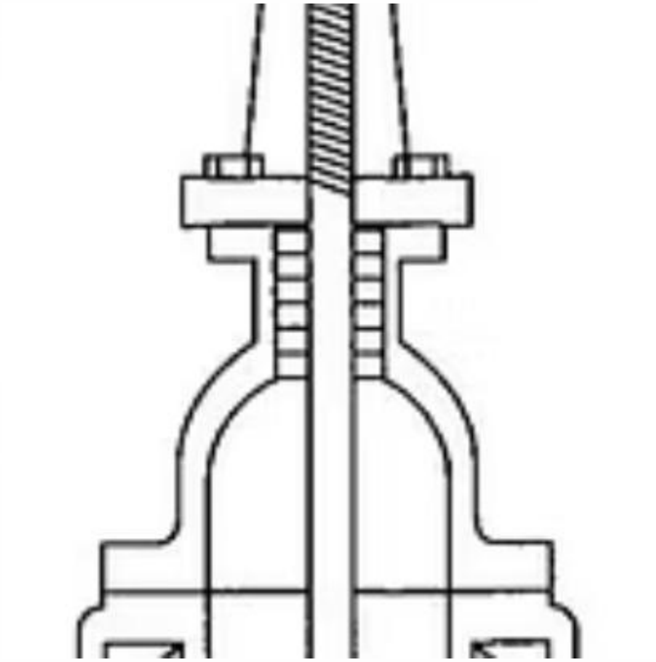
Clear any obstructions in the heat exchanger or flue passages.

Reset System

After correcting the cause, reset the flame rollout switch and test system operation.

Flow Control Devices

The following valves and other devices help control the flow of water through hydronic systems.



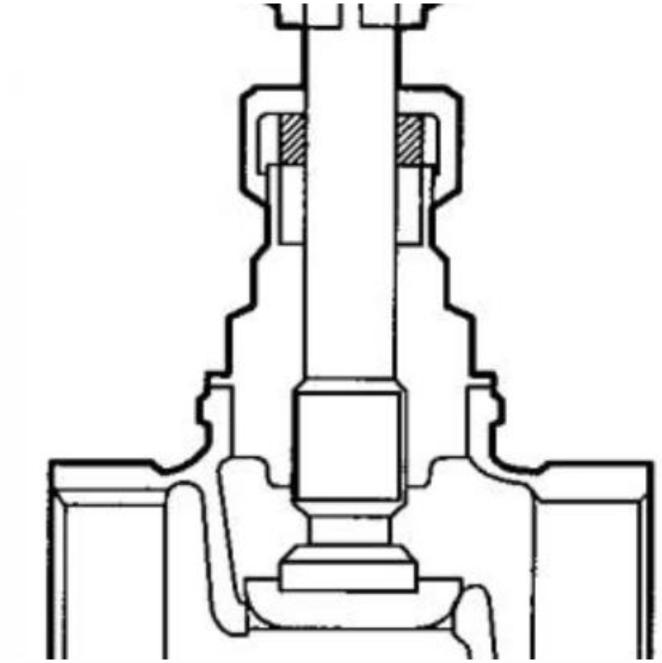
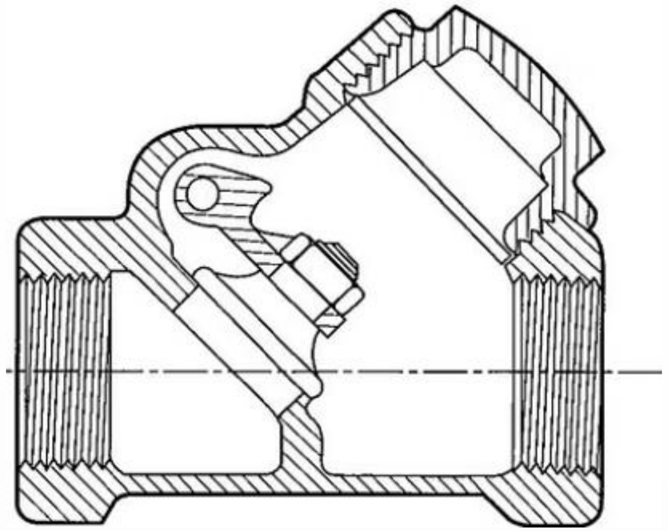
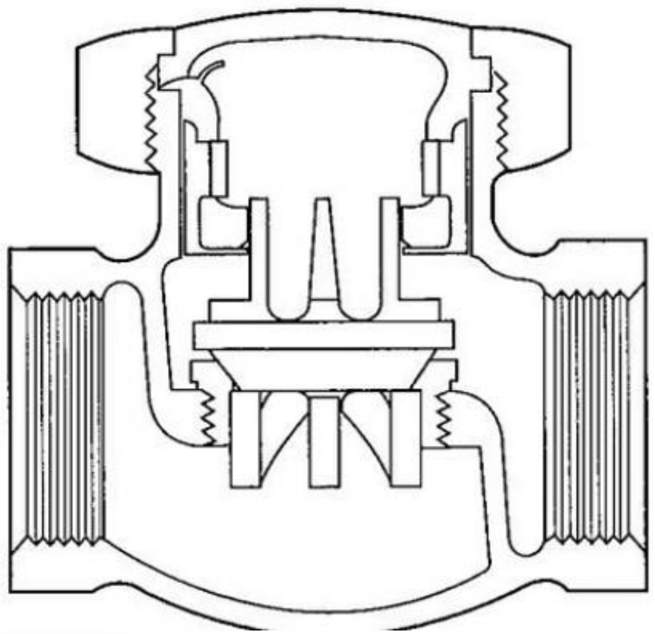


Figure 2-40
Swing check valve



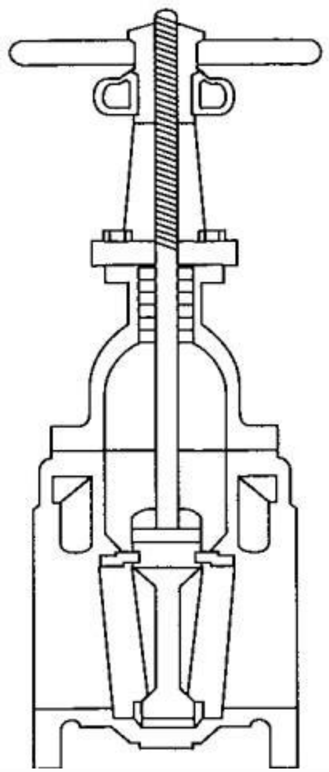


Gate Valve

Purpose and Function

Gate valves (Figure 2-38) are used in hydronic systems for isolation purposes only. They are not designed for flow throttling.

Figure 2-38
Gate valve



Globe Valve

Applications

You can use globe valves (Figure 2-39) for throttling flow, but their main service application is balancing.

The greater the number of the valve handle from fully open to fully closed, the finer you can control the flow.

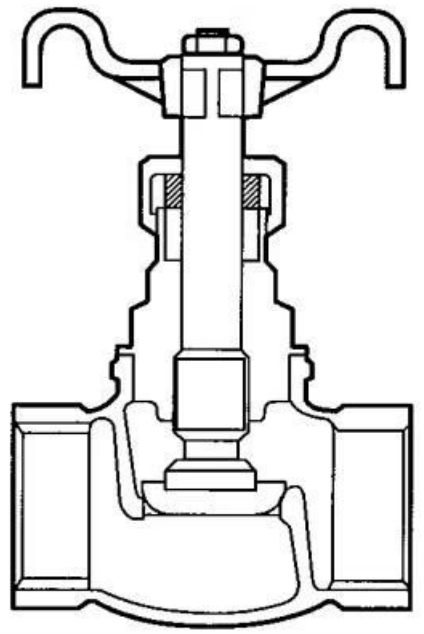


Figure 2-39 Globe valve

Check Valves Overview

Definition

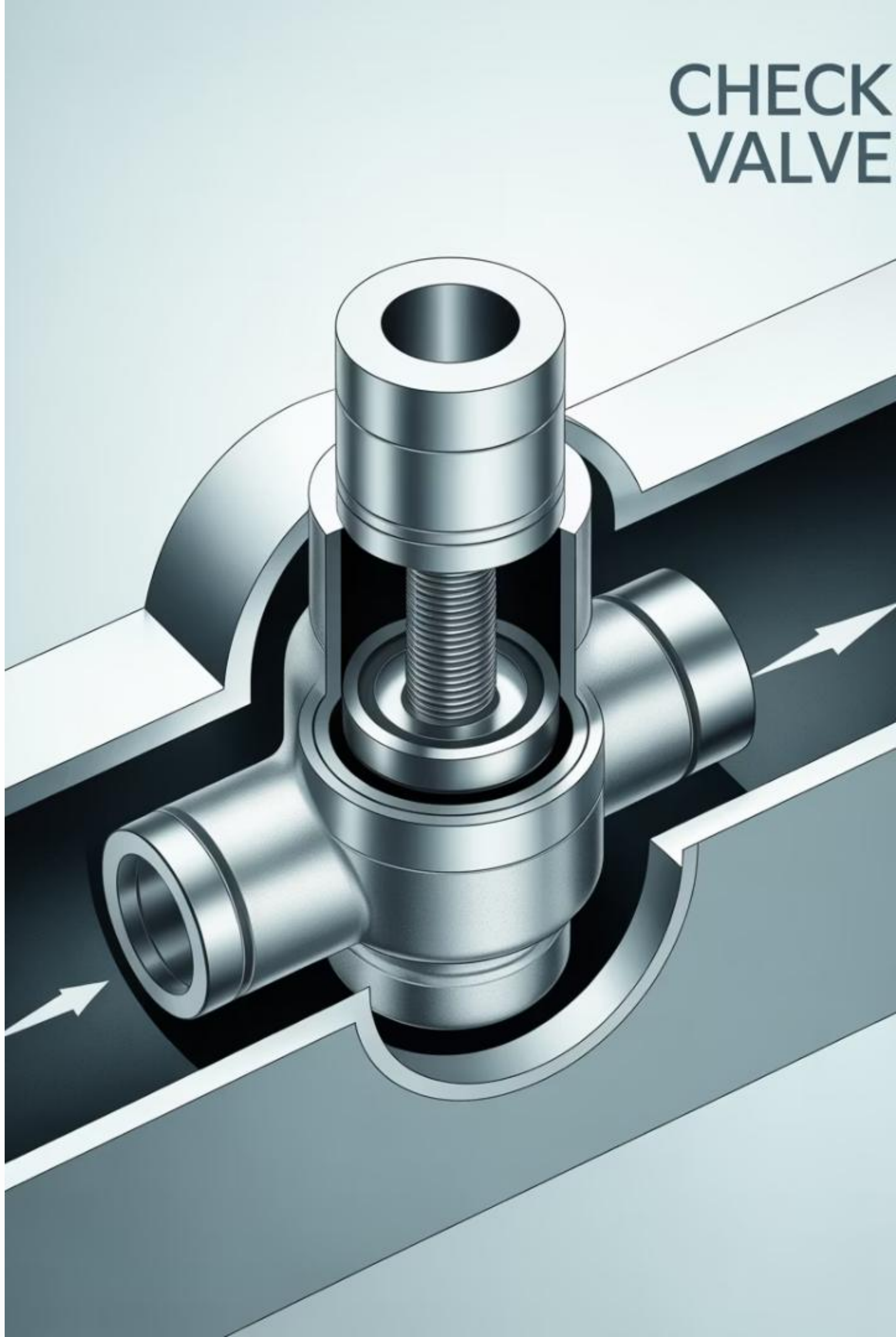
Check valves are sometimes referred to as a non-return valve. They are normally closed valves that open to permit flow in one direction, but close to prevent flow in the reverse direction.

Closing Mechanism

They may close due to gravity or be aided with a spring.

Common Types

There are two common types available: swing check and lift check.



Swing Check Valve

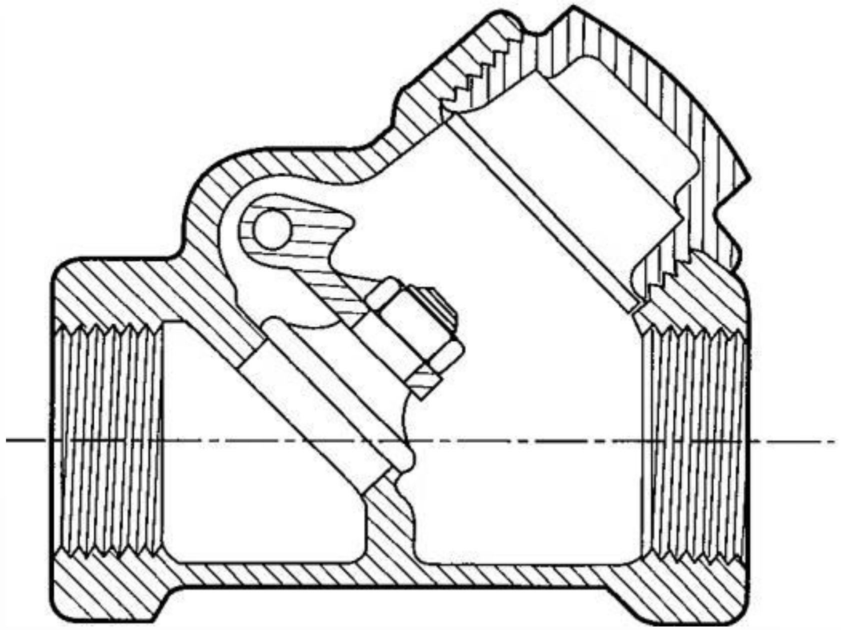
Operation

A swing check valve has a disc that swings on a hinge pin (Figure 2-40). When water flow reverses the disc is pushed against a valve seat, preventing backflow.

Installation

You must install swing check valves horizontally for effective operation. Check orientation for proper installation.

Figure 2-40
Swing check valve



Lift Check Valve

Operation

The disc of a lift check valve (Figure 2-41) rises from the valve seat with upward flow pressure. A reversal in flow pushes the disc down against the seat, stopping backflow.

Characteristics

A lift check valve has greater resistance to flow than a swing check valve but is more suitable for rapid operation cycles.

Installation

Lift check valves are available for horizontal and vertical applications.

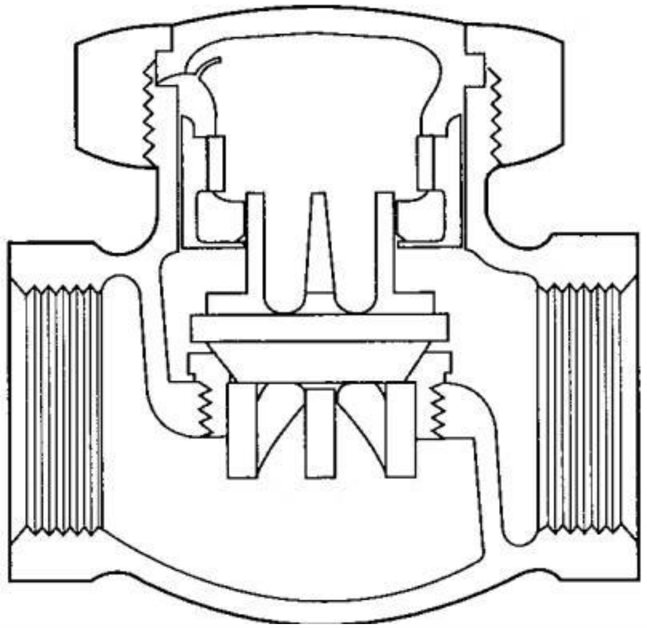


Figure 2-41 Lift check valve

Flo Check Valves

Function and Application

A Flo check (Figure 2-42) is a special type of flow control valve that is usually installed in a supply line of a heating circuit.

This device is a normally closed valve that stays closed when the circulator is not operating. Its function is to prevent gravity circulation of hot water in circuits that are not calling for heat.

Flo checks are typically required when you use circulators, instead of zone valves, for zone control.

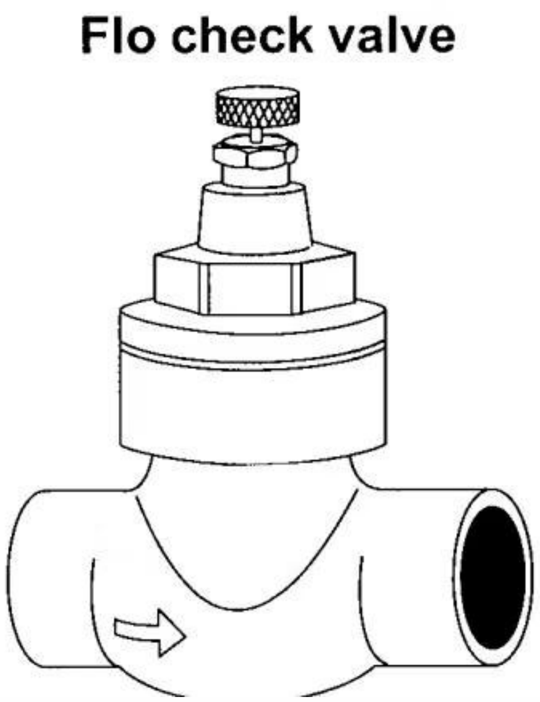


Figure 2-42

Three-Way Diverting Valve

One inlet port

Receives flow from system

Valve mechanism

Controls flow direction

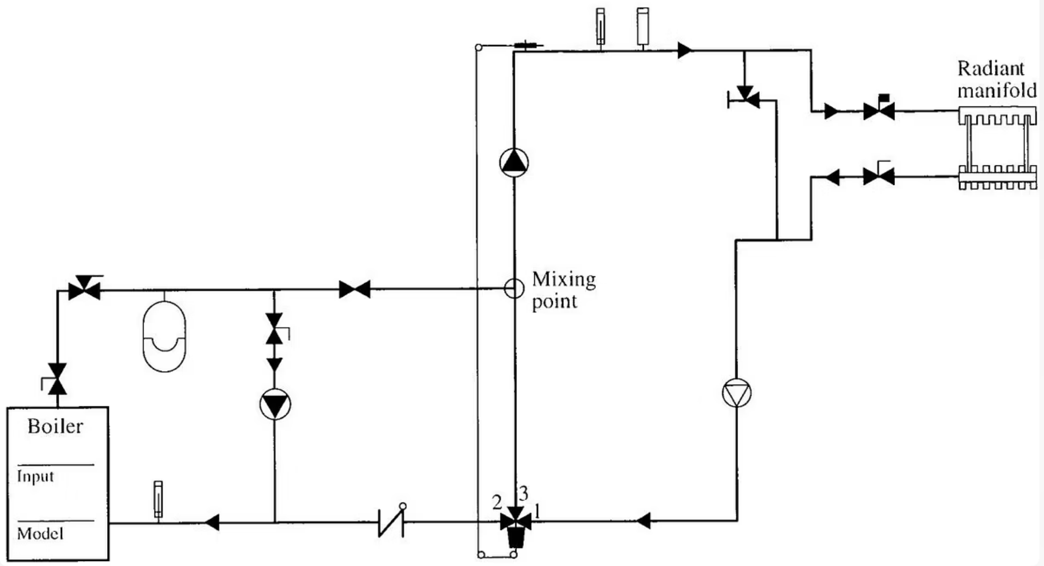
Two outlet ports

Directs flow to different paths

As its name implies, the three-way diverting type of valve is designed to divert flows (Figure 2-43). Flow can be supplied to one or both of the outlet ports, depending on the positioning of the two valve discs.

Three-Way Diverting Valve Operation

Three-way diverter valve application



As water temperature	Then the valve seat
Increases	Closes, diverting flow to the boiler bypass outlet
Decreases	Opens, allowing water to flow through the valve to the boiler where it will be heated

A three-way diverting valve operates like a thermostatic radiator valve with three ports. The two valve disks are mounted to the main spring-loaded stem. Pushing down on the valve-head pin changes the position of the valve discs.

An arrow on the valve body indicates the direction of flow through the valve.

Diverting Valve in Radiant Floor Systems

Cold Return Water

From radiant floor panels

Diverting Valve

Splits flow in two directions

Mixed Supply

Combined with hot boiler water

Boiler Heating

Portion sent to boiler for reheating

If the valve is used as a diverter in a radiant floor heating system, it must be installed in the return side of the system. The valve will divert the colder return water flow into two directions. Some of the return water will flow to the boiler to be reheated. The rest will bypass the boiler and be mixed with hot boiler water in the system supply pipe.

The mixture of hot supply water and cold return water is required by low-temperature radiant floor heating panels.

Temperature Control Devices

Valve Drive Mechanisms

Control valve operation based on temperature changes

Thermostatic Radiator Valves

Regulate flow to individual heating units

Injection Valves

Control water flow for heating or cooling applications

Mixing Valves

Blend water of different temperatures

Temperature Controllers

Maintain desired system temperatures

Reset Controls

Adjust system based on indoor/outdoor conditions

Thermostatic and Manual Bypass Valves

Function

Bypass valves help control temperature rise across a boiler.

Manual Systems

Manual systems use a ball or gate valve to divert boiler outlet water to mix it with returning boiler inlet water.

Thermostatic Systems

You can use a thermostatic valve in place of the ball or gate valve. Thermostatic valves often work with fin tube boilers to reduce or prevent condensation problems. Pool heaters have thermostatic bypass valves built into the head of the fin tube heat exchanger.

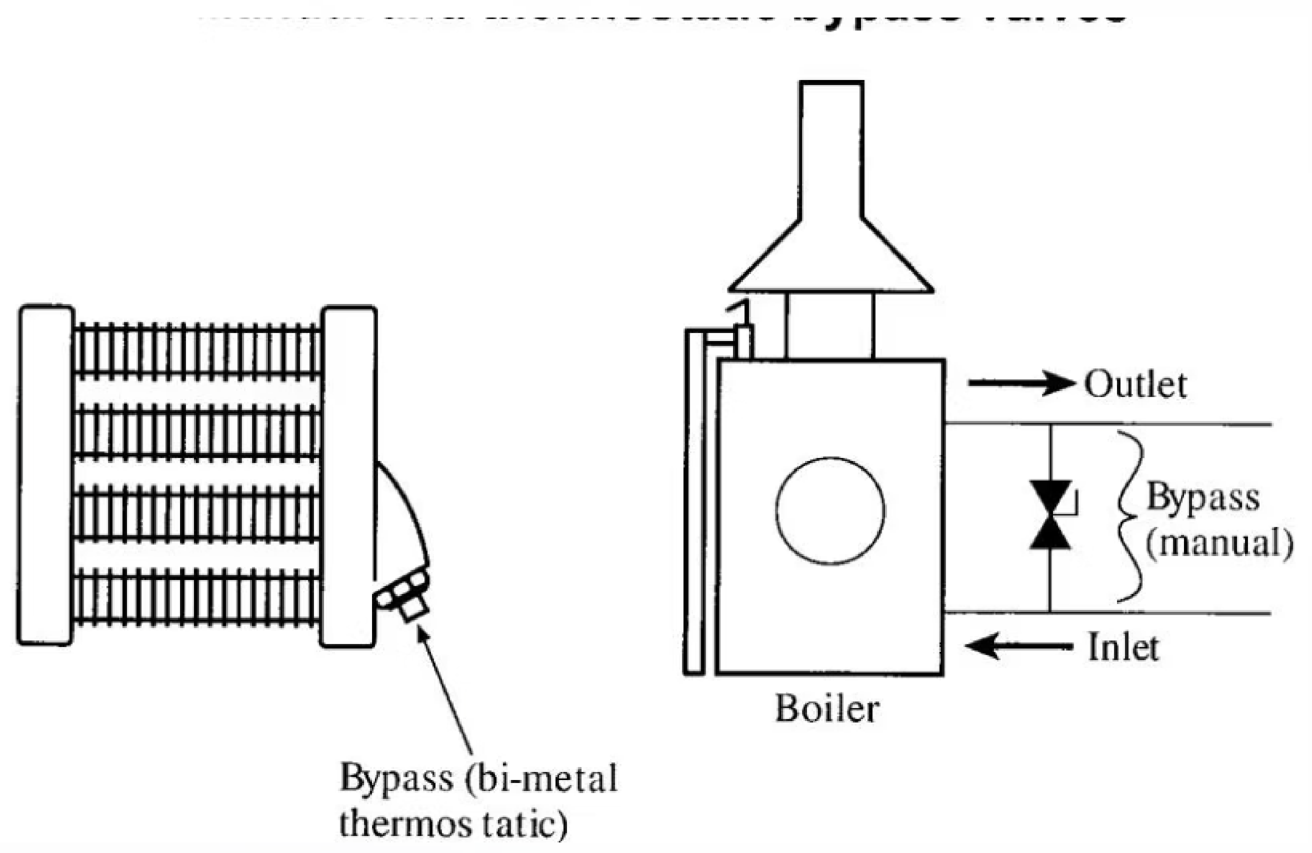


Figure 2-45 Manual and thermostatic bypass valves

Thermostatic Radiator Valve

Operation

A thermostatic radiator valve is a spring-loaded two-port valve operated by a mechanical or electric drive head. It runs on the same principle as a thermostatic control head and electric actuator motor.

A thermostatic radiator valve with an electric drive head also requires a room thermostat.

A rubber gasket inside the valve allows flow in one direction only. The arrow on the valve body indicates flow direction. The valve pin is pushed in to close the valve and released to open it.

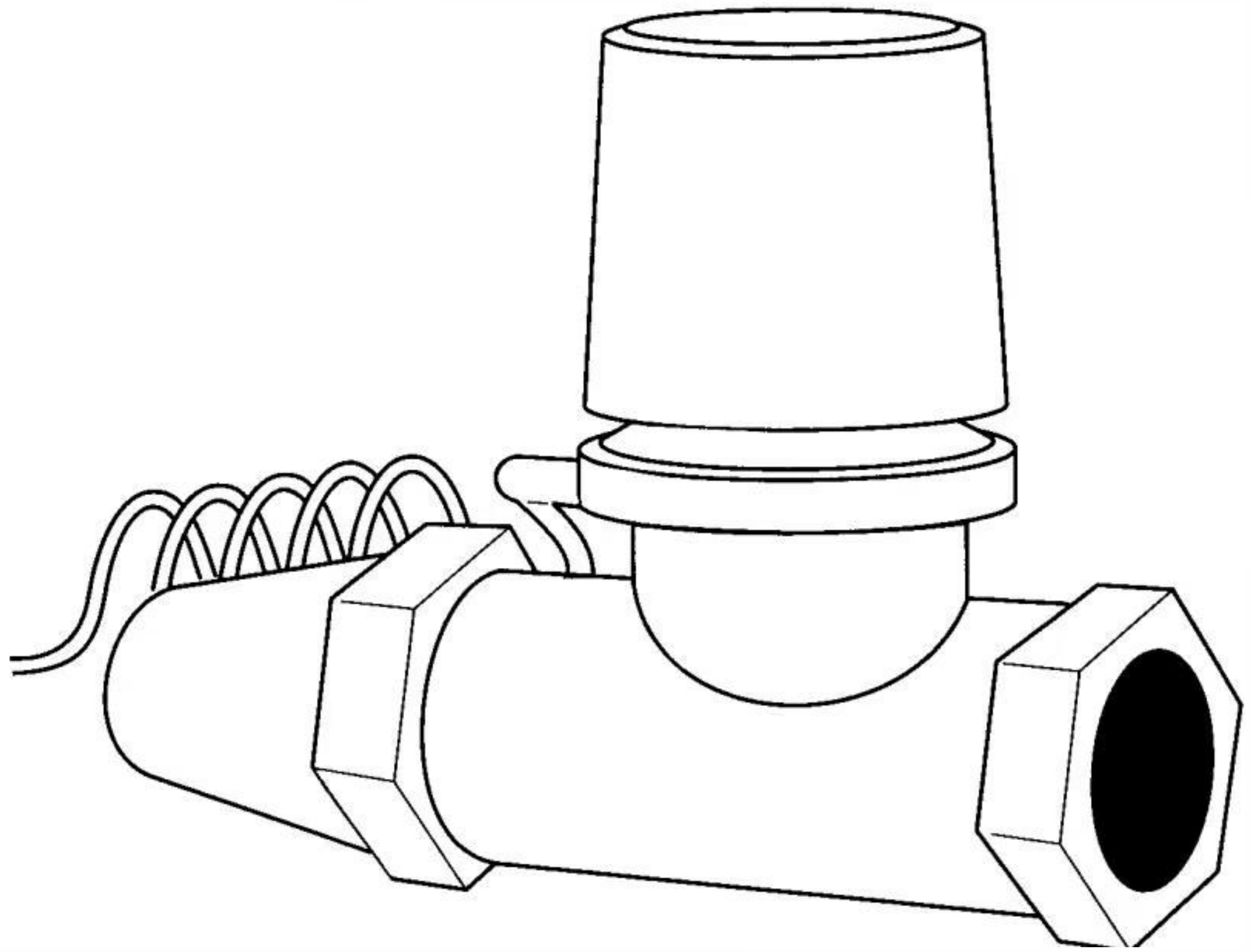


Figure 2-46 24 V actuator motor combined with a thermostatic radiator valve

Electric Thermal Actuating Motor

Thermostat Signal

Upon a demand for heat from the wall-mounted thermostat, a contact inside the thermostat closes to allow electricity to flow to the motor.

Heating Process

The motor, drawing approximately 3 W, uses the energy to activate an electric heating coil, which heats a small wax-filled container.

Expansion Action

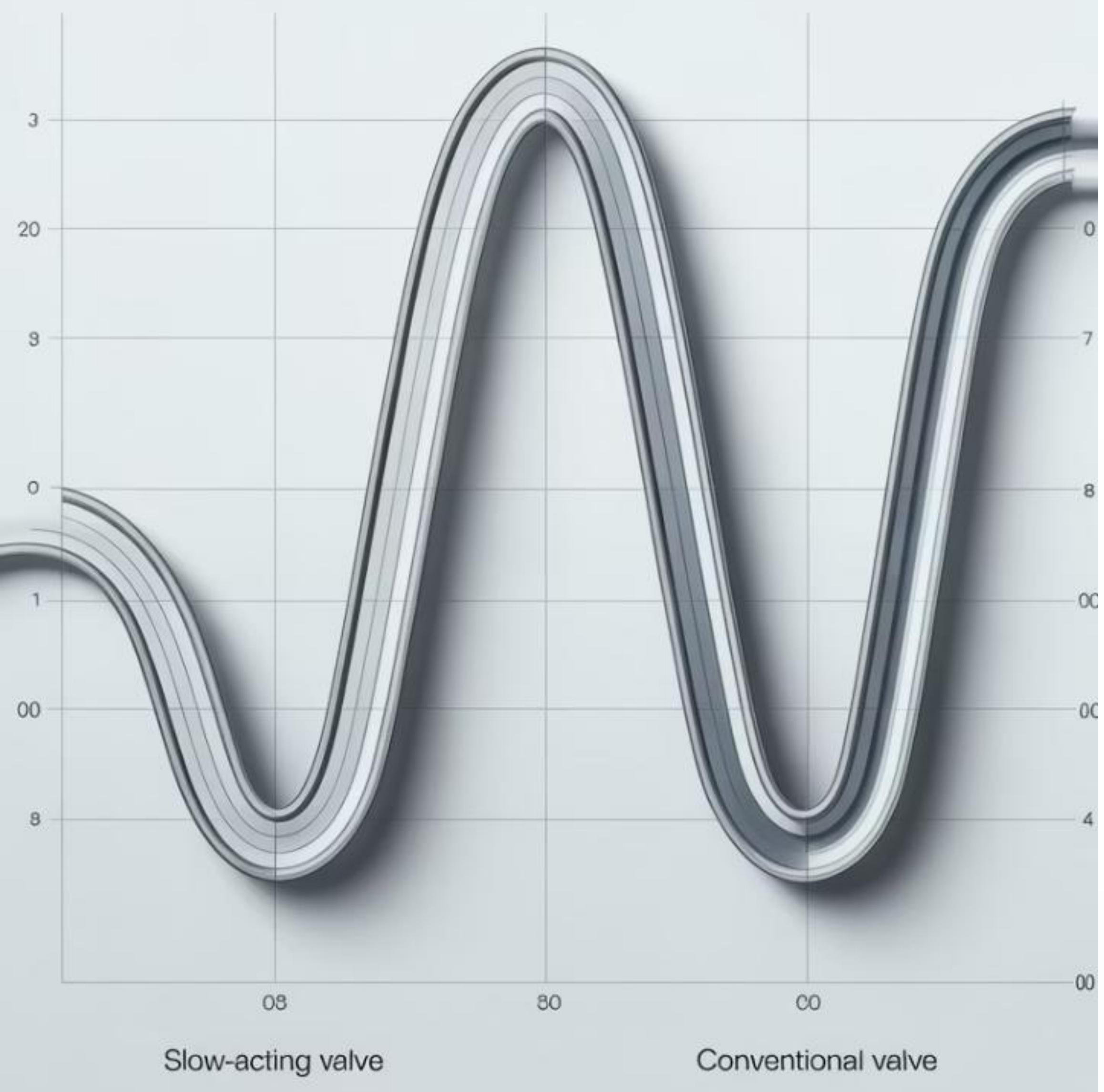
As the wax heats, it expands and puts pressure on a membrane, which pushes a piston out of the shaft of the motor.

Valve Operation

If the motor is mounted to a radiator valve, three-way diverting valve, or three-way mixing valve, the spring-loaded pin of the valve is pushed into the valve body and the valve opens.

Cooling Cycle

When power is turned off, the wax cools and the process is reversed, closing the valve.



Advantages of Slow-Acting Valves

Gradual Response

When driven by an electric thermal actuating motor (Figure 2-46), a thermostatic radiator valve has a longer operating time. After receiving a room thermostat signal, a fully closed thermostatic radiator valve may take 50 seconds or longer to open fully.

Reduced Cycling

This slow operation has one advantage - this type of valve does not cycle as easily as other valves.

Stability

It will not open during short-term temperature drops at the room thermostat when an outside door is opened briefly.

System Efficiency

The slow reaction time takes the peaks off the heat demand and allows the system to work more smoothly.

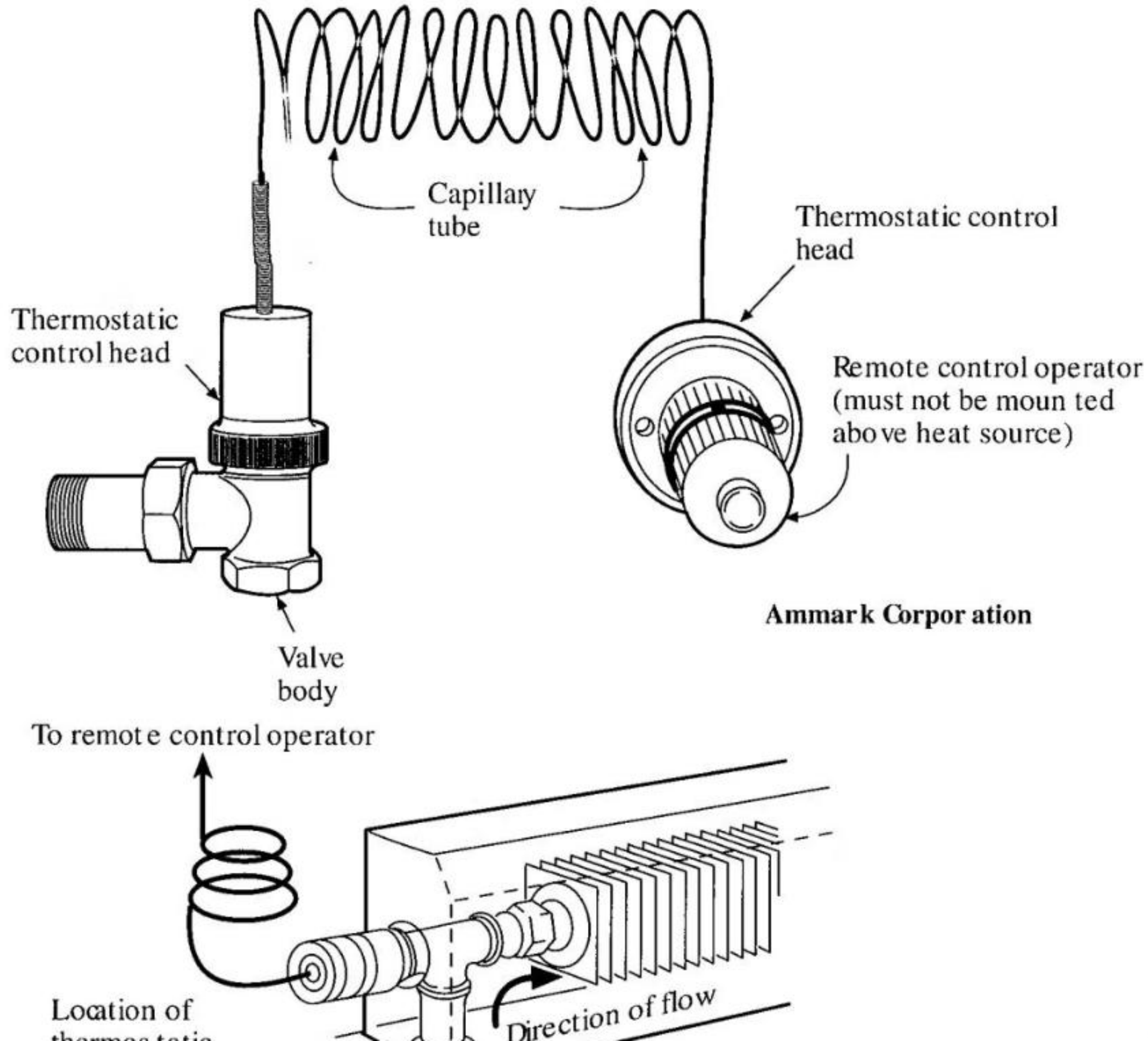
Valve Drive Mechanisms

Common Types

Common valve drive mechanisms include:

- Thermostatic control heads (heat motors)
- Electric actuator motors

Figure 2-47
Thermostatic control head
Courtesy of Danfoss Automatic Controls



Thermostatic Control Head

Temperature Sensing

Control head contains fluid or wax in a membrane

Expansion

Fluid expands with increasing temperature

Mechanical Action

Expansion forces spring-loaded pin to move

Valve Operation

Pin pushes on valve, opening or closing it

Thermostatic control heads (heat motors) are the most common type of valve drive. You may mount them directly on the valve or use them as a remote control with an additional drive mounted on the valve and connected to a capillary tube sensor (Figure 2-47).

Injection Valve

Applications

Injection valves are used for heating or cooling applications (Figure 2-48). They come with an immersion bulb and are available in various temperature ranges.

Valve Type

Injection valves are two-way valves - no mixing occurs within the valve body.

Installation Requirements

A bypass line is required between the valve body and the immersion bulb.

Mixing Process

The actual mixing occurs at the junction of the bypass line and supply line, similar to the action of a diverting valve.

Operation

As the temperature changes at the immersion bulb, the valve opens or closes proportionally to allow more or less supply water into the system.

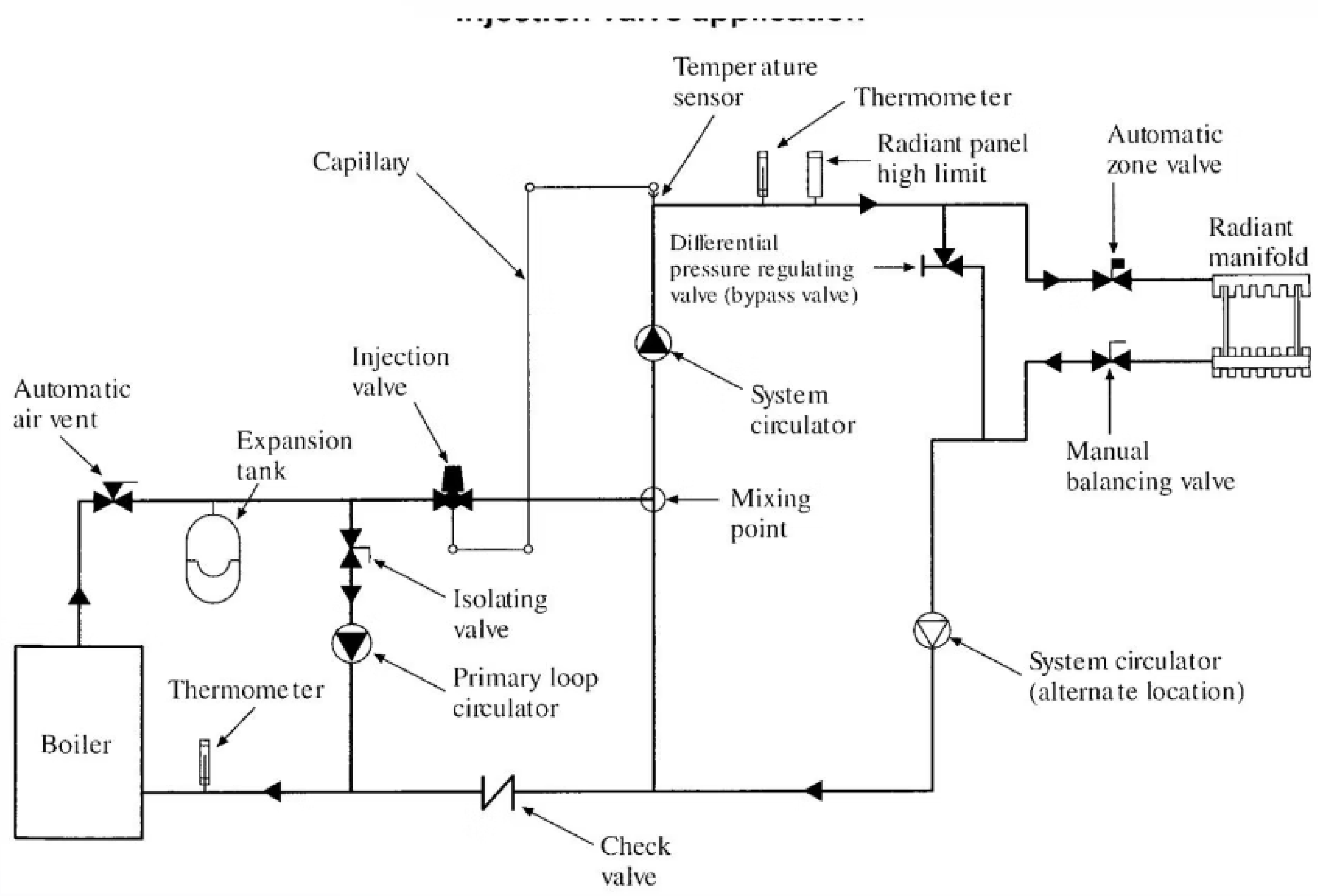


Figure 2-48 Injection valve application

Temperature Controllers

Applications

You may use temperature controllers with diverting or mixing valves.

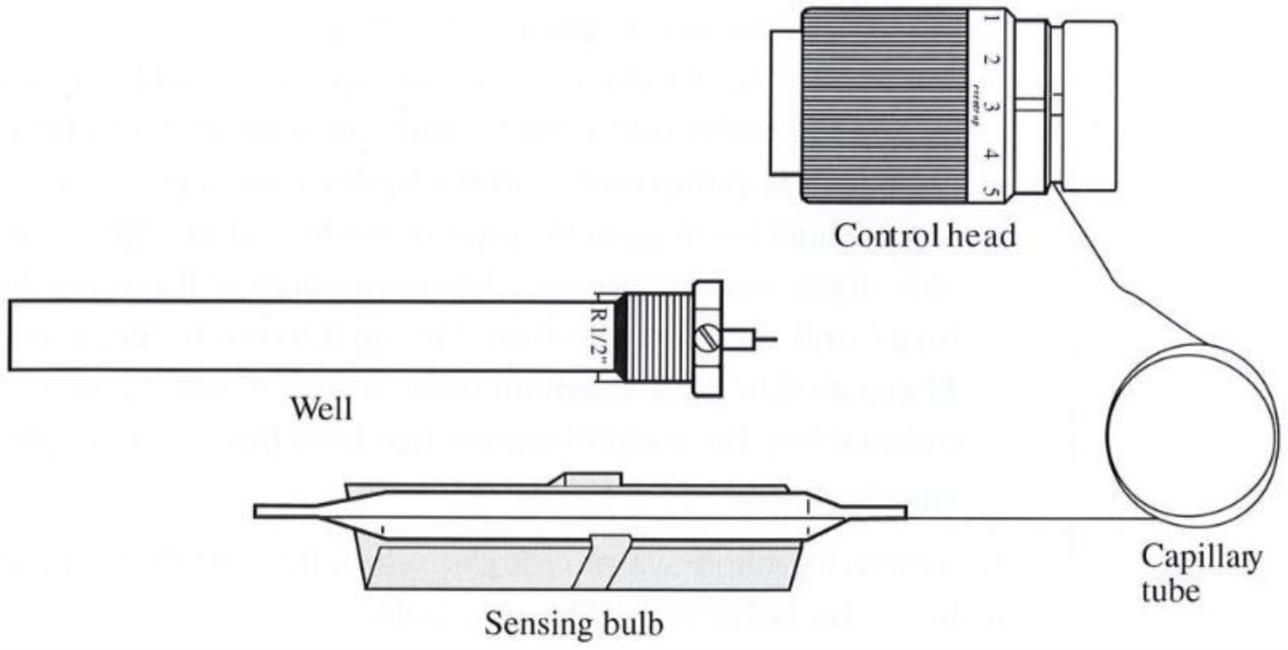
Components

Temperature controllers have a control head that screws on to the head of the valve (Figure 2-49). Place the sensor at the end of the capillary tube where you are to take the actual temperature reading. In a radiant floor heating system, this sensor is placed into or at the supply pipe about 2 feet away from the mixing point.

Sensor Types

Both immersion types and strap-on types are available. The sensor and the capillary are filled with a fluid that expands when heated and contracts when cooled.

Figure 2-49
Temperature controller
Courtesy of JANCA Enterprises, Ltd.



Operation

When the fluid expands, the membrane in the actuator pushes down on the pin in the valve and changes the position of the valve or discs. In the three-way valve, the amount of hot and cold water to be supplied to the system changes until the right supply water temperature is reached.

Injector Pump

Purpose

Injects hot fluid to maintain temperature

Variable Speed

Modulates based on temperature needs

Electronic Control

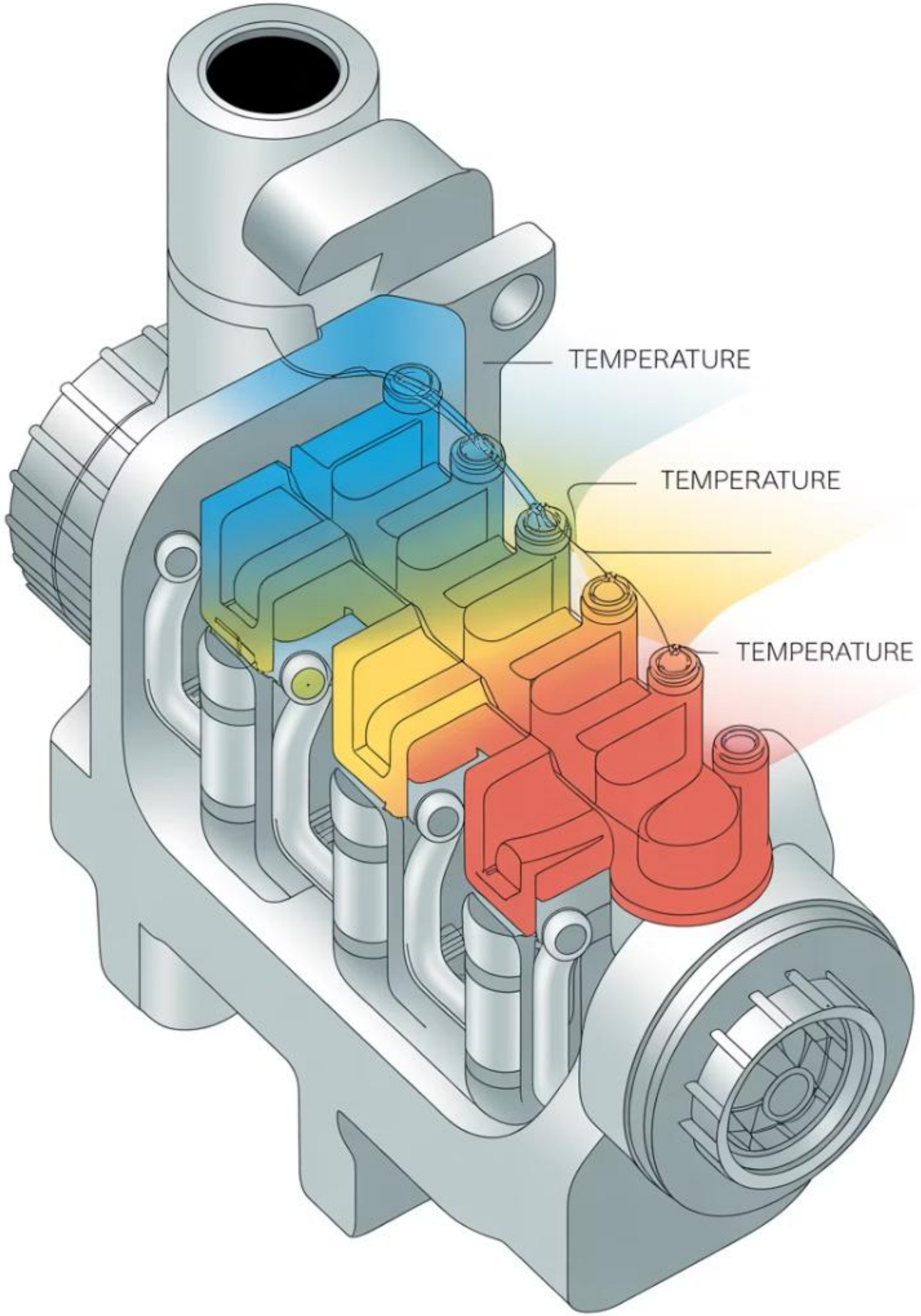
Monitors boiler and system temperatures

An injector pump can help inject hot fluid into the heating loop to maintain the desired temperature. When used, an injector pump should be variable-speed (speed-modulated) or set to turn on and off automatically in direct response to heating unit fluid temperature requirements.

The injector pump is operated by an electronic control that senses boiler return water temperature and system supply water temperature.

Injector Pump Operation

When	Then
The boiler return water temperature falls to a pre-set low limit.	The control speeds the pump up to inject hotter water into the system.
The system supply water temperature rises to a pre-set high limit.	The control slows the pump down to maintain a flow rate that will maintain the desired temperature.



Direct Injection System

Configuration

In a direct injection system, the boiler return loop is supplied from the cool system return water (Figure 2-50a).

When the pump is turned off, no heat should transfer from the boiler loop to the system loop.

Installation Requirements

- The injection piping should be at least one pipe diameter smaller than the boiler and system loop piping.
- There must be a maximum of four pipe diameters between the tees in the boiler and system loops (to prevent ghost flow) when the injection pump is off and the system circulator is on.
- There must be at least six pipe diameters of straight pipe on either side of the tees.
- There should be a minimum drop of 1 ft (30 cm) to create a thermal trap.

Reverse Injection System

Configuration

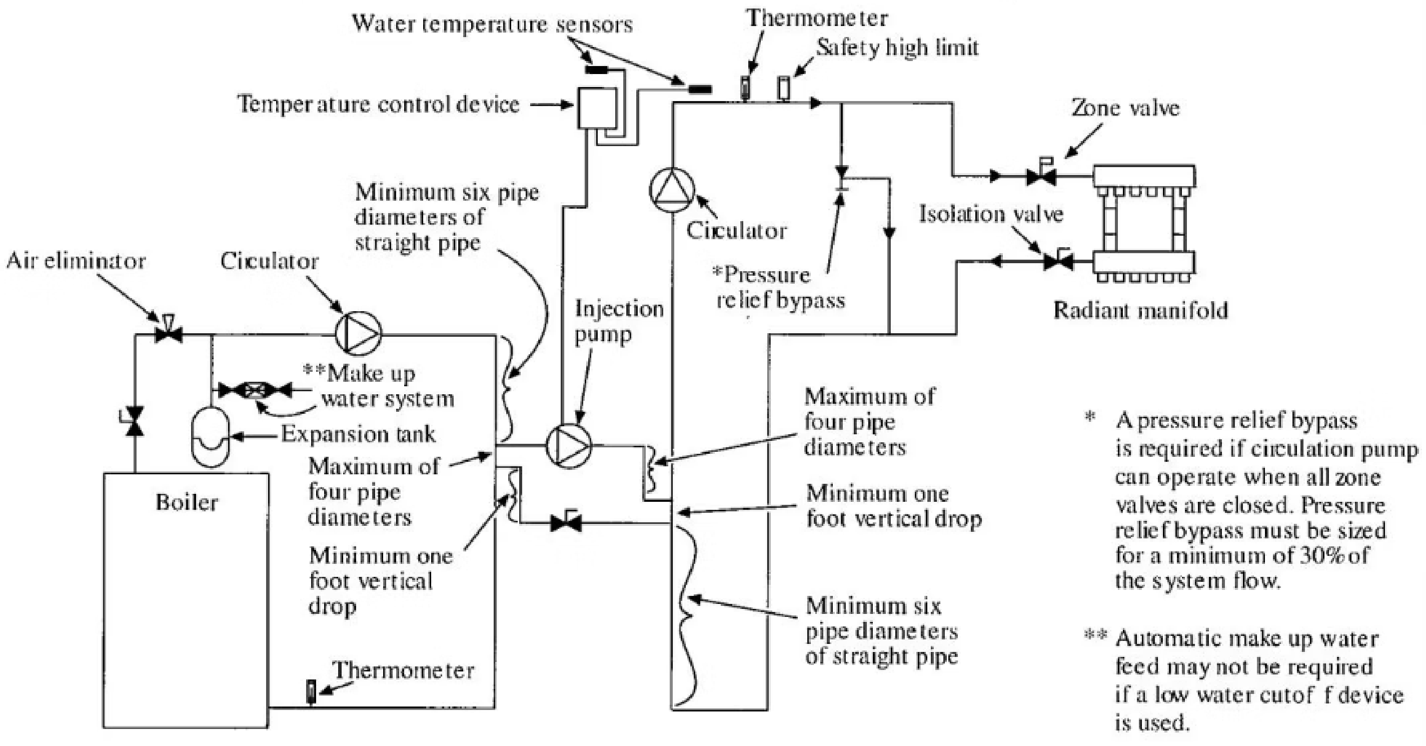
A reverse injection system returns warm (mixed) system supply water to the boiler loop (Figure 2-50b).

A horizontal swing-check valve minimizes ghost flow and eliminates the need for the more complex piping requirements of a direct injection system. However, a thermal trap should be installed to prevent convective heat transfer through the pipe without the check valve.

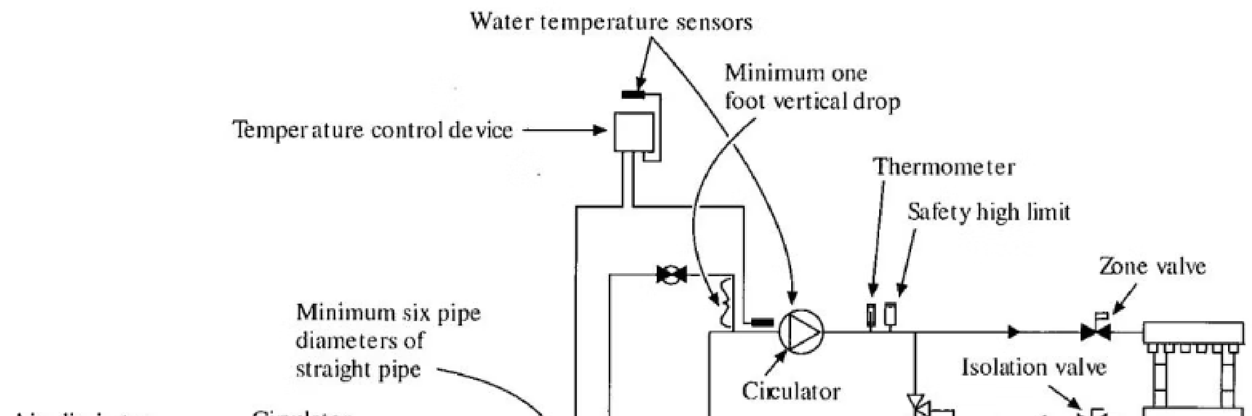
Operation

When the injection pump is turned off, the momentum of water flow and the pressure drop in the system keep the check valve closed.

Figure 2-50
Injector pump applications: (a) direct, (b) indirect



(a) Direct injection pump system



Three- and Four-Way Mixing Valves

Purpose

Three- and four-way mixing valves are used for proportional water mixing.

Unlike a diverting valve, all mixing occurs within the valve body of this type of valve.

Types

Mixing valves can be:

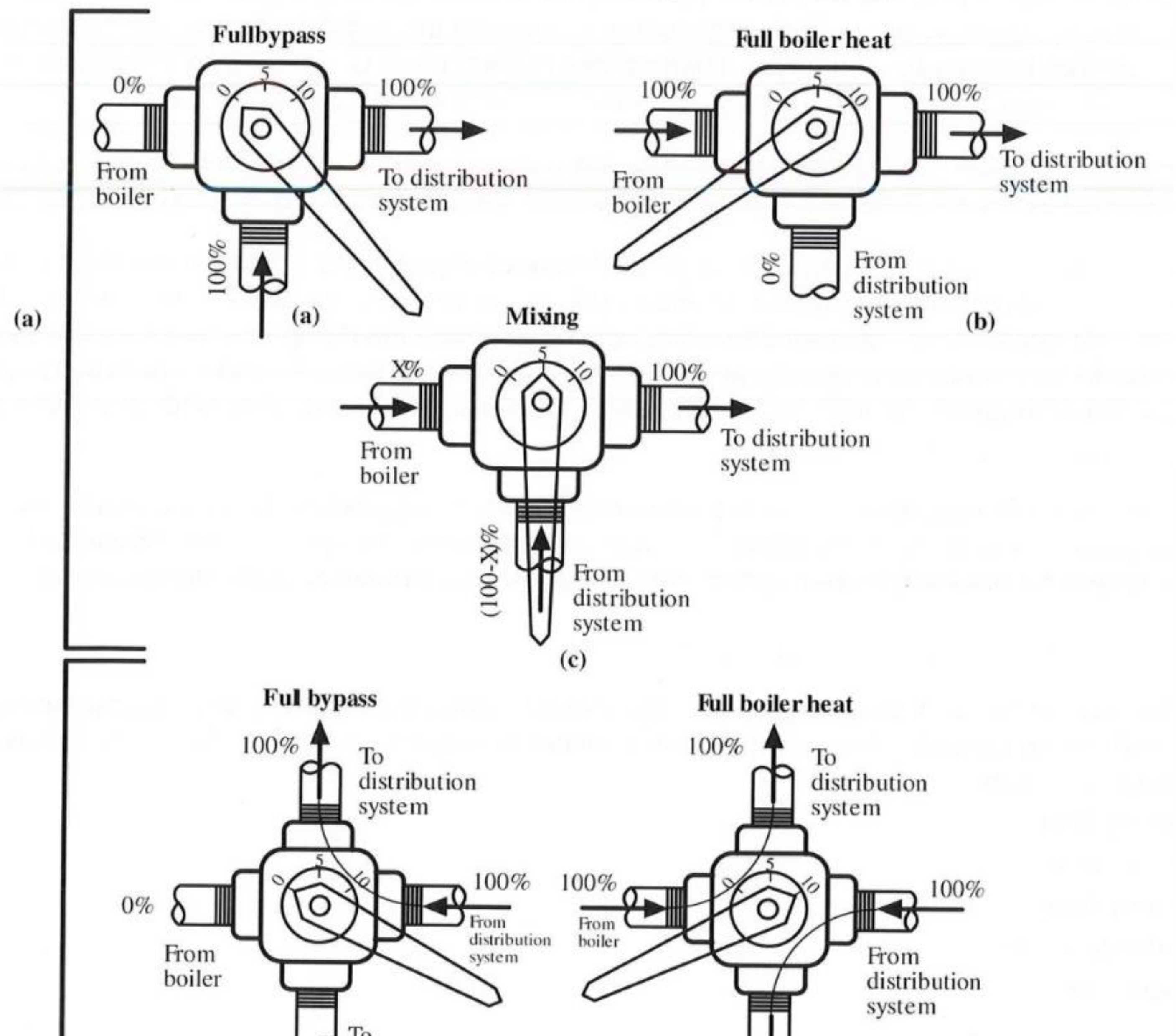
- Automatic
- Motorized
- Manually operated

Manual valves are not recommended because they cannot compensate for varying pressure and flow changes within the heating system.

Automatic Operation

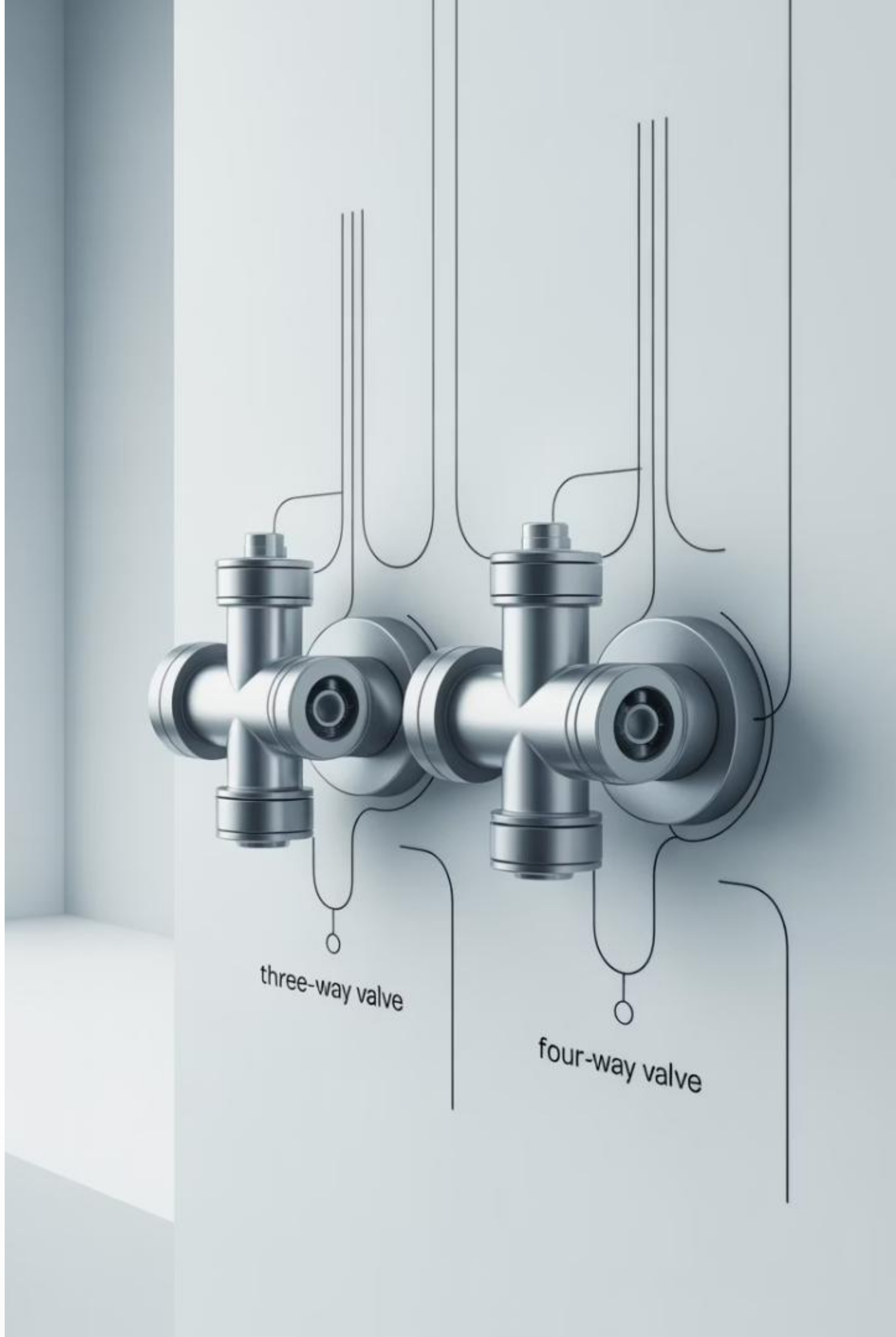
An automatic three-way mixing valve has a built-in or remote thermostatic control, which regulates the amount of water entering the valve to maintain the pre-set temperature. The temperature selection adjustment is on the valve body.

Figure 2-51
Three- and four-way mixing valve operation



Comparing Three-Way and Four-Way Mixing Valves

Type	Description
Three-way mixing valve	When the valve is fully closed, there is no flow through the boiler. When a demand for heat exists and the three-way valve opens, the untempered return water to the boiler could be cool enough to cause flue gas condensation.
Four-way mixing valve	Using a four-way mixing valve ensures full flow through the boiler and that return water to the boiler is adequately tempered, regardless of the valve position.



Indoor/Outdoor Reset Control

Indoor Reset Control

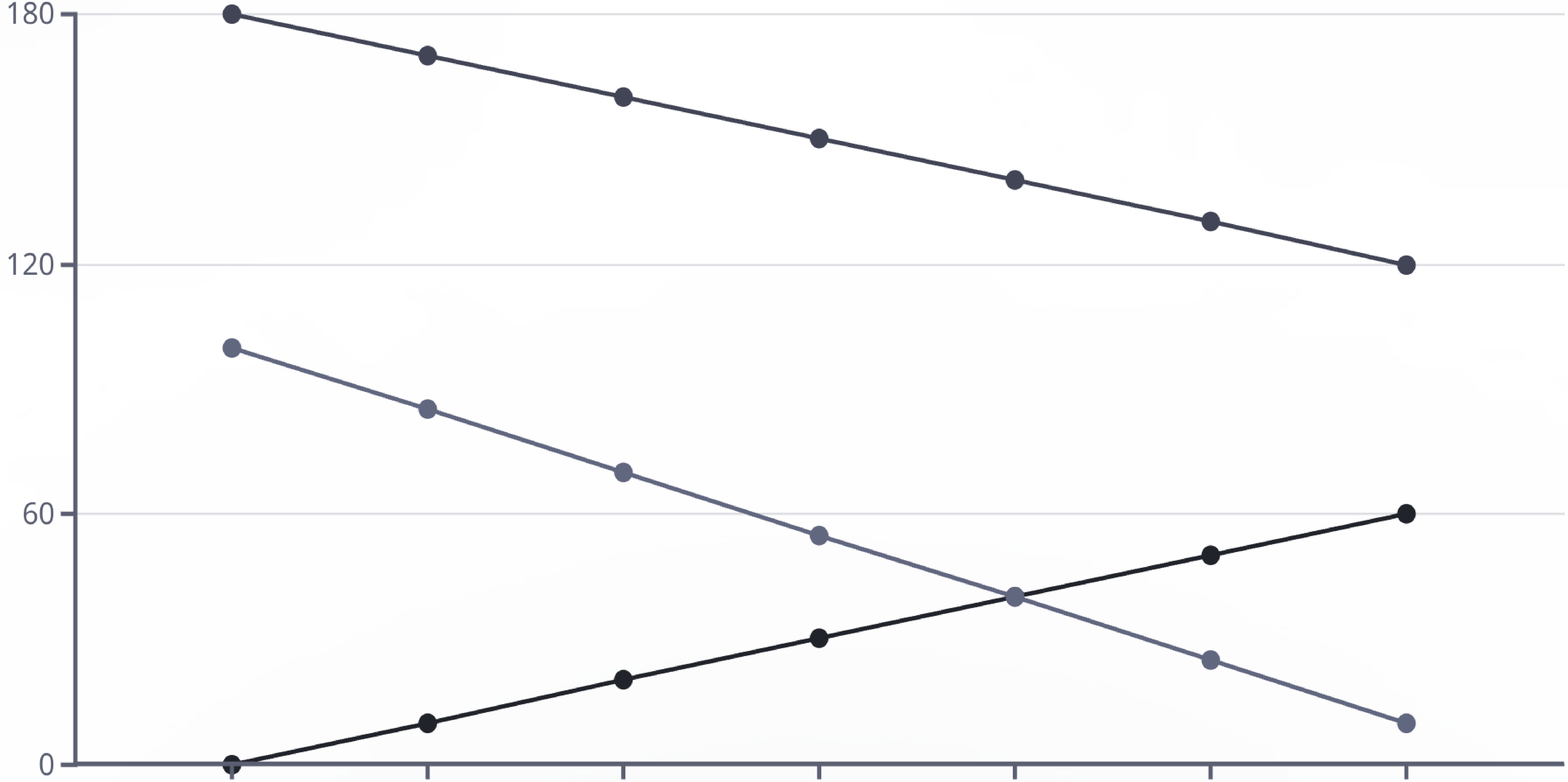
Indoor reset control is based on the temperature in the building being heated. The term reset means that the control automatically resets (raise or lower) the heating medium control set point as the outdoor temperature changes. Thermostats in each room or area sense the temperature in the room and demand heat when the temperature drops below the selected set point.

Outdoor Reset Control

Outdoor reset control factors in the outside air temperature as part of the overall temperature control strategy. As the outside temperature changes, the building's heating load changes too.

Indoor/outdoor reset control depends on small, frequent adjustments of the temperature of the water in the hydronic heating system to allow optimal run-times for the boiler and minimize short cycling.

Temperature-Load Relationship



Building Automation Systems

Integrated Control

Most modern buildings have a building automation system installed for the management of all HVAC system, and all the boiler reset functions are controlled from this system.

Advanced Technologies

Advanced technologies for attaining further system efficiencies are continuously under development.

Centralized Management

Allows for monitoring and control of multiple building systems from a single interface.

Energy Optimization

Provides data-driven adjustments to maximize system efficiency and reduce energy consumption.

Set Point and Reset Controls

Control Sensors

Electrical or mechanical temperature sensors should control motor-driven or thermostatically actuated mixing devices.

Temperature Inputs

You may set these sensors to respond to one or more of the following temperature inputs: supply fluid, mixed fluid, return fluid, outdoor air, and indoor air.

Adjustable Reset Ratios

Uses of devices with adjustable reset ratios are recommended.

Safety Limits

Set controls to ensure that the maximum heating unit supply temperature is not exceeded.

Temperature Sensor Placement

Fluid Temperature Sensors

Fluid temperature sensors should be mounted in sensor wells or fastened directly to metal pipe and insulated according to manufacturer's recommendations.

Outdoor Air Sensors

Outdoor air temperature sensors should be placed in free air away from direct sunlight or other heat sources (preferably on the north side of the building).

Indoor Air Sensors

Indoor air temperature sensors should be placed approximately 5 feet (1.75 m) above floor level on an interior wall, away from heat sources and out of direct sunlight.

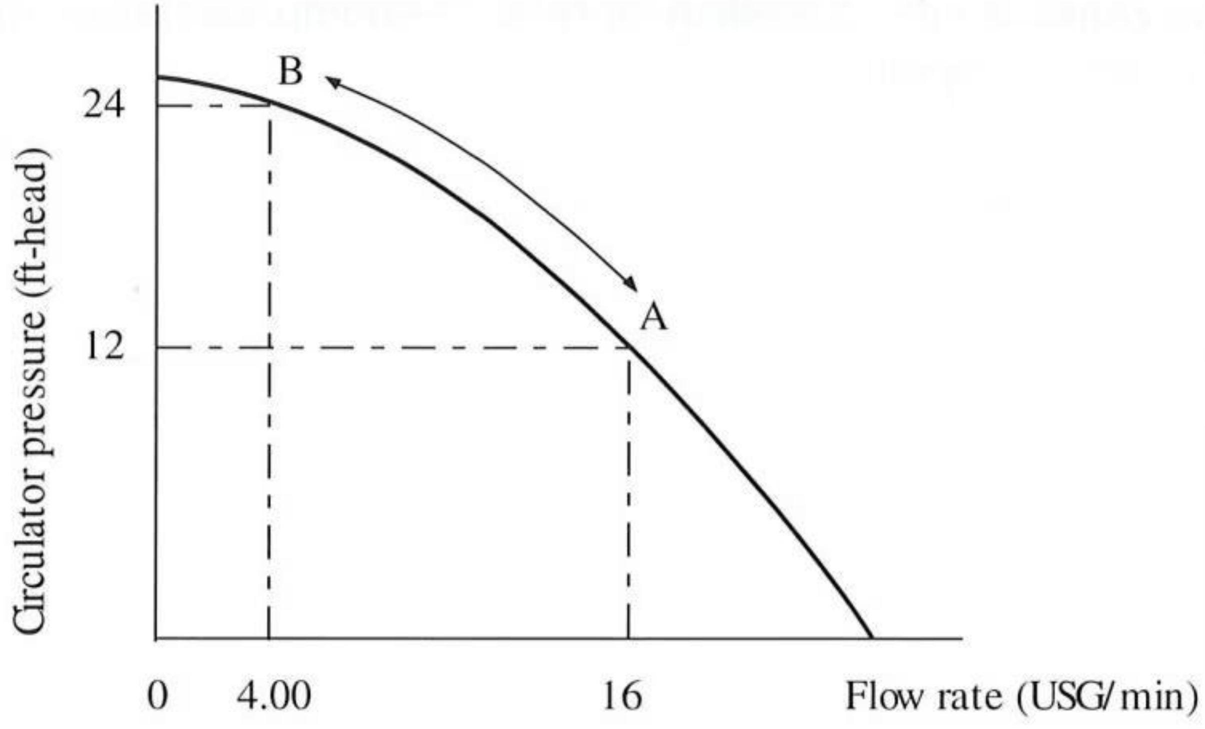
Differential Pressure Devices

Circulating Pumps

A full understanding of differential pressure regulating valves requires a discussion and understanding of circulating pump performance. Circulating pumps are also called circulators.

In a hydronic heating system, the hot water that the boiler produces travels to the heating units through a piping system by a circulating pump. A circulating pump can only perform within the limits of its performance curve.

Figure 2-52
Pump performance curve



Refer to the example in Figure 2-52, which indicates that the pump can operate at 12 feet of head with a flow of 16 gpm (operating point A).

Pump Performance Curve Analysis

Performance Curve

Shows pump capabilities at different flow rates

Zone Valve Effects

Closing valves changes system pressure

Pressure Increase

Lower flow rate creates higher head pressure

Operating point A is located directly on the performance curve. The flow rate of 16 gpm is the total water circulation for the system if all heating units are operating and supplying heat to the building.

Zone valves installed in the supply pipe control the heat supply to individual rooms or areas. At any given time, zone valves will open, allowing water to pass through the heating unit(s), or close because heat is not required at that moment. Closing zone valves results in a lower flow rate of hot water through the system. However, at the same time, the circulating pump still runs at the same speed, which produces a higher pressure in the system. This means that the operating point of the pump will shift to the left on the curve (point B). The curve indicates a pressure difference between point A at 12 feet of head and point B at 24 feet of head. This pressure difference operates the differential pressure regulation valve.

Differential Pressure Regulation Valve

Purpose

A differential pressure regulation valve is installed in a system to ensure continuous flow in the system, no matter how many zone valves are open or closed.

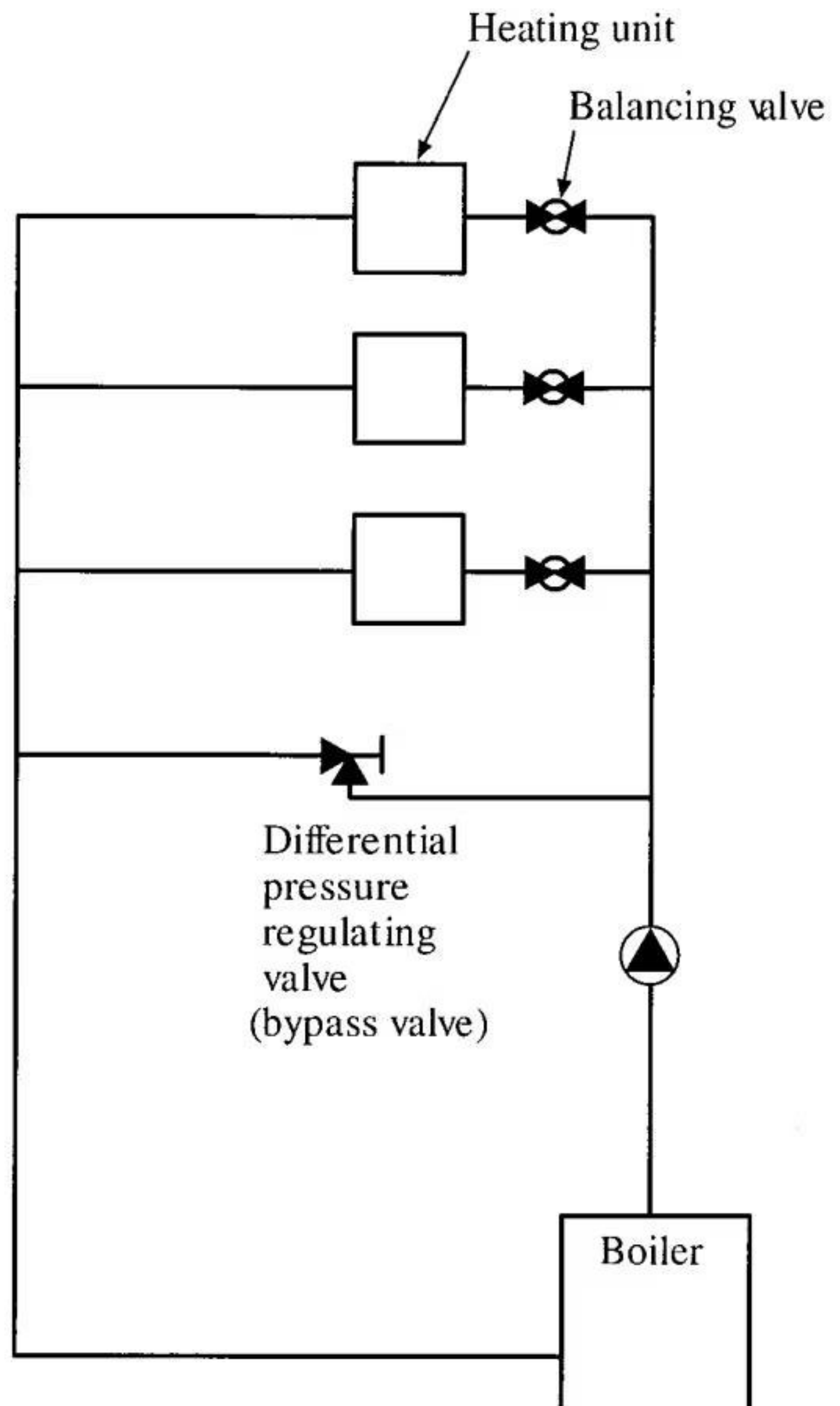
Construction

A differential pressure regulation valve is spring-loaded and has one inlet port and one outlet port. The spring applies pressure to a valve disk, closing the connection between the inlet and outlet ports.

Operation

To keep the valve closed, the valve-spring pressure must be higher than the pressure of the circulating water (circulation pump pressure).

As zone valves close, the flow rate drops and system pressure increases, opening the differential pressure regulation valve. The opening of the differential pressure regulation valve has the effect of increasing the flow rate because of the flow through the pressure regulation valve.



Differential Pressure Valve Operation

25%

Opening Pressure

Of full flow pressure

3

Zones

In typical multi-zone system

In a multi-zone, parallel-path hydronic system such as the system shown in Figure 2-53, the circulator is sized to deliver the proper flow when all three circuits (zones) are calling for heat. When only one or two zones is open or calling for heat, the pump will deliver the same flow as it does when all three zones are open.

The differential pressure regulation valve opens when it senses pressure. Opening of the pressure regulation valve causes fluid to go around the closed zone(s), reducing pressure in the system.

The pressure required to open the valve is approximately 25% of the pressure at full flow rate. The manufacturer's technical data supplied with the valve explains adjustment of the opening pressure of a differential pressure regulation valve.

Zone Controls

Definition

Zoning is the division of a hydronic heating system into two or more independently controlled distribution circuits.

Benefits

This affords hydronic systems (even in small system installations) to provide optimized control of comfort in many areas.

Applications

Zoned hydronic heating systems help service residential and commercial buildings. This type of distribution system allows heat to be delivered only to the area in the building that requires it.

Components of Zoned Hydronic Systems

Heat Source

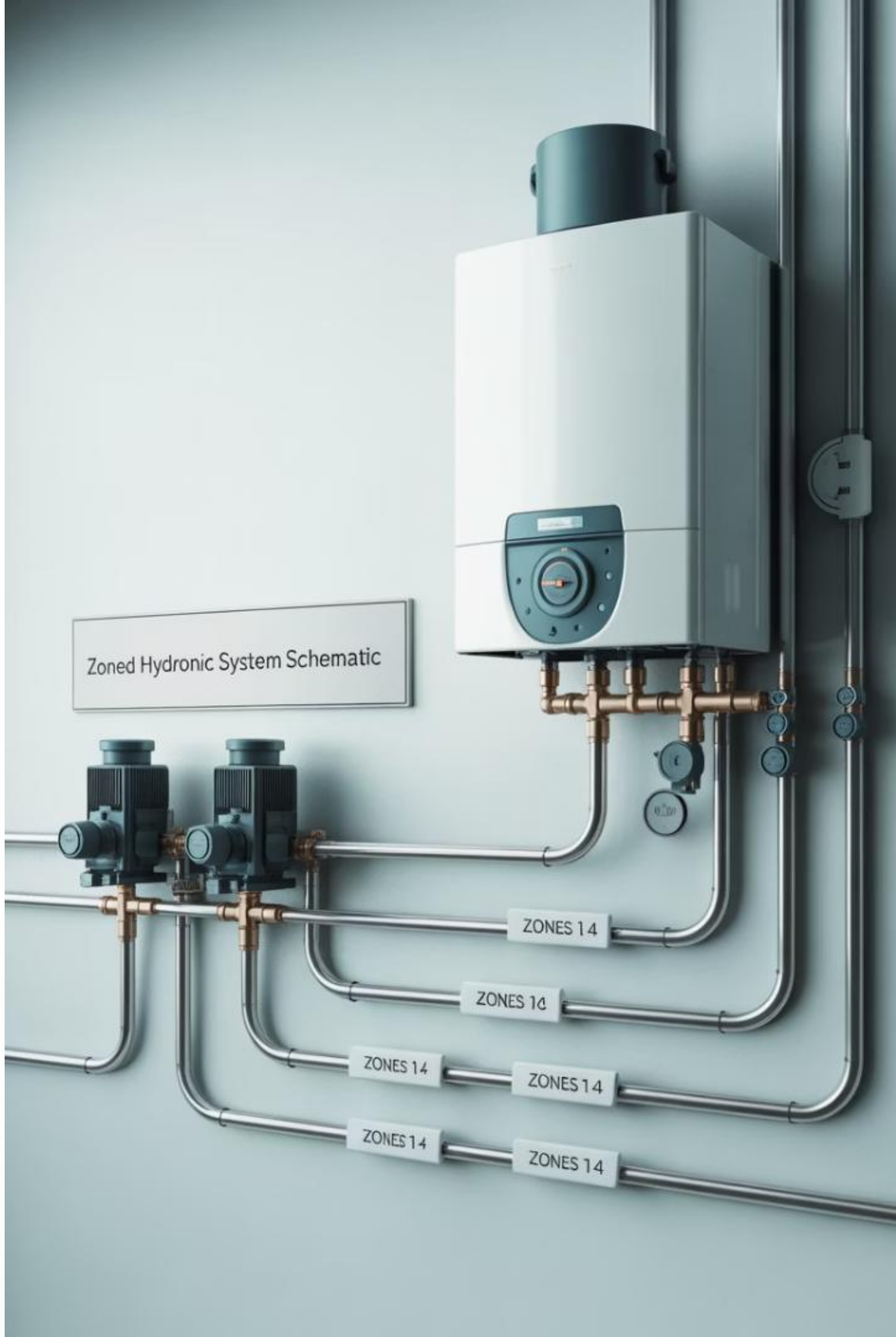
Hot water heater or boiler

Distribution Circuits

Two or more independent heat distribution circuits

Control Methods

- Circulating pumps
- Zone valves
- Thermostatic radiator valves



Circulating Pump Zoning

Operation

In the circulating pump or circulator type of system, the thermostat turns on the pump in its zone in response to a fall in temperature. The boiler is either turned on by a second contact in the pump control relay or uses a hot boiler system.

Hot Boiler System

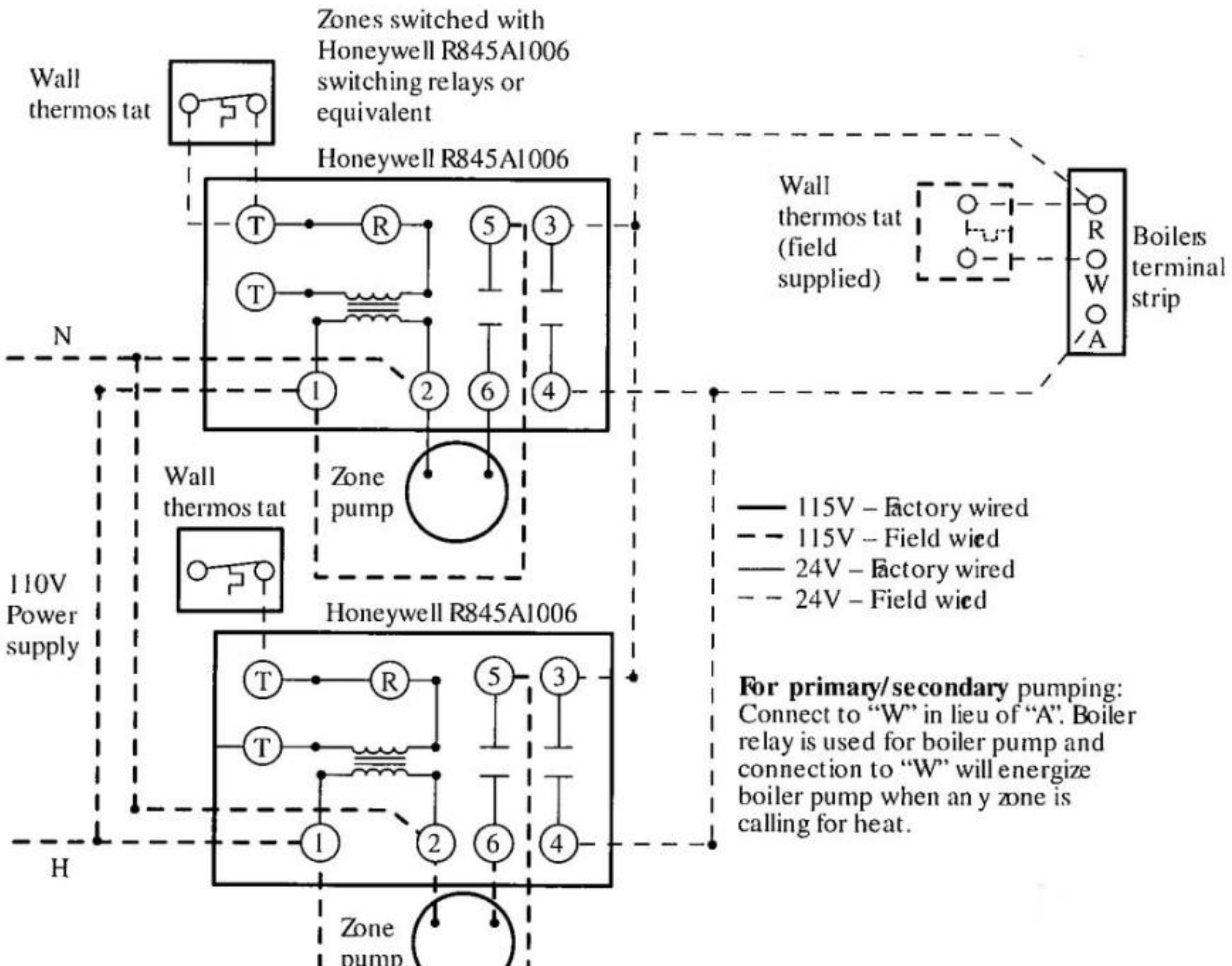
In a hot boiler system, the aquastat maintains the boiler at the system's design temperature. When zones call for heat, the water is already hot and, therefore, the zone system requires no switching of the burners.

Control Method

When you use a circulating pump (circulator) as a zone control device, a signal from the thermostat that energizes a relay to turn on the pump (Figure 2-54) controls it.

When you use two or more circulators in a zone system, you must install a check valve to prevent circulation through zones that are turned off.

Courtesy of Teledyne Laars



Zone Valves

Types and Operation

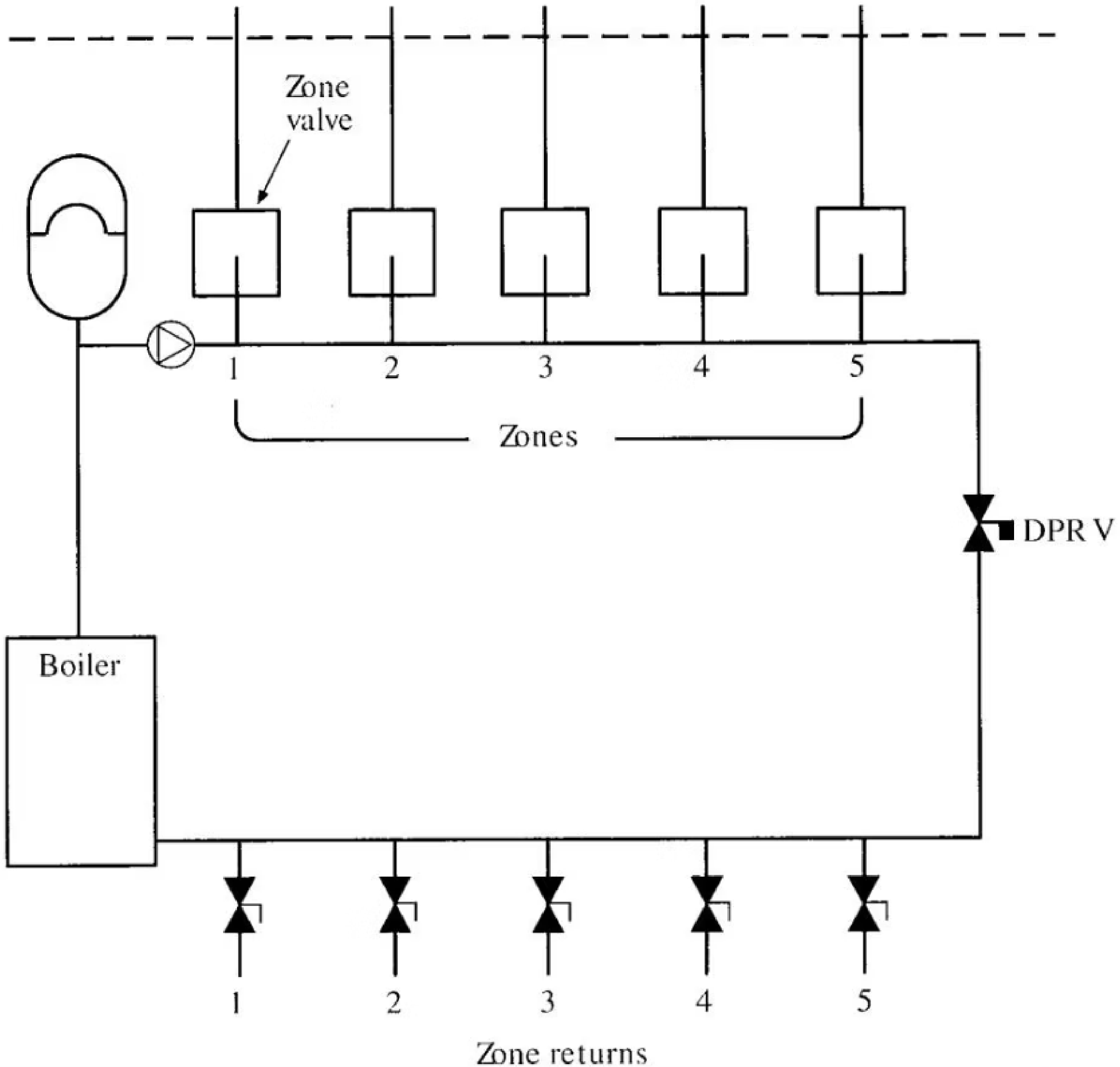
A low-voltage electric motor or a heat motor drives most zone valves. When used as a controller, the zone valve operates in response to a signal from a thermostat, opening or closing to regulate water flow through a piping zone. In a zone valve system, the circulator does not run continuously — it is energized with the burners are turned on by an end switch in the zone valve that closes after the valve opens.

Valve Designs

Some zone valves require one signal to open and another signal to close.

Simpler, spring-loaded zone valves require only one signal. This type of valve is held in its normally closed position by a spring. On a demand for heat, a thermostat signal powers the valve motor that opens the valve. When the desired temperature is reached, the thermostat signals the motor to switch off and the spring closes the valve.

Figure 2-55
Zone valve locations



Zone Header

Definition and Purpose

A zone header is an assembly of two or more zone valves and their associated heat motors (Figure 2-56) designed to be installed as a unit.

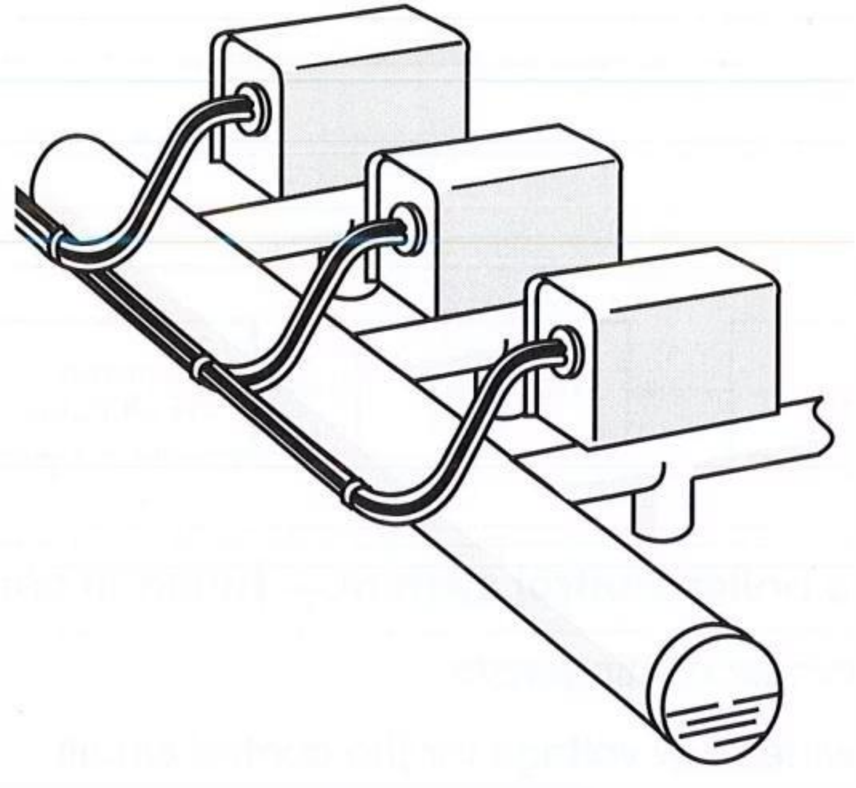


Figure 2-56 Zone header assembly

Balancing Valves

Importance

Balancing a system to perform as designed, which allows for system variables, is as important as proper design itself.

Manual Balancing

In some heating systems, manually operated balancing valves are placed on the different zones or branches. These adjustable valves can modulate and balance the flow through each branch.

Position Locking

When you have properly balanced the system, you can lock some balancing valves in position in such a way that you can completely close them but only open them as far as the locked position.

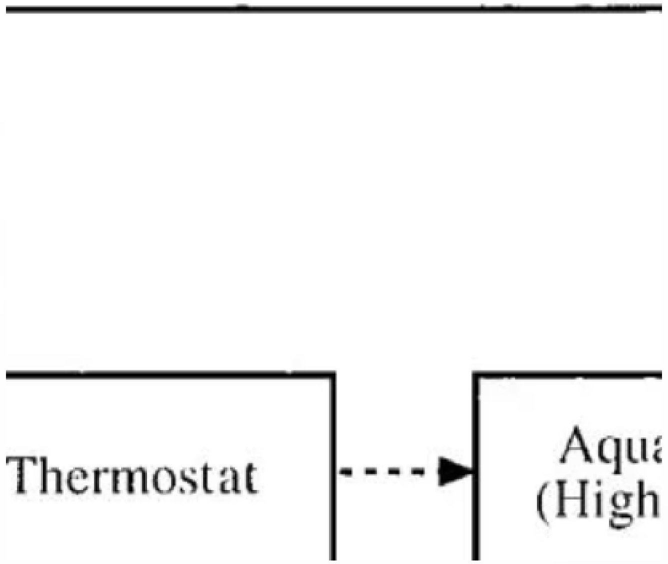
Automatic Balancing

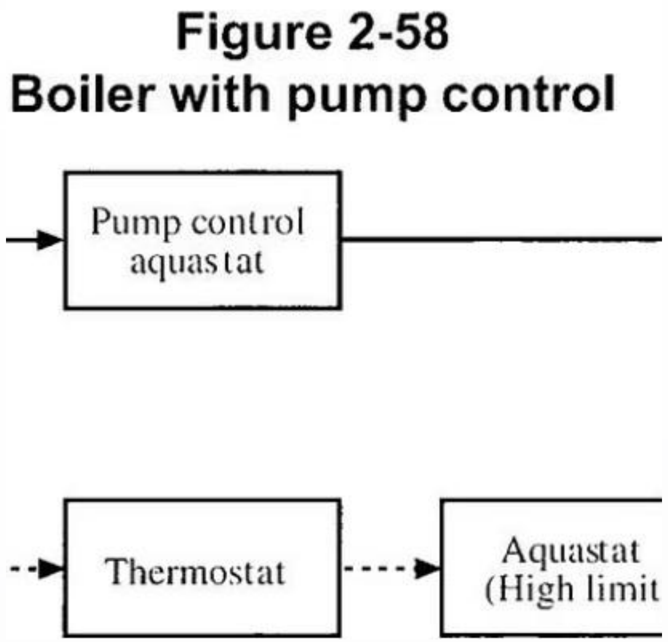
Automatic balancing valves available from various manufacturers are becoming more popular in hydronic systems; however, you must select and install them to meet design.

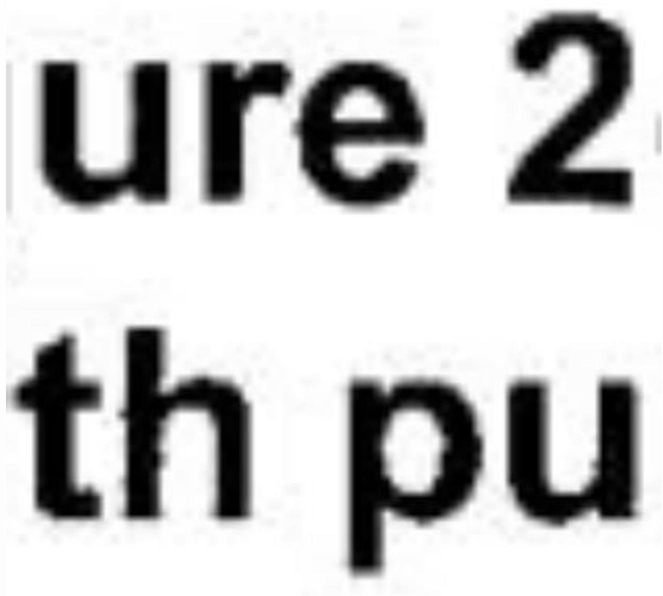
Examples of Control Strategies

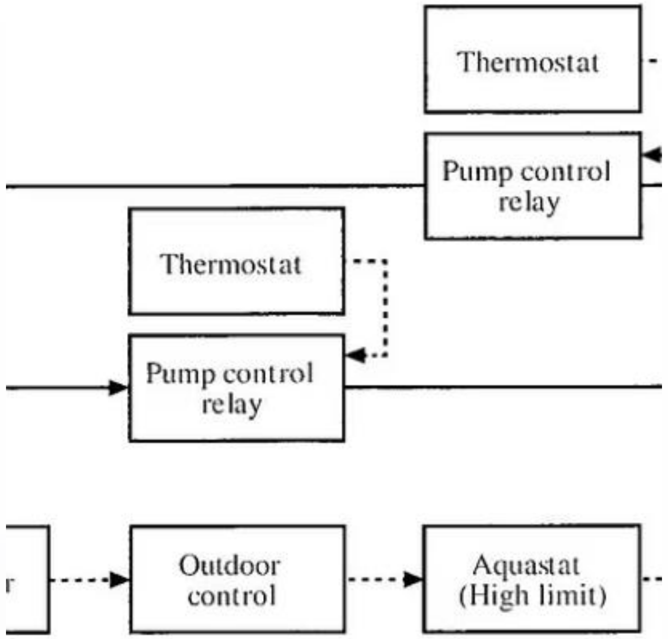
Control strategies vary, depending on the complexity of the hydronic system and the type of control devices used.

The following are examples of various boiler and burner control configurations.









Simple Boiler Control System

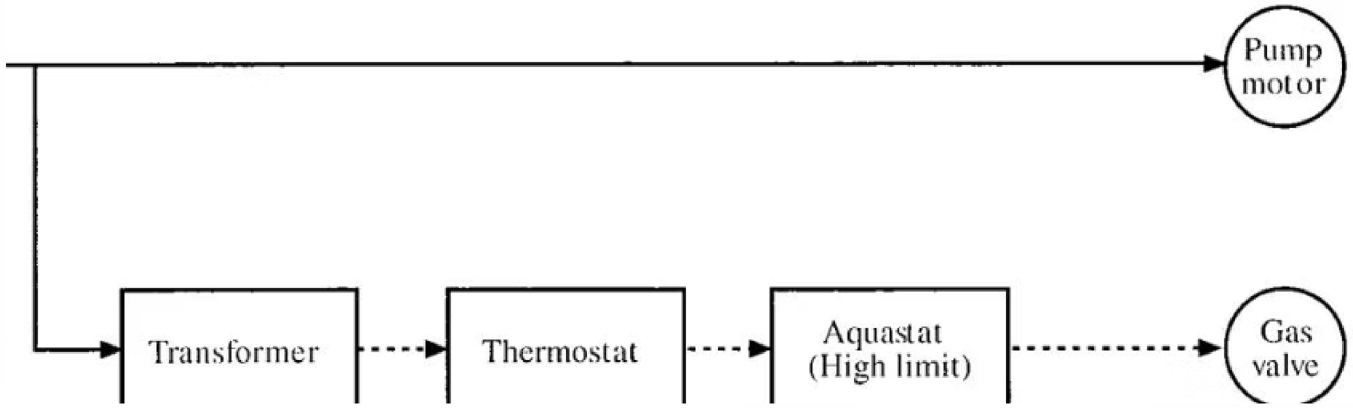


Figure 2-57 Simple boiler control system

Control device	Simple boiler control system - function and operation
Transformer	Operates continuously. Provides low voltage for the control circuit
Thermostat	Operated by room temperature. Turns the gas valve on and off
Aquastat	Operated by water temperature. Controls temperature of the radiation system
Pump motor	Operates continuously. Circulates water through the system
Gas valve	Operated by the thermostat and aquastat. Ignites the boiler burner

Boiler with Pump Control

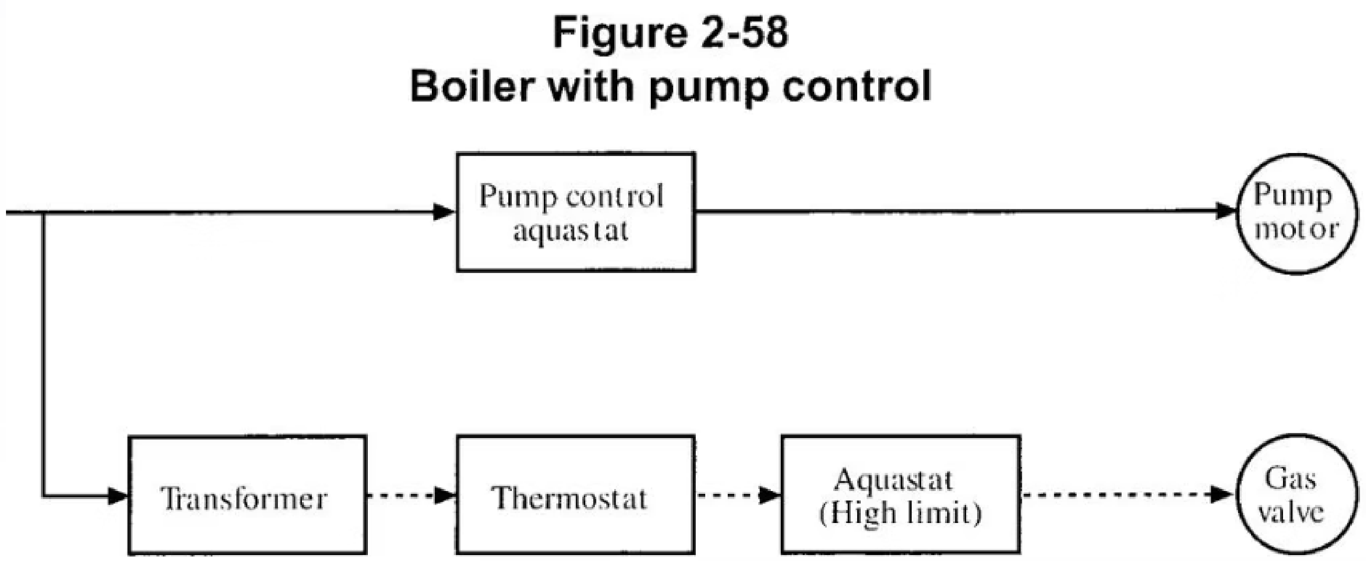
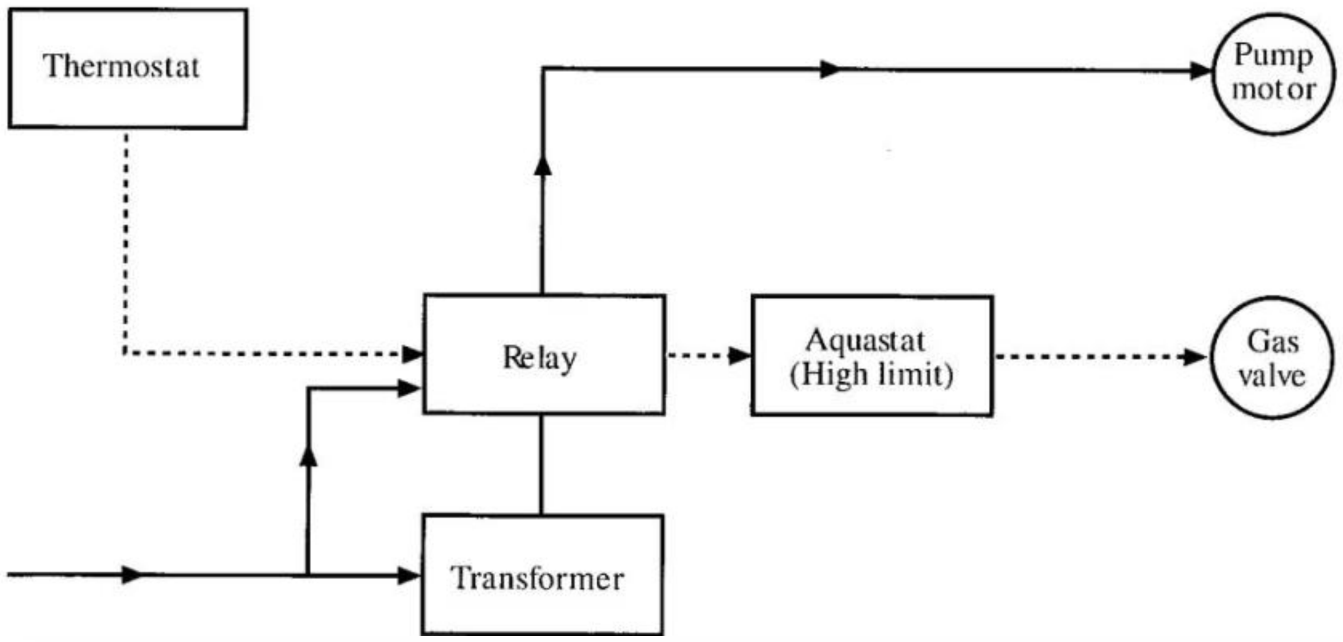


Figure 2-58

Control device	Boiler with pump control - function and operation
Transformer	Operates continuously. Provides low voltage for the control circuit
Thermostat	Operated by room temperature. Turns the gas valve on and off
Aquastat	Operated by water temperature. Controls temperature of the radiation system
Pump motor	Operated by pump control. Circulates water through the system
Pump control	Operated by water temperature in boiler. Turns the pump on
Gas valve	Operated by the thermostat and aquastat. Ignites the boiler burner

Boiler with Pump Relay

Figure 2-59
Boiler with pump relay



Control device	Boiler with pump relay - function and operation
Transformer	Operates continuously. Provides low voltage for the control circuit
Thermostat	Operated by room temperature. Turns the relay on and off
Aquastat	Operated by water temperature. Controls temperature of the radiation system
Relay	Operated by the thermostat. Turns on pump and burners
Pump motor	Operated by the relay. Circulates water through the system
Gas valve	Operated by thermostat, aquastat, and relay. Ignites the boiler burner

"Hot Boiler" with Zone Pumps and Outdoor Controller

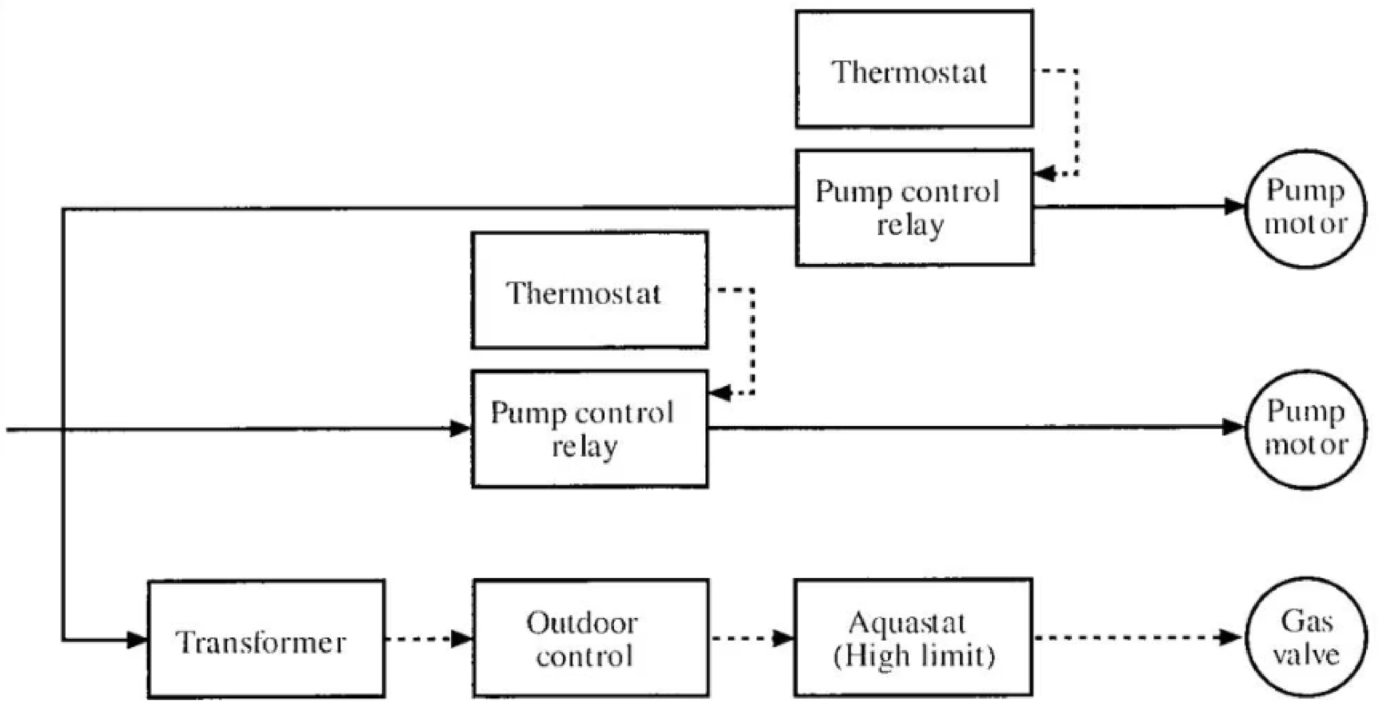


Figure 2-60 "Hot boiler" with zone pumps and outdoor controller

Control device	"Hot boiler" with zone pumps and outdoor controller - function and operation
Transformer	Operates continuously. Provides low voltage for the control circuit
Thermostat	Operated by room temperature. Turns the pump(s) on and off
Aquastat	Operated by water temperature. Controls temperature of the radiation system
Pump control relay	Operated by the thermostat. Turns on pump
Pump motor	Operated by the pump control relay. Circulates water through the system
Outdoor control	Operated by outdoor temperature. Regulates boiler water temperature
Gas valve	Operated by aquastat and outdoor control. Ignites the boiler burner

Boiler with Zone Pumps

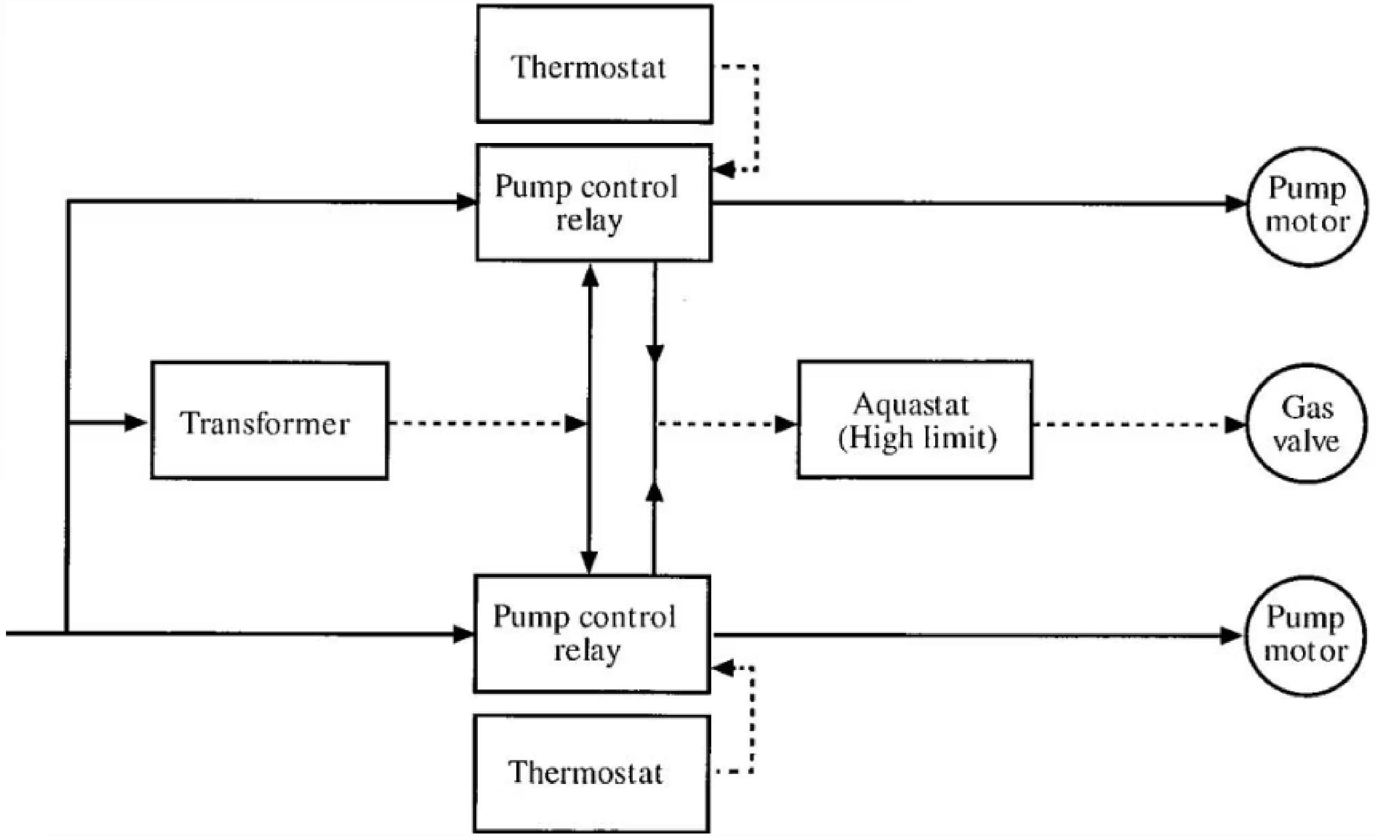


Figure 2-61 Boiler with zone pumps (burner controlled by auxiliary contacts in pump relays)

Control device	Boiler with zone pumps - function and operation
Transformer	Operates continuously. Provides low voltage for the control circuit
Thermostat	Operated by room temperature. Turns the pump control relay(s) on and off
Aquastat	Operated by water temperature. Controls temperature of the radiation system
Pump control relay	Operated by the thermostat. Turns on pump and burners
Pump motor	Operated by the pump control relay(s). Circulates water through the system
Outdoor control	Operated by outdoor temperature. Regulates boiler water temperature
Gas valve	Operated by aquastat and pump control relay(s). Ignites the boiler burner

Boiler Using Zone Valves

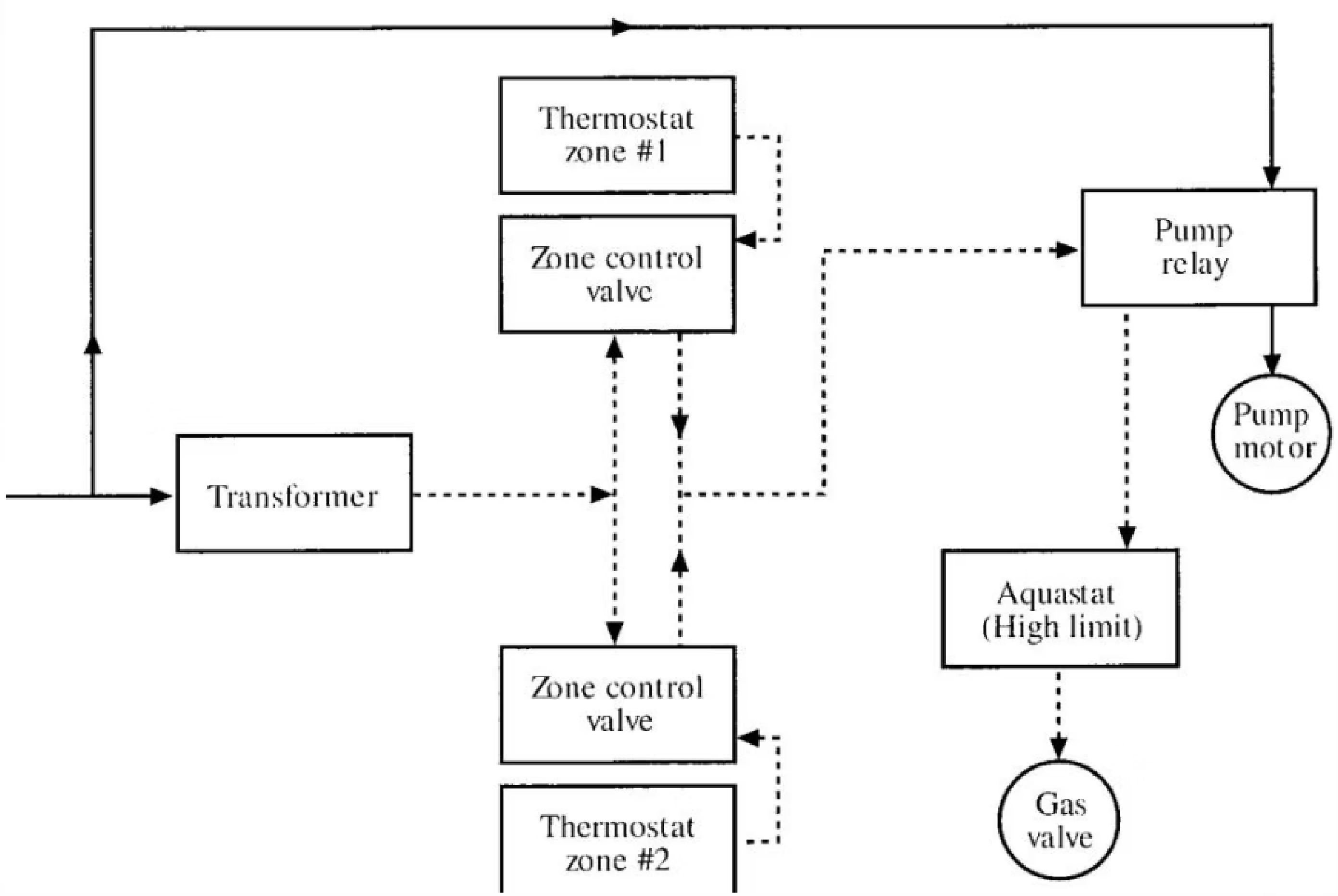


Figure 2-62 Boiler using zone valves

Control device	Boiler using zone valves – function and operation
Transformer	Operates continuously. Provides low voltage for the control circuit
Thermostat	Operated by room temperature. Turns the zone valve(s) on and off
Aquastat	Operated by water temperature. Controls temperature of the radiation system
Pump relay	Operated by thermostat and zone valve end switch. Turns on pump and burners
Pump motor	Operated by the pump relay(s). Circulates water through the system
Zone control valve	Operated by thermostat. Opens water flow to zone and activates burner and pump with its end switch
Gas valve	Operated by aquastat, pump control relay(s), and zone valve end switch (es). Ignites the boiler burner

Boiler Using Zone Valves, Two Transformers, and Outdoor Control

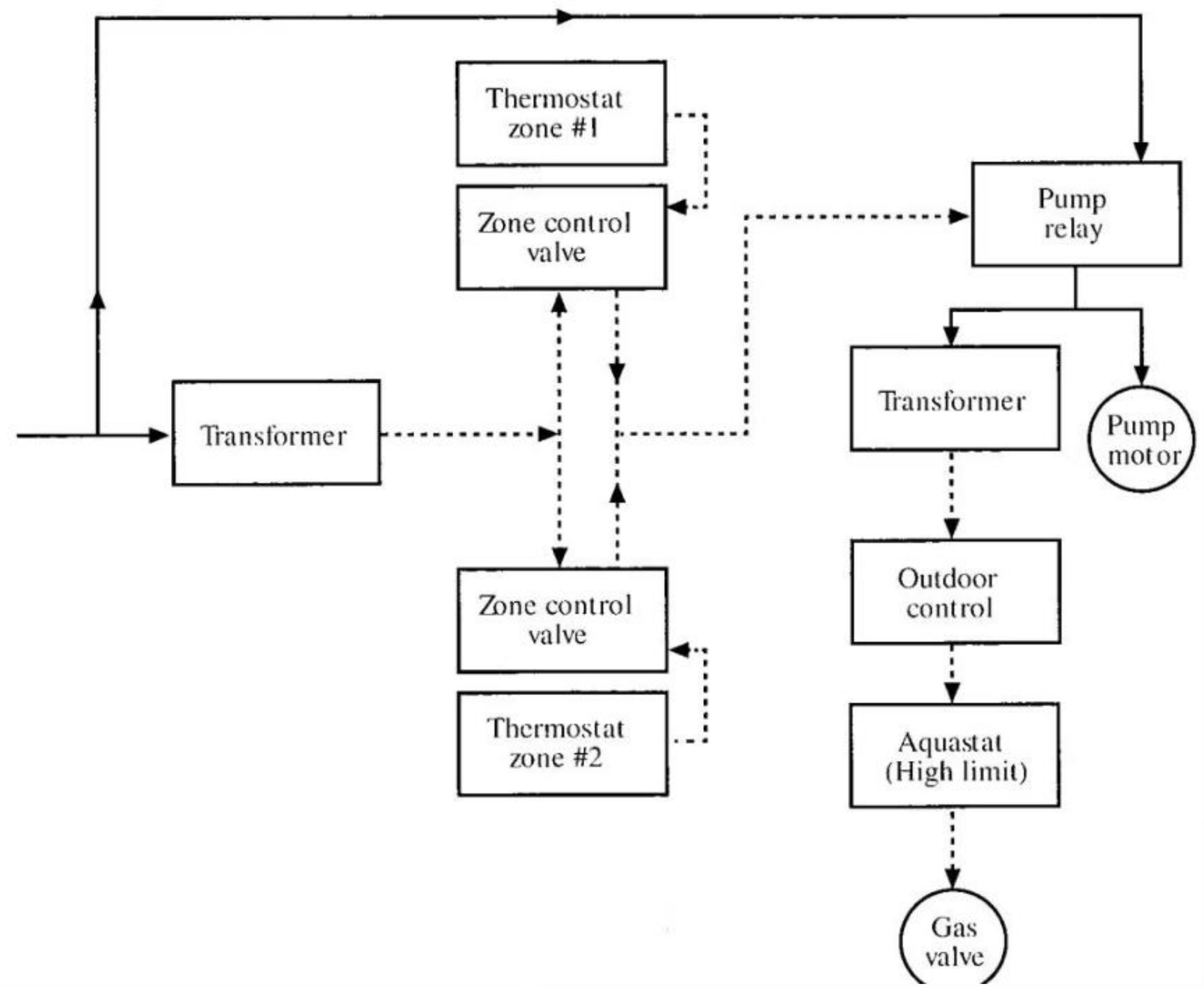


Figure 2-63 Boiler using zone valves, two transformers, and outdoor control

Control device	Boiler using zone valves, two transformers, and outdoor control - function and operation
Transformer	Operates continuously. Provides low voltage for the control circuit
Thermostat	Operated by room temperature. Turns the zone valve(s) on and off
Aquastat	Operated by water temperature. Controls temperature of the radiation system
Pump relay	Operated by thermostat and zone control end switch. Turns on pump and burners
Pump motor	Operated by the pump relay(s). Circulates water through the system
Zone control valve	Operated by thermostat. Opens water flow to zone and activates burner and pump with its end switch
Outdoor control	Operated by outdoor temperature. Regulates boiler water temperature
Gas valve	Operated by aquastat, pump control relay(s), and zone valve end switch (es), thermostat, and outdoor control. Ignites the boiler burner

Boiler with Water-Heating Function

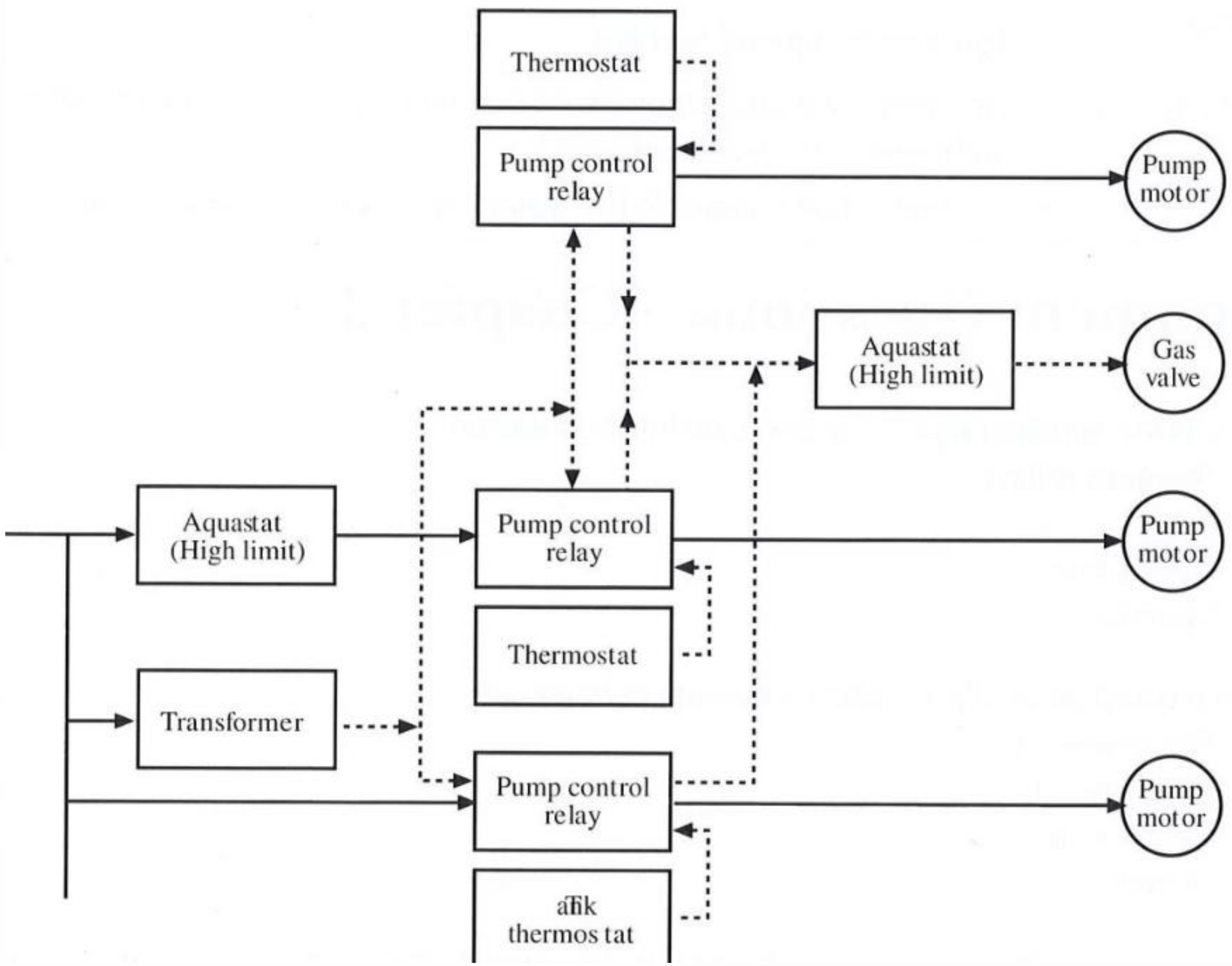


Figure 2-64 Boiler with water heating function

Control device	Boiler with water heating function - function and operation
Transformer	Operates continuously. Provides low voltage for the control circuit
Thermostat	Operated by room temperature. Turns the zone valve(s) on and off
Aquastat (high limit)	Operated by water temperature. Controls temperature of the radiation system
Aquastat (pump control)	Operated by boiler temperature. Shuts pumps off if boiler water temperature is too low during hot water heating operation
Pump control relay (zones)	Operated by thermostat. Turns on pump and burners
Pump motor (zones)	Operated by the pump relay and pump control aquastat. Circulates water through the zone
Pump control relay (tank)	Operated by tank thermostat. Turns on pump and burners
Pump motor (tank)	Operated by aquastat, pump control relay, zone control end switch, thermostat, and outdoor control. Circulates boiler water to hot water heat exchanger in water tank

Integrated Boiler Control Systems

Safety Controls

Prevent dangerous operating conditions

Flow Controls

Manage water movement through system

Zone Controls

Provide targeted heating to specific areas

Temperature Controls

Maintain optimal operating temperatures

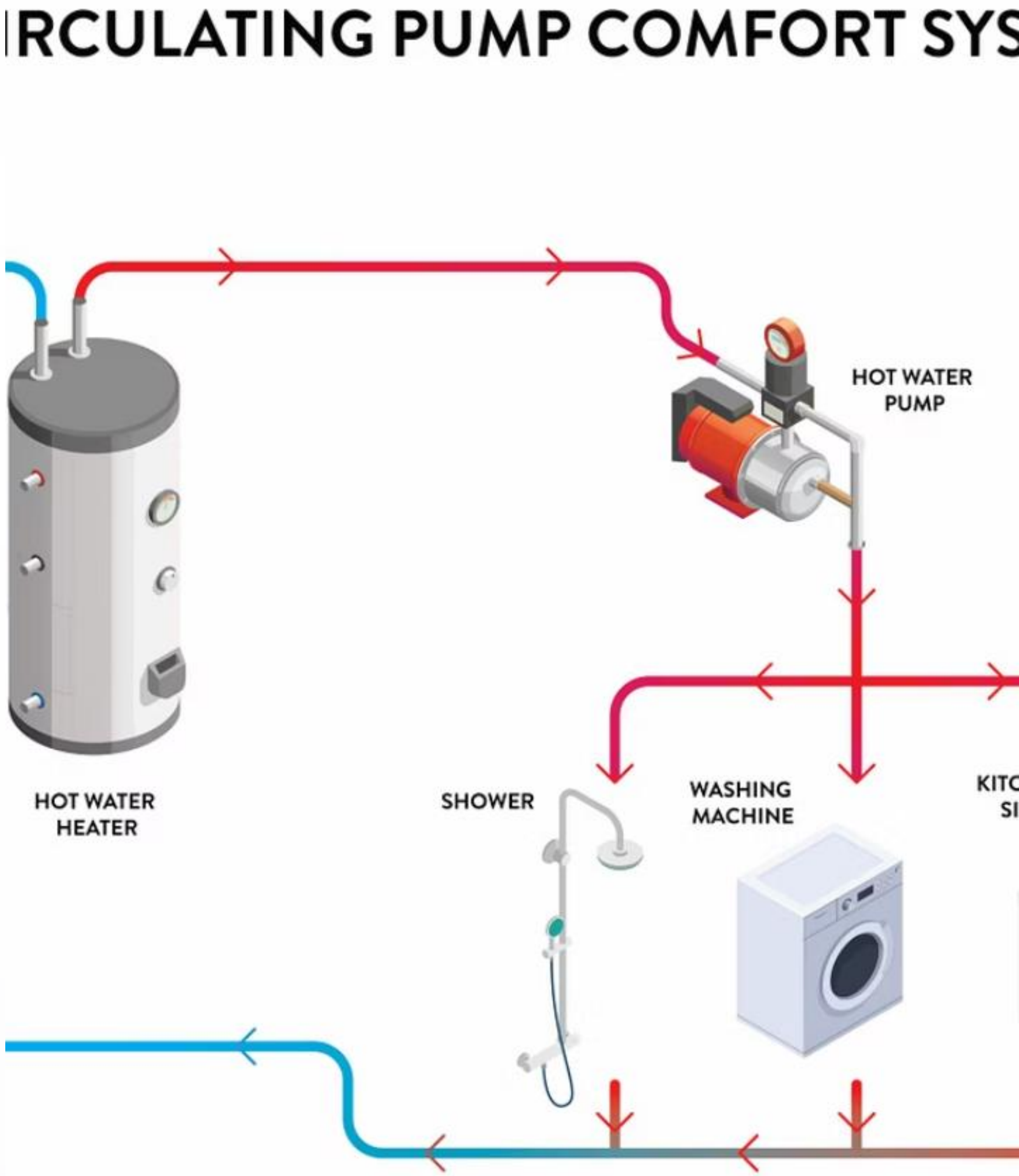
Modern hydronic boiler systems integrate multiple control strategies to provide safe, efficient, and comfortable heating. From basic safety devices like low water cut-offs and relief valves to sophisticated temperature management with outdoor reset controls, these systems require proper component selection and installation to function effectively.

Understanding the interaction between various control devices is essential for system design, troubleshooting, and maintenance. As building automation systems become more prevalent, the integration of these controls continues to evolve, offering improved efficiency and performance.

CSA Unit 20

Chapter 3 Circulators in Hydronic Heating Systems

Circulators, or circulating pumps, are essential components in hydronic heating systems, pool filtration systems, and condensate management in steam boilers. This presentation explores the principles, components, and applications of different types of circulators, providing gas technicians and fitters with the knowledge needed for proper selection, installation, and maintenance.



Purpose of Circulators

Pool Heater Recirculation

Filter pumps draw water from the pool through drains and skimmers, passing it through filters and heaters before returning it to the pool.

Hydronic Heating Systems

Circulators provide the pressure differential required to maintain fluid flow throughout the heating system.

Condensate Pumping

In large hydronic systems with steam boilers, condensate pumps return collected condensate back to the boiler as makeup water.

Learning Objectives

Describe Circulators and Components

Understand the various types of circulators, their construction, and the function of each component.

Explain Basic Principles

Comprehend the fundamental principles that govern circulator operation, selection, and installation in hydronic systems.

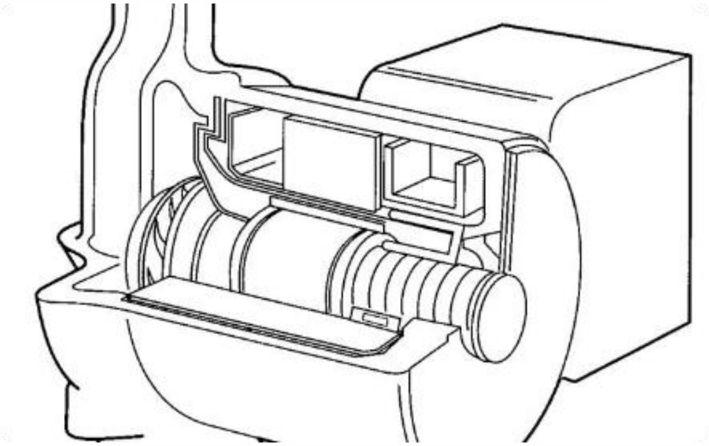
Key Terminology

Term	Definition
Design water temperature drop	The difference between the water temperature at the point where it leaves the boiler and the point where it returns
Point of no pressure change	The point where the expansion tank is attached to the system piping
Pump head	The mechanical energy added per pound of fluid

Types of Circulators

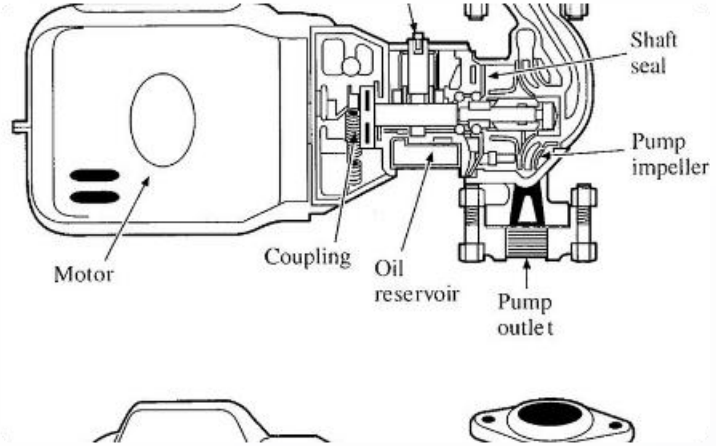
Centrifugal Pumps

Powered by an induction motor, these pumps use a rotating impeller to accelerate fluid through the pump chamber.



Wet Rotor Circulators

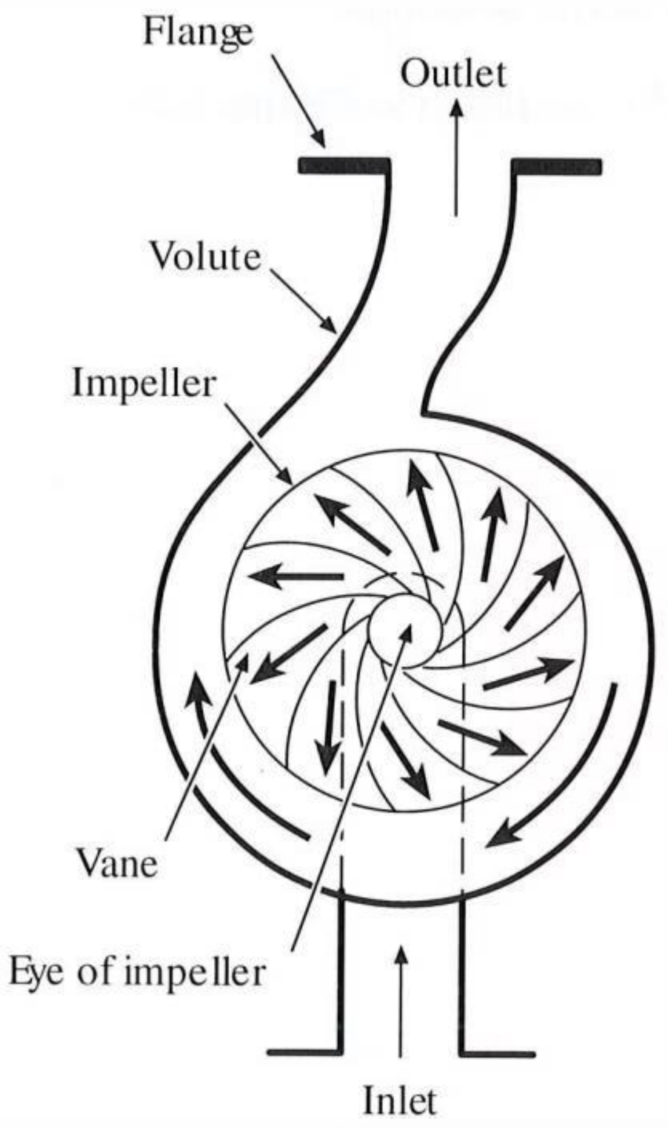
These have the motor, shaft, and impeller combined in one assembly, housed in a chamber filled with system fluid that acts as coolant and lubricant.



Three-Piece Circulators

Consisting of a motor, pump body, and coupling, allowing servicing without disconnecting from the piping system.

Centrifugal Pump Operation



How Centrifugal Pumps Work

A centrifugal pump has a rotating impeller that accelerates fluid coming into the pump chamber, or volute. The spinning action increases the speed and mechanical energy of the fluid, developing a pressure head in the volute that forces the fluid out the pump's discharge port.

The pump includes a bearing and seal assembly that holds the impeller in place while allowing it to rotate. This assembly also secures the motor, seal, and oil reservoir, while the shaft seal prevents water from leaking around the shaft.

Impeller Factors

Blade Length

The longer the blades of the impeller, the higher the pressure it can produce.

Impeller Width

The wider the impeller, the more water it can move.

Suction Opening

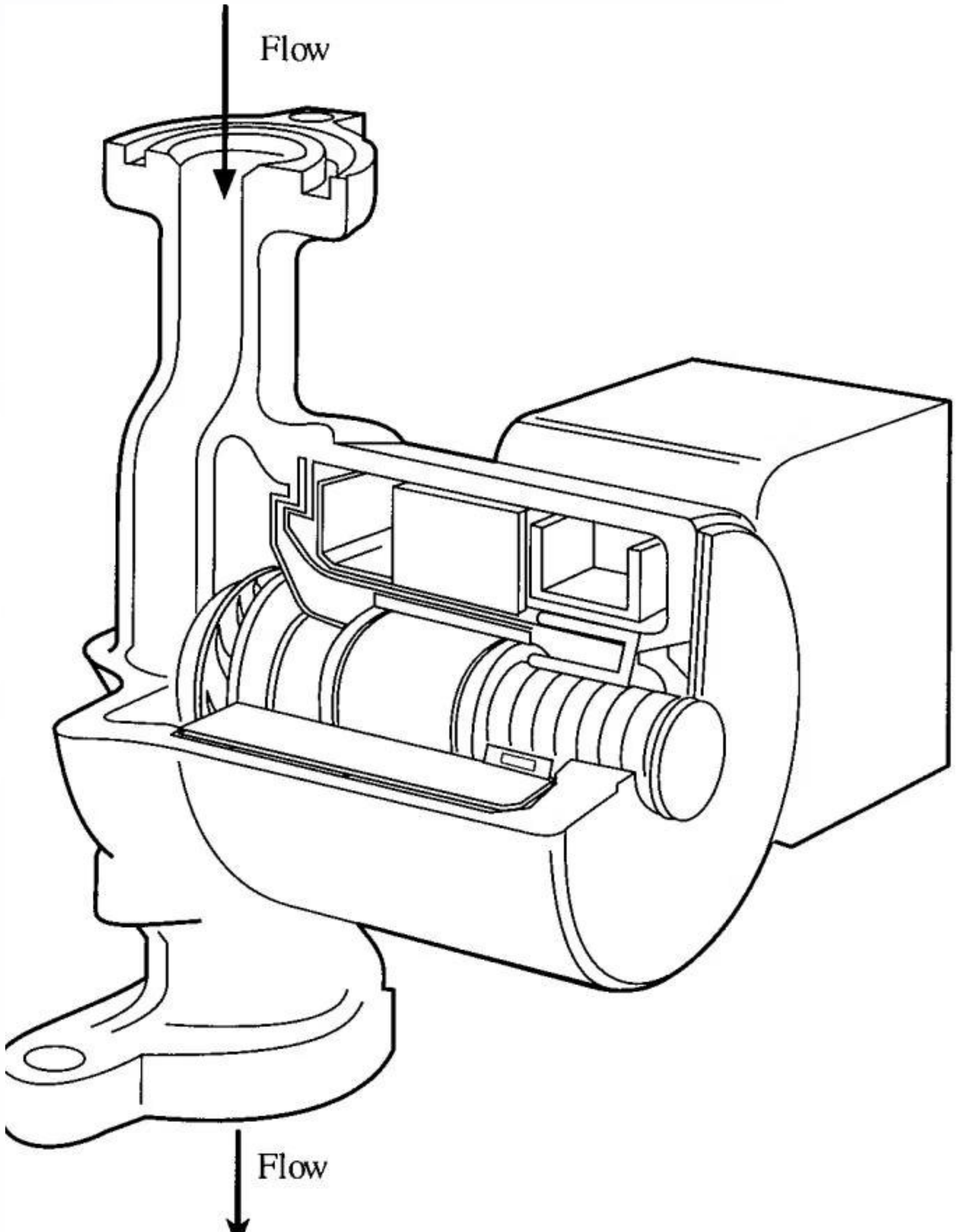
The larger the suction opening, the more water it can move.

Rotation Speed

The faster the impeller turns, the more water it can move and the higher pressure it can produce.

Note: When replacing a pump impeller, avoid excessive lateral movement of the shaft. The shaft seal is fragile and may leak if subjected to excessive lateral movement during installation.

Wet Rotor Circulators

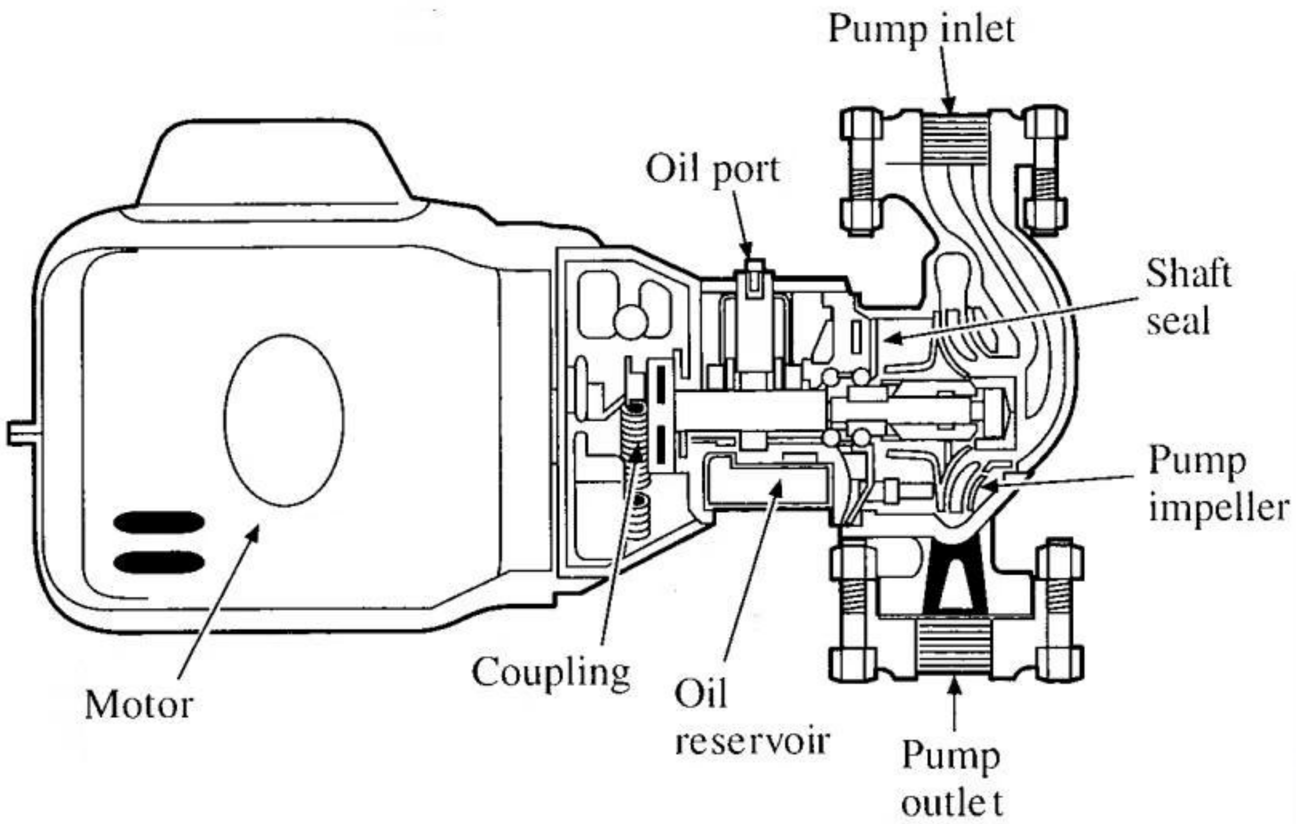


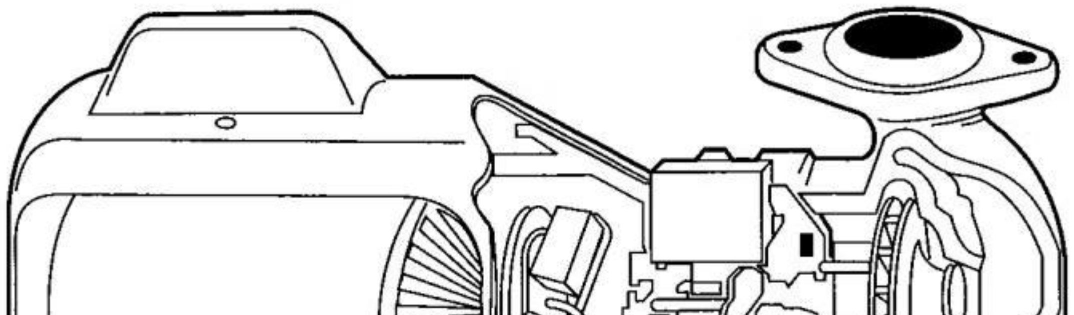
Features of Wet Rotor Circulators

- Commonly used in many hydronic systems
- Usually constructed of iron or bronze
- Motor, shaft, and impeller combined in one assembly
- Assembly housed in a chamber filled with system fluid
- Fluid acts as coolant for the motor and lubricant for pump bearings

Three-Piece Circulators

Figure 3-3
Three-piece circulator
Courtesy of ITT Bell and Gossett





Advantages of Three-Piece Design

The three-piece circulator consists of a motor, pump body, and coupling. This design offers significant maintenance advantages:

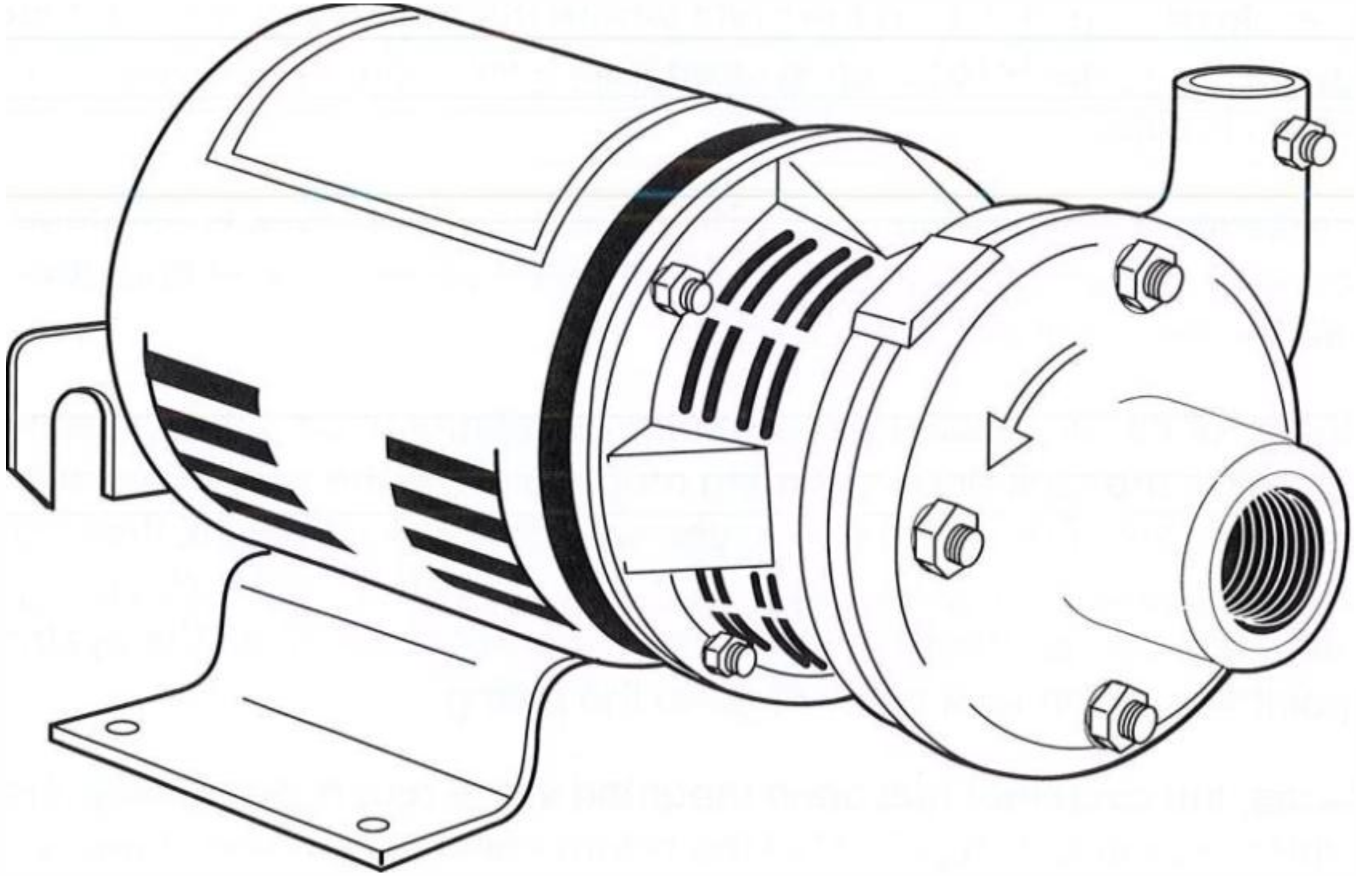
- Motor is separate from the wetted part
- Allows servicing or replacement of the motor or coupling without disconnecting the pump body from the piping system
- No need to open up the piping system for motor maintenance
- Reduces system downtime during repairs

Inline-Suction vs. End-Suction Circulators

Inline-Suction Circulators

Most common configuration for hydronic system circulators.

- Inlet and outlet ports located on a common centerline
- Can be installed in a piping run with no lateral offsets between ports
- Simplifies installation in straight pipe runs



End-Suction Circulators

Creates a 90-degree bend in the piping run at the pump location.

- Requires an offset between inlet and outlet ports
- Often used in larger commercial applications
- Base-mounted for stability

Circulator Selection Factors

Flow Characteristics

The pump must provide appropriate flow rate and pressure for the system requirements.

System Location

Proper placement within the system affects overall performance and efficiency.

Electrical Requirements

Voltage, phase, and power consumption must match available supply.

Maintenance Needs

Consider accessibility, serviceability, and long-term maintenance requirements.

Additional Selection Considerations

Coupling Type and Alignment

Must be appropriate for the application and properly aligned for efficient operation.

Motor Type

Should match the system requirements and environmental conditions.

Safety Considerations

Must meet all applicable safety standards and requirements.

Environmental Conditions

Temperature, humidity, and other environmental factors affect pump selection.

Optimal Circulator Selection

		IDS Light	IDS Premium
Heat Pump		O	O
SEER (up to)		15	20.5
Cooling Operation Range (°F)		40 ~ 120	15 ~ 125
Heating Operation Range (°F)		5 ~ 86	-4 ~ 86
ODU	Ton	2, 3, 5	3, 5
	Compressor	Inverter Rotary 33%-110% 1% increments	Inverter Rotary 36%-130% 1% increments
	dbA (Min)	59	56
	EEV	O	O
	Crankcase Heater	O	O
IDU	Ton	2, 3, 4, 5	2, 3, 4, 5
	Blower Motor	PSC	Two-Stage ECM
	Al Coil	O	O
	Multi Position	O	O
Thermostat		24V	24V
Maximum Line Length		100ft	150ft
Maximum Elevation Diff.		50ft	50ft
Warranty*		10yr	10yr
Dual Fuel Application		O	O

*Product Must be registered. Please visit boschheatingandcooling.com for full limited warranty detail

The Ideal Circulator

For a given application, the perfect circulator would be one that produces the desired flow rate, at maximum efficiency, with the lowest electrical power consumption.

To achieve this balance, utilize the manufacturer's pump sizing charts that apply to your specific selection criteria.

The pump should operate near its highest efficiency point, which is usually close to the knee of its performance curve.

Circulator Location in Hydronic Systems

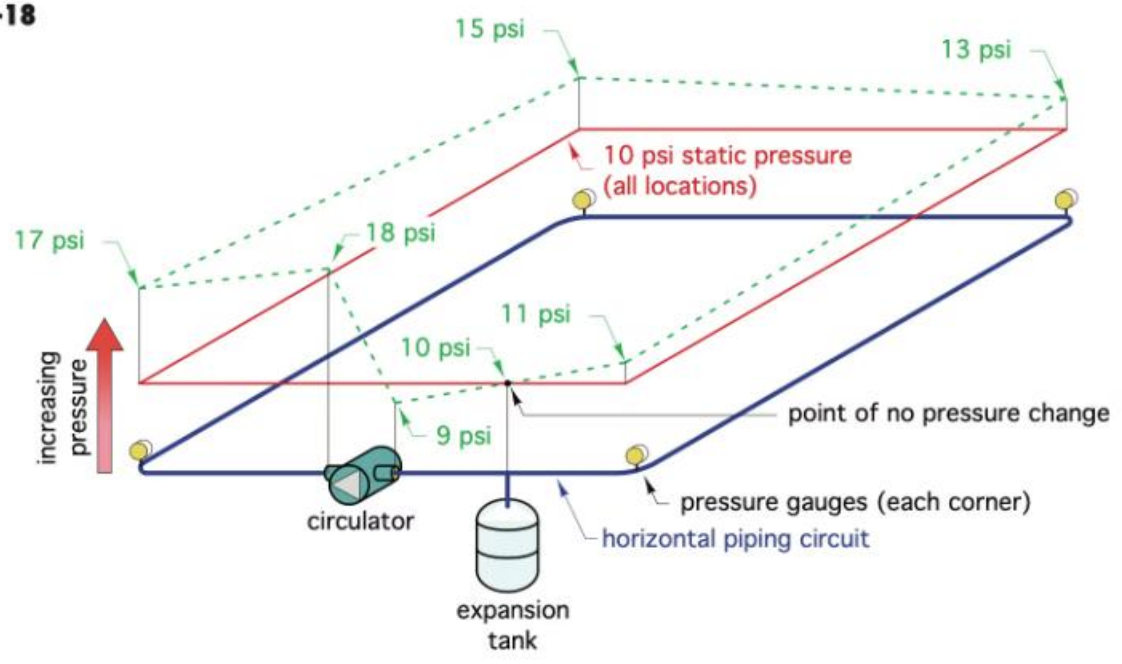
Optimal Placement

The location of circulators in hydronic systems in relation to other system components is critical to quiet, reliable, trouble-free operation.

In most installations, the circulator should be located with its inlet port as close as possible to the point where the expansion tank connects to the system.

This allows the circulator to pump system fluid away from the expansion tank and the point of no pressure change.

Figure 2-18



Point of No Pressure Change

Definition

The point of no pressure change is the point where the expansion tank is attached to the system piping.

Fixed System Fluid

In a closed-loop system, the amount of fluid is fixed and does not change, regardless of whether the circulator is on or off.

Expansion Tank Function

The air-side chamber of the expansion tank contains a volume of air under pressure. Pressure can only change by forcing more fluid into the tank or removing fluid from it.

Fixed Pressure Point

Since the amount of fluid in the closed system is fixed and incompressible, the expansion tank fixes the system's fluid pressure at the point where the tank is attached to the piping.

Traditional vs. Modern Circulator Placement

Traditional Return Line Mounting

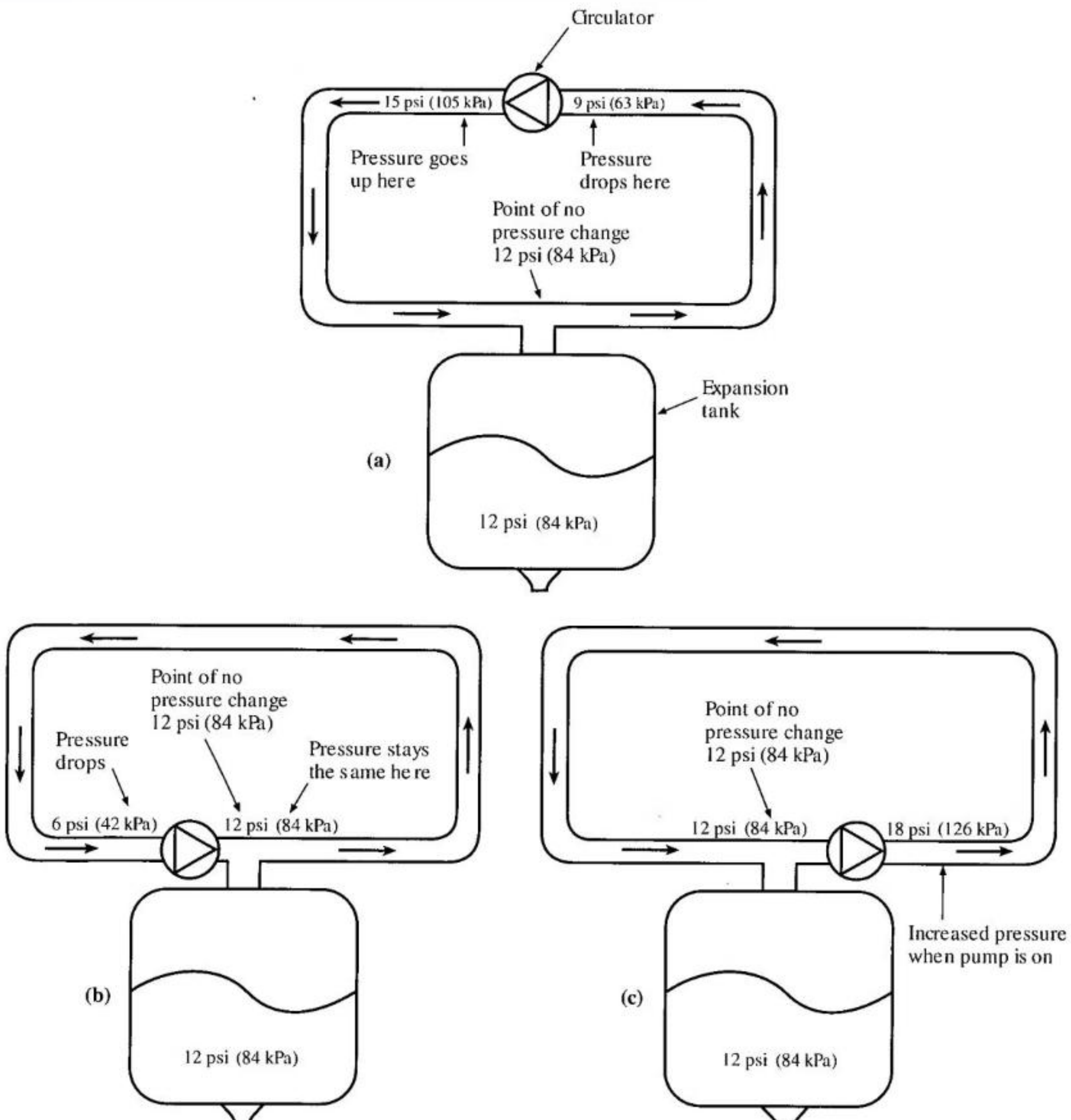
In many installations, the circulator has traditionally been mounted in the return piping near the boiler. The main reason for this was the cooling effect of the return water, which was thought to prolong the life of the pump motor, packing, and seals.

Modern Approach

This is not a problem for modern, wet rotor circulators, many of which are rated for continuous operation while handling fluids at temperatures up to 230°F (110°C).

When system pumps have a large capacity, it is better to place them in the supply line to reduce the effective boiler pressure during pumping. This reduces the need to oversize the expansion device required, and a lower water feed pressure can be tolerated.

Effect of Circulator Location on System Pressure



Pressure Distribution in Simple Loop

In the simple loop shown, the system static pressure is 12 psi (84 kPa). The pressure differential produced by the circulator across its inlet and outlet ports is 6 psi (42 kPa).

When the circulator is installed in the system loop an equal distance downstream and upstream from the expansion tank, the 6 psi (42 kPa) pressure differential that the circulator creates would be distributed as shown in Figure 3-5(a).

The placement of the circulator relative to the expansion tank significantly affects system pressure distribution and operation.

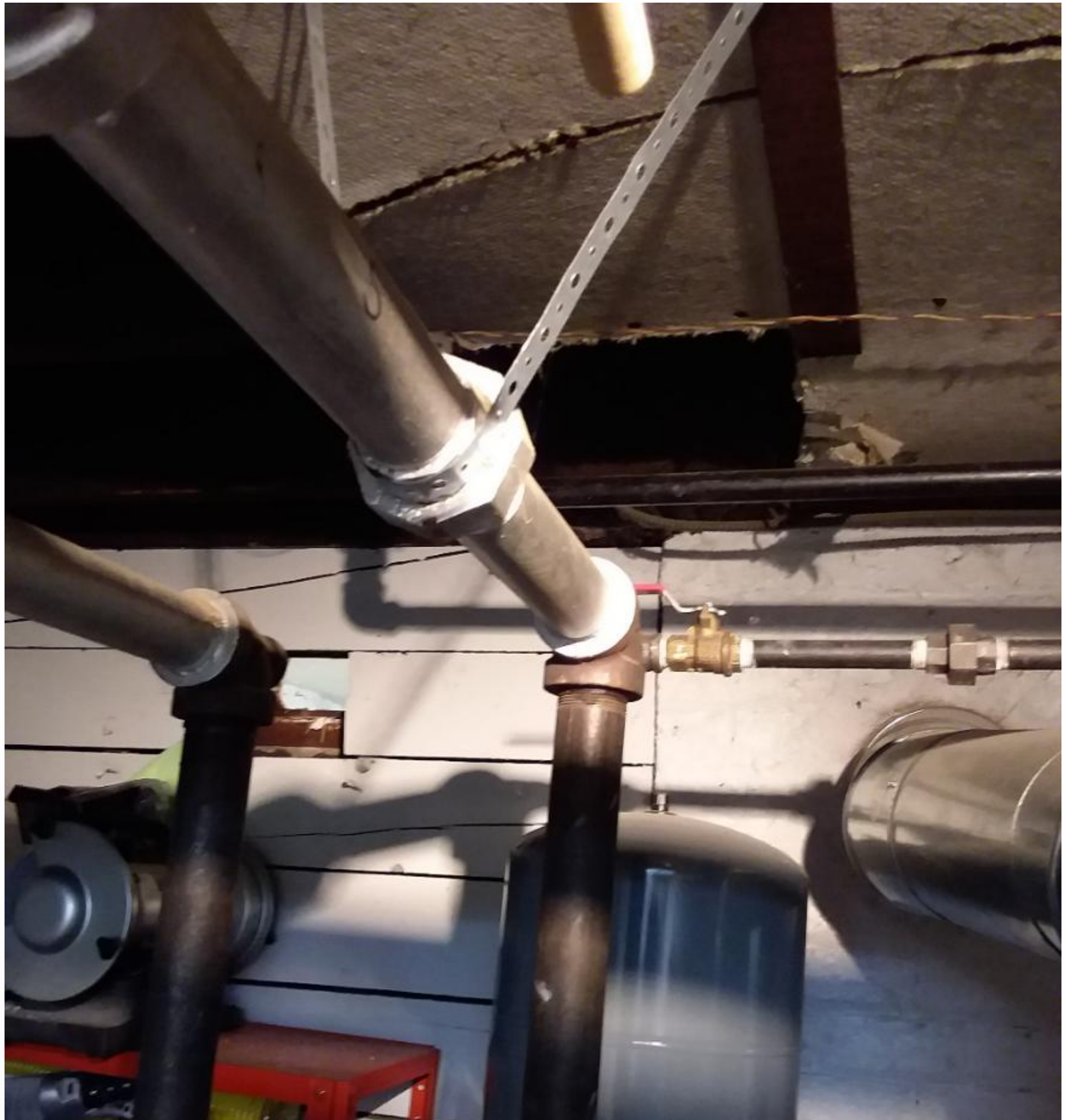
Circulator Placement Before Expansion Tank

Negative Effects

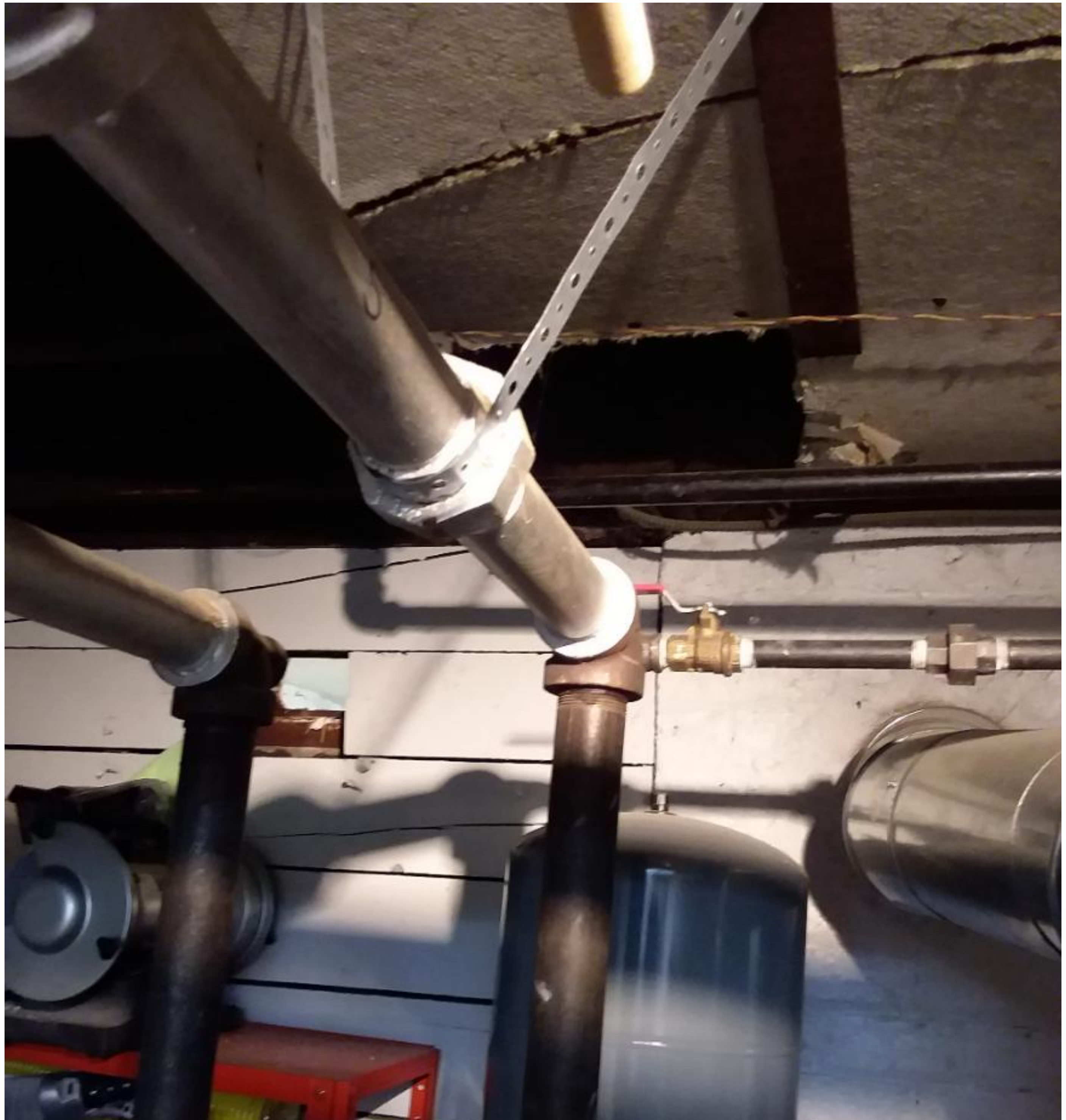
When the circulator is installed ahead of the expansion tank [Figure 3-5(b)] the tank absorbs the pressure differential produced by the circulator.

This means that the circulator can only move the water by pulling it through the system, which creates a pressure loss that can draw air and additional water into the system.

Air drawn into the system by the vacuum effect of a pressure loss introduces corrosion-causing oxygen into the system. New water containing additional air and minerals will contribute to system corrosion, liming, and sludge buildup.



Circulator Placement After Expansion Tank



Positive Effects

When the circulator is installed after the expansion tank, the tank will compensate for the pressure differential created by the circulator [Figure 3-5(c)].

As a result, the inlet pressure of the circulator will remain at system static pressure. This will prevent additional air and water from being drawn into the system.

The circulator can then effectively do its job of developing the pressure to move the water through the system.

Pump Mounting Orientation

Horizontal Shaft Mounting

Most circulators for residential and small commercial systems are designed to be mounted with the pump shaft in the horizontal position.

This configuration eliminates thrust loads on the pump bearings caused by the weight of the rotor and impeller.

You must orient a pump in the correct direction of fluid flow. An arrow on the volute indicates the direction of flow.

You can install the pump with the arrow pointing up, down, or horizontally as long as the pump shaft is horizontal.

Pump Support and Vibration

Piping Support

The system piping cannot be relied upon to support the circulator, unless the circulator is light, and the piping is well supported.

Vibration Control

Vibration-absorbing mounts and couplings are recommended for installations in which the circulator could transmit vibrations to the building through the piping.

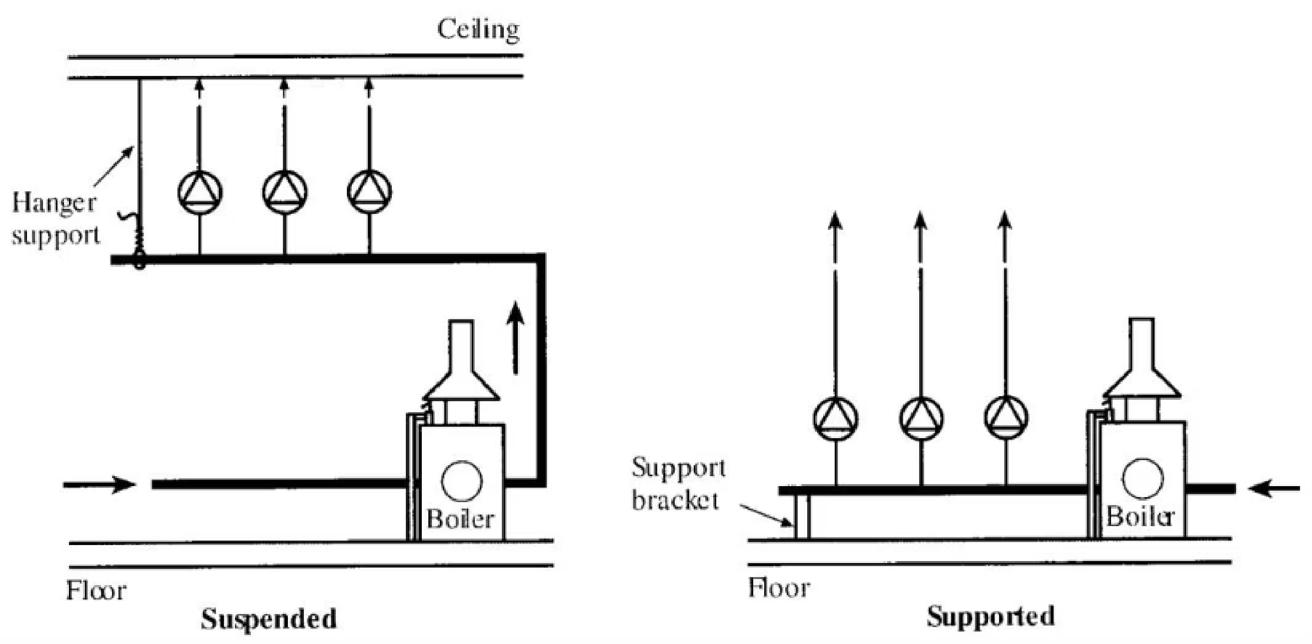
Shaft Alignment

When replacing a pump coupler, also check the pump shaft to make sure it is not out of alignment. Misalignment of the pump shaft can cause premature coupler failure.

Oil Reservoir Positioning

Pump bearing assemblies contain oil reservoirs, and you must not install them in any way that allows oil to drain from the bearing assembly.

Header Mounting for Multi-Zone Systems



Header Assembly Construction

Some multi-zone installations require the mounting of circulators on a common header assembly.

The header is usually made of steel or iron pipe that is strong enough to support the weight of the circulators.

However, the bending effect of the assembly puts a great deal of stress on its connection to the boiler. For this reason, you should support or suspend the end of the header assembly farthest from the boiler.

Piping Connection Methods

Flanged Connections

Most circulators are designed to be connected to piping with bolted flanges. Flange-mounting makes the removal of circulators from the system easier for servicing.

Isolation Flanges

An isolation flange allows the unbolting and removal of a circulator from the system with no loss of fluid other than what is left in the pump volute.

Union Connections

Some small circulators are connected to the piping by means of a tail piece or half-union, which threads directly onto the pump volute.

Soldered Connections

Other small circulators are soldered directly to copper tubing system distribution lines.

Understanding Pump Head

Definition

Pump head can be defined as the height to which a pump can lift and maintain a column of water.

Pressure Difference

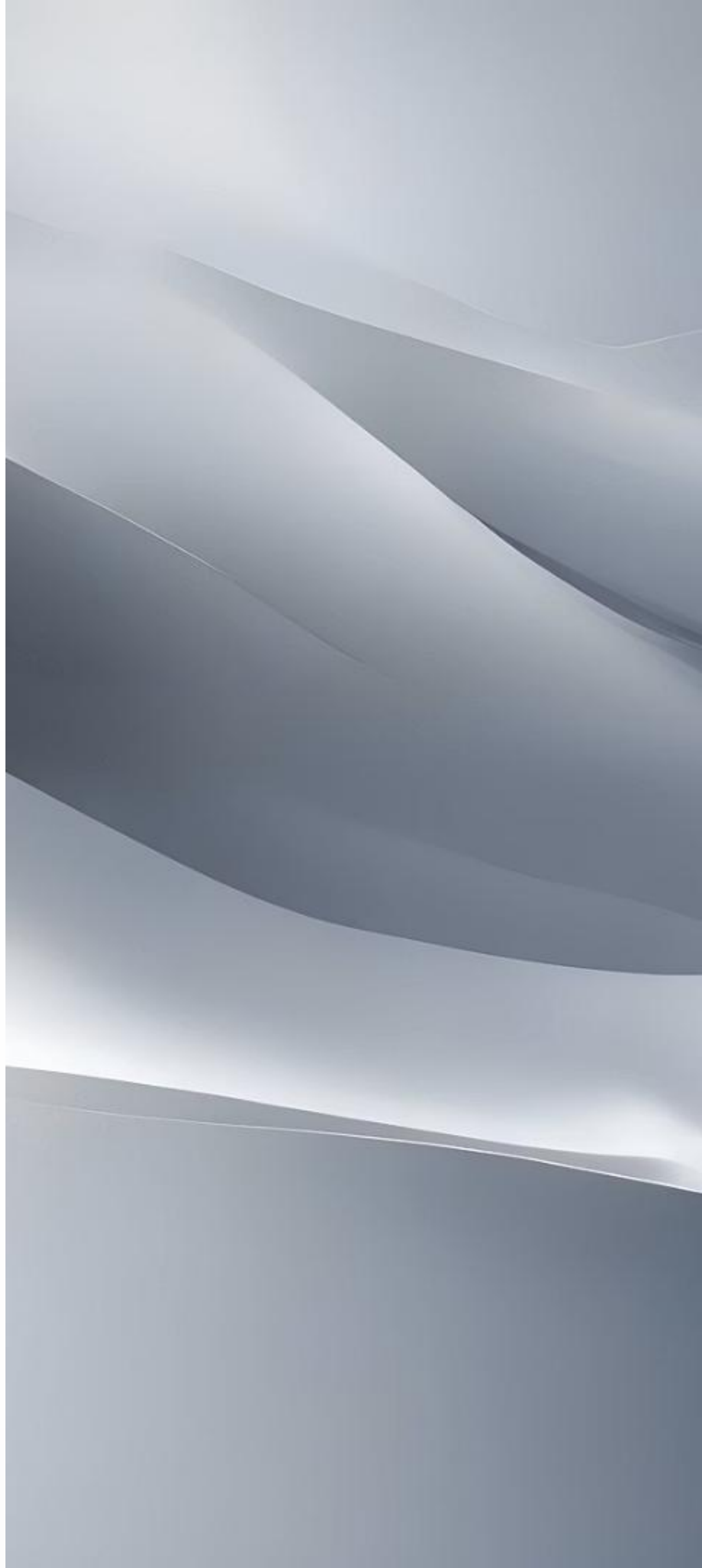
It represents the pressure difference a pump can produce between its inlet and discharge ports.

Energy Transfer

It indicates the mechanical energy imparted by the pump to the fluid being pumped.

Measurement Units

Pump head is expressed in units of feet of head, representing the mechanical energy added per pound of fluid.



Energy Conversion in Pumps

Energy Transformation

The energy imparted to the fluid results in an increased flow rate (kinetic energy) or increased pressure (potential energy).

In hydronic systems, the flow rate and the flow velocity of fluids entering a pump are always equal to those leaving the pump.

In this case, the mechanical energy (pump head) produces an increase in fluid pressure between the pump's inlet and discharge ports.

The amount of pressure increase is inversely proportional to the flow rate through the

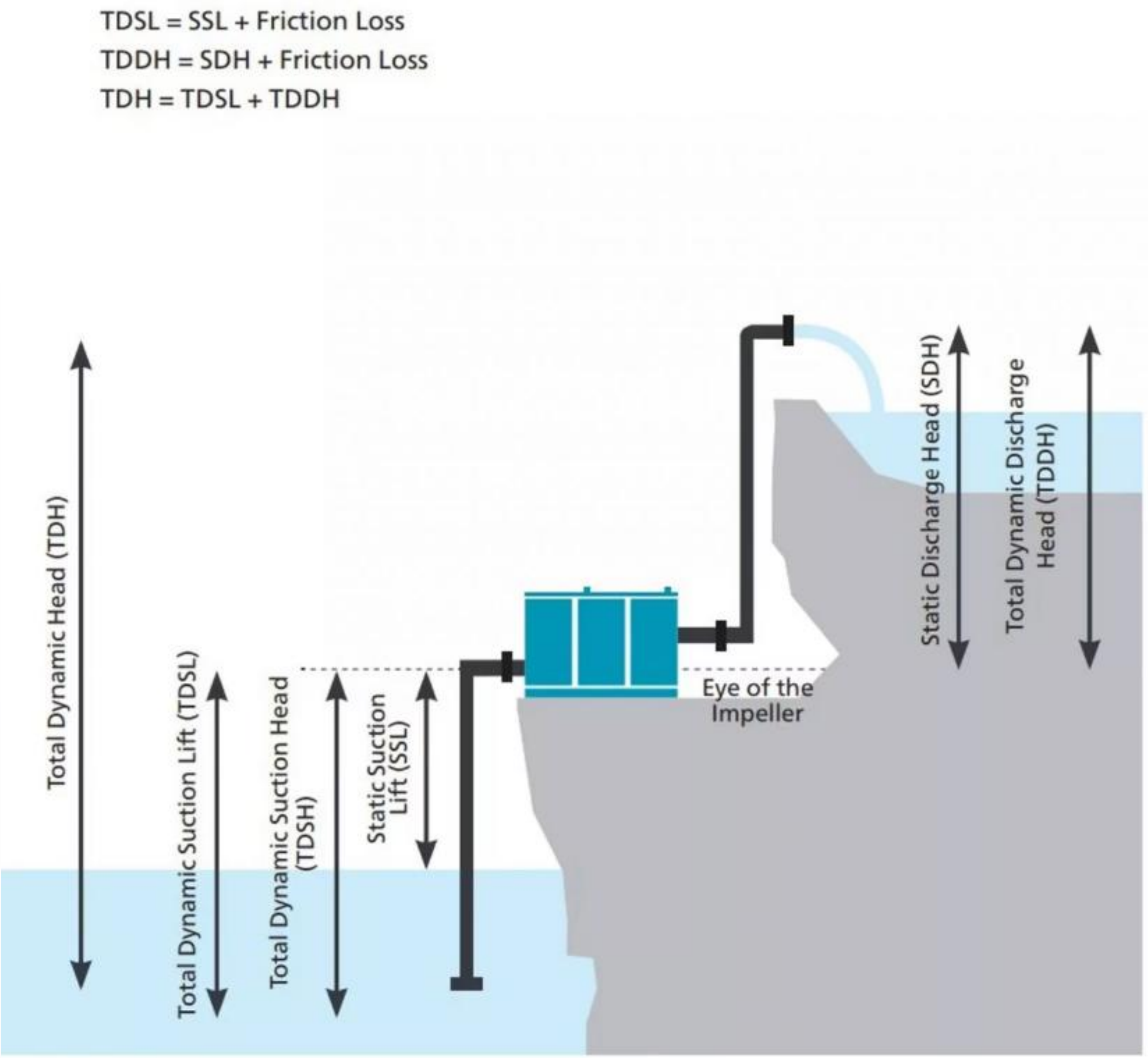
Pump Head Formula

Mathematical Expression

Pump head is expressed in units of feet of head, which is derived from the following equation:

$$Head = \frac{ft \quad lb}{lb} = \frac{energy}{lb} = \frac{ft \quad lb}{lb} = ft$$

Since ft·lb is a measure of energy, pump head can be described as the mechanical energy added per pound of fluid.



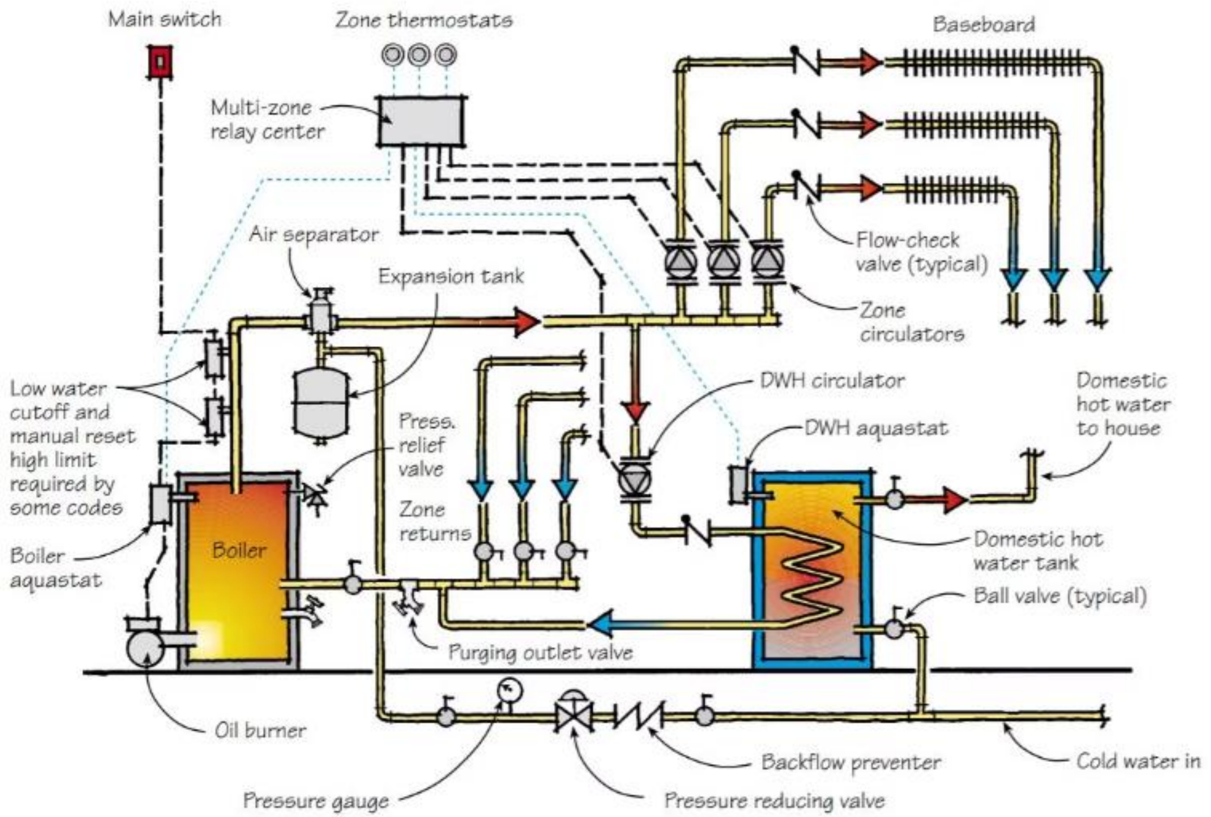
Design Water Temperature Drop

Definition

The design water temperature drop is the difference between the water temperature at the point where it leaves the boiler and the point where it returns.

The recommended temperature drop depends on the type of terminal unit used and the manufacturer's rating.

Components of a Hydronic Baseboard System



Recommended Temperature Drops

System Type	Radiation Equipment	Temperature Drop
Series loop system	Baseboard or commercial fin-tube boilers units	Up to 50°F (28°C)
Two-pipe systems	Cast iron radiators	Up to 30°F (17°C)
	Convectors	10 to 30°F (6 to 17°C) depending on manufacturers ratings
	Unit heaters	Up to 50°F (28°C) as long as minimum flow rates are maintained

System Flow Rate Calculation - Method 1

Using Performance Curves

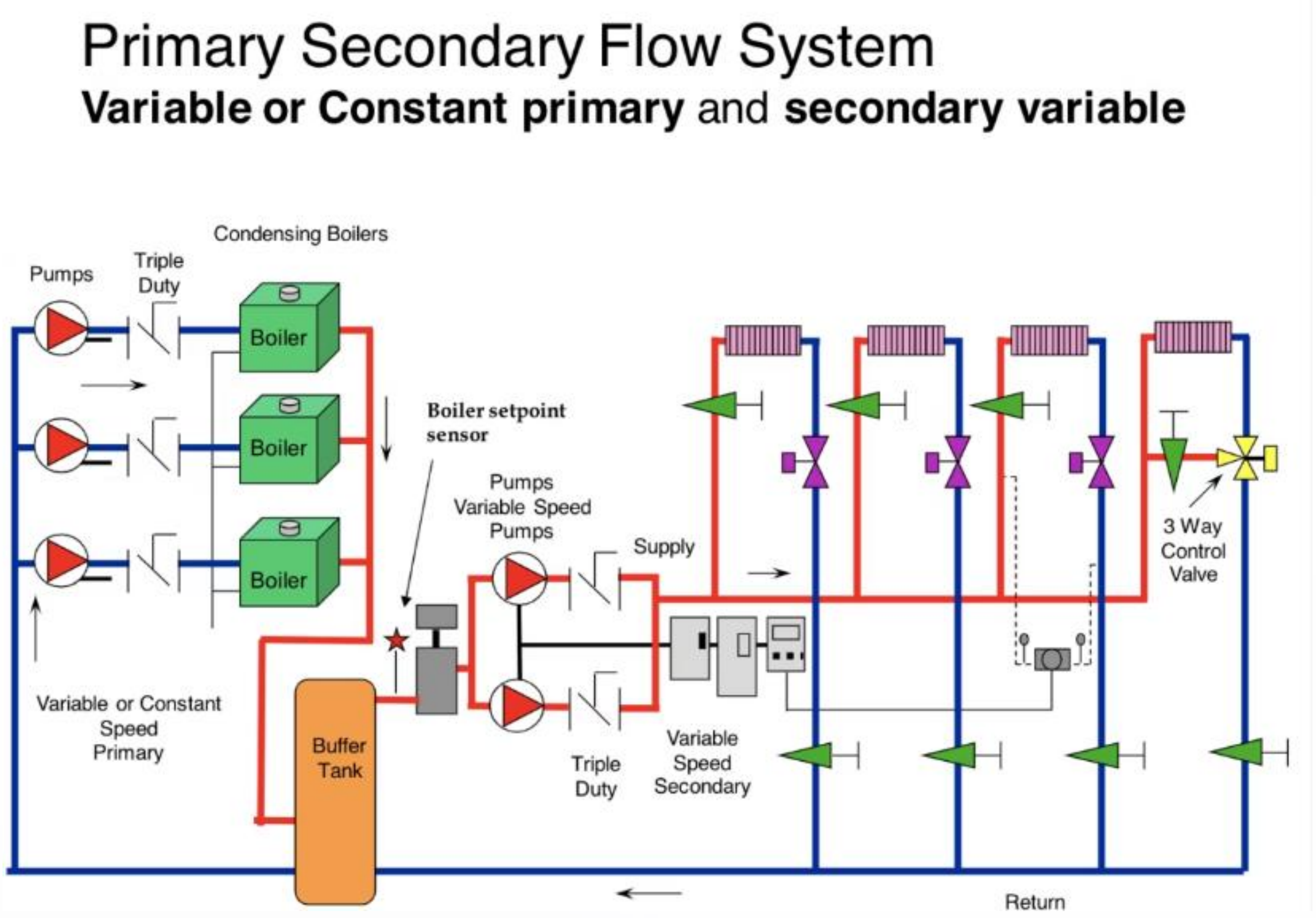
To size a pump using its performance curve, first calculate the system flow rate using the following formulae:

Imperial Formula

$$Flow\ rate(US\ gpm) = \frac{System\ heat\ loss(Btu/h)}{Temperature\ drop\ (°F) \times 500}$$

Metric Formula

$$Flow\ rate(L/s) = \frac{System\ heat\ loss\ (kW)}{Temperature\ drop\ (°C) \times 4.2}$$



In these formulae, the system heat loss is the total of the heat requirements of the system's heating units. The temperature drop is the design water temperature drop.

Flow Rate Calculation Example

Problem Statement

It has been determined that a building has a heat loss of 35,000 Btu/h.

The design temperature drop is 20°F.

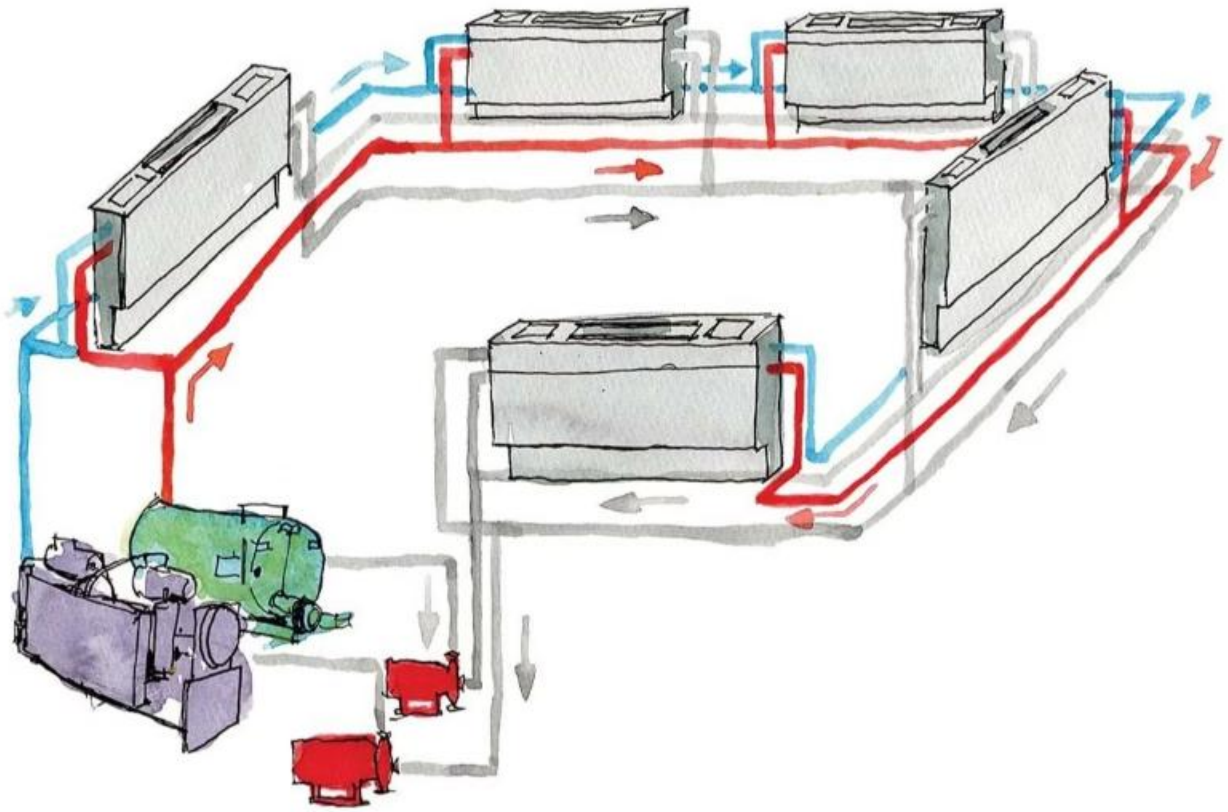
Calculation

$$Flow\ rate = \frac{35,000\ Btu/h}{20°F\ \times\ 500} = \frac{35,000}{10,000} = 3.5\ gpm$$

Result

Accordingly, the pump must be capable of a flow rate of 3.5 gpm.

System Flow Rate Calculation - Method 2



Terminal Unit Approach

The second method is to determine the flow rate for each terminal unit and then total the flow rates for the system depending on the type of layout used (i.e., series loop or parallel).

This approach can be more accurate for complex systems with multiple zones or different types of terminal units.

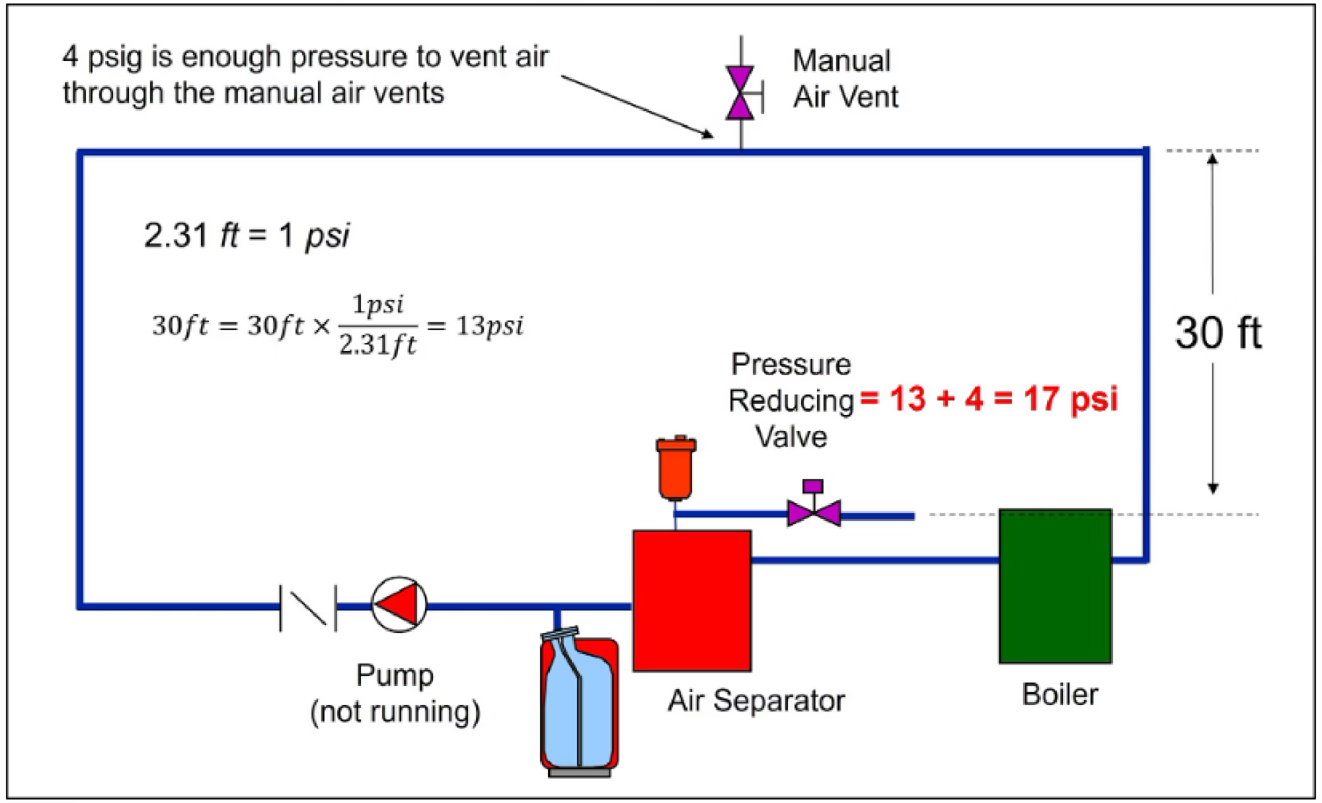
Each terminal unit's flow rate is calculated based on its heat output requirements and the design temperature drop across that unit.

System Pressure Loss (Resistance)

Total Pressure Loss

The total pressure loss, or system resistance, is the sum of the resistances of all the flow-restricting components of the system.

The resistance losses of components and piping are listed in manufacturer's specifications and trade reference manuals.



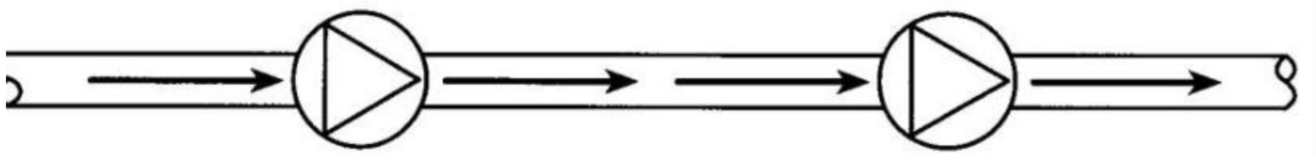
Understanding system pressure loss is crucial for proper pump selection, as the pump must overcome this resistance to maintain the desired flow rate.

Increasing Flow and Pressure

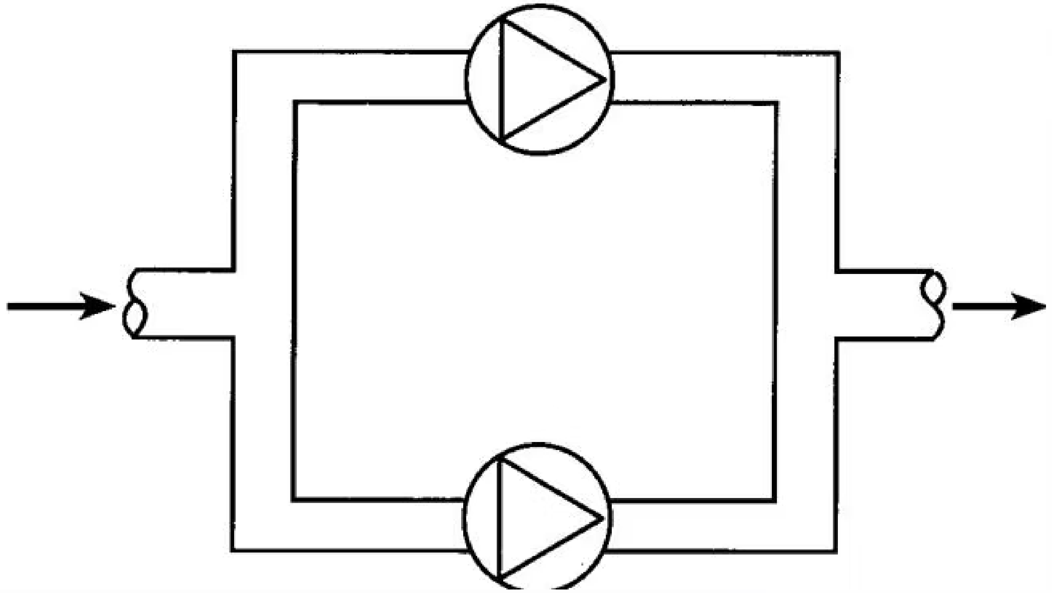
Multiple Pump Configurations

You can install circulators in pairs to increase flow rate and pressure in a hydronic system.

Two pumps of the same size	Will
Installed in series	Double system pressure
Installed in parallel	Double system flow rate



Series installation



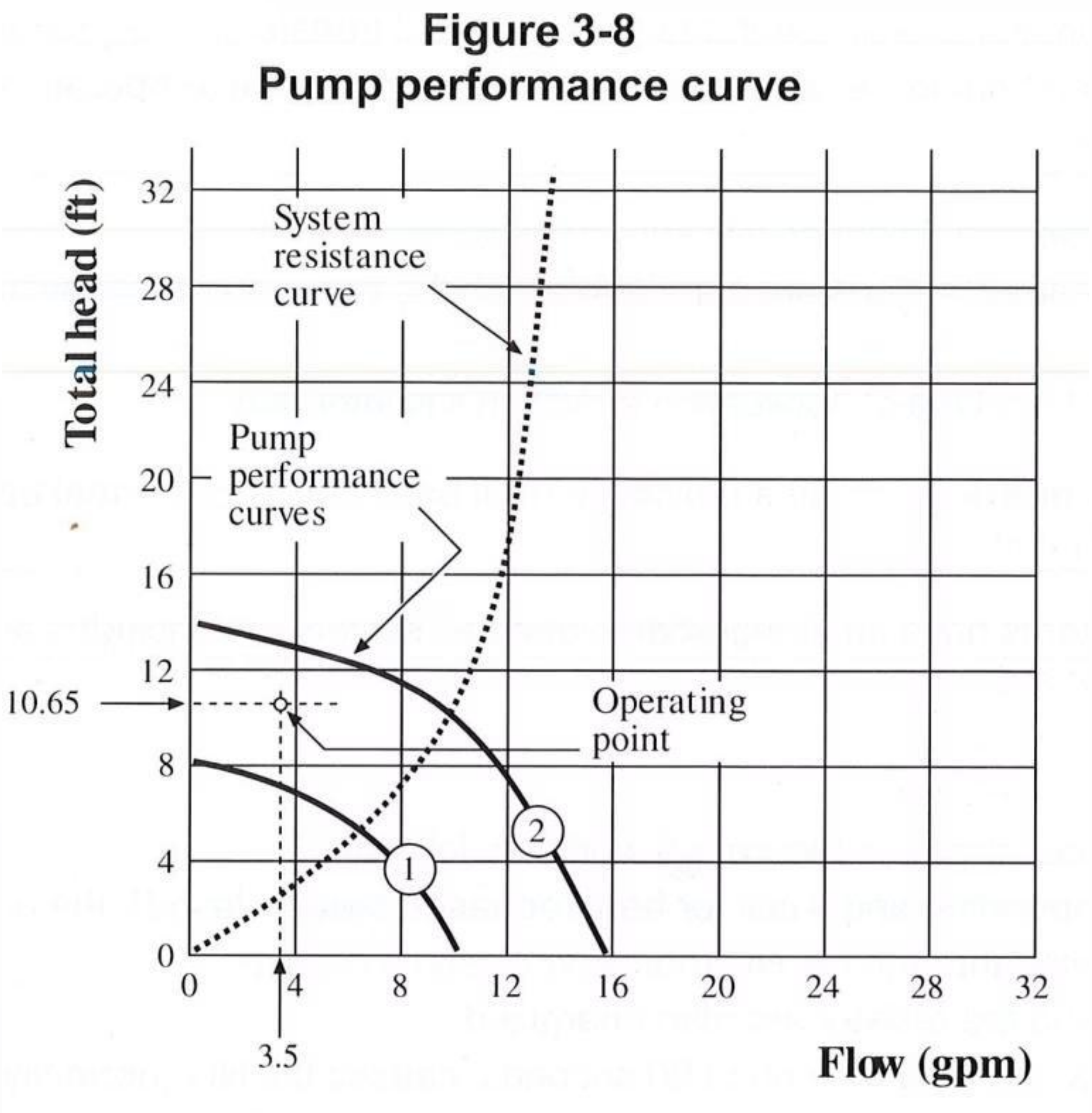
Parallel installation

Pump Curves

Selection Tool

The pump curves published by manufacturers are the basic pump selection tool.

The pump curve works in combination with the system resistance curve to determine which circulator will best match system head and flow requirements.



Pump performance curves showing the operating point for a system with a head loss of 10.65 and a required flow rate of 3.5 gpm.

Pump Selection Procedure

Determine Flow Rate

Calculate the desired flow rate based on the heat required by the system's heating units (the system heat loss).

Calculate Head Loss

Determine the head loss of the system at the required flow rate using the system resistance curve. Use the system circuit or loop with the highest resistance for this purpose.

Plot Operating Point

Plot a point (the operating point) representing the desired flow rate and the head loss at that rate on the same set of axes as the pump curve.

Add Safety Margin

The circulator should have between 10 to 20% extra head capacity above the calculated head loss at the desired flow rate to ensure system requirements will still be met if the installation requires more piping and other flow-restricting components than originally specified.

Check Efficiency

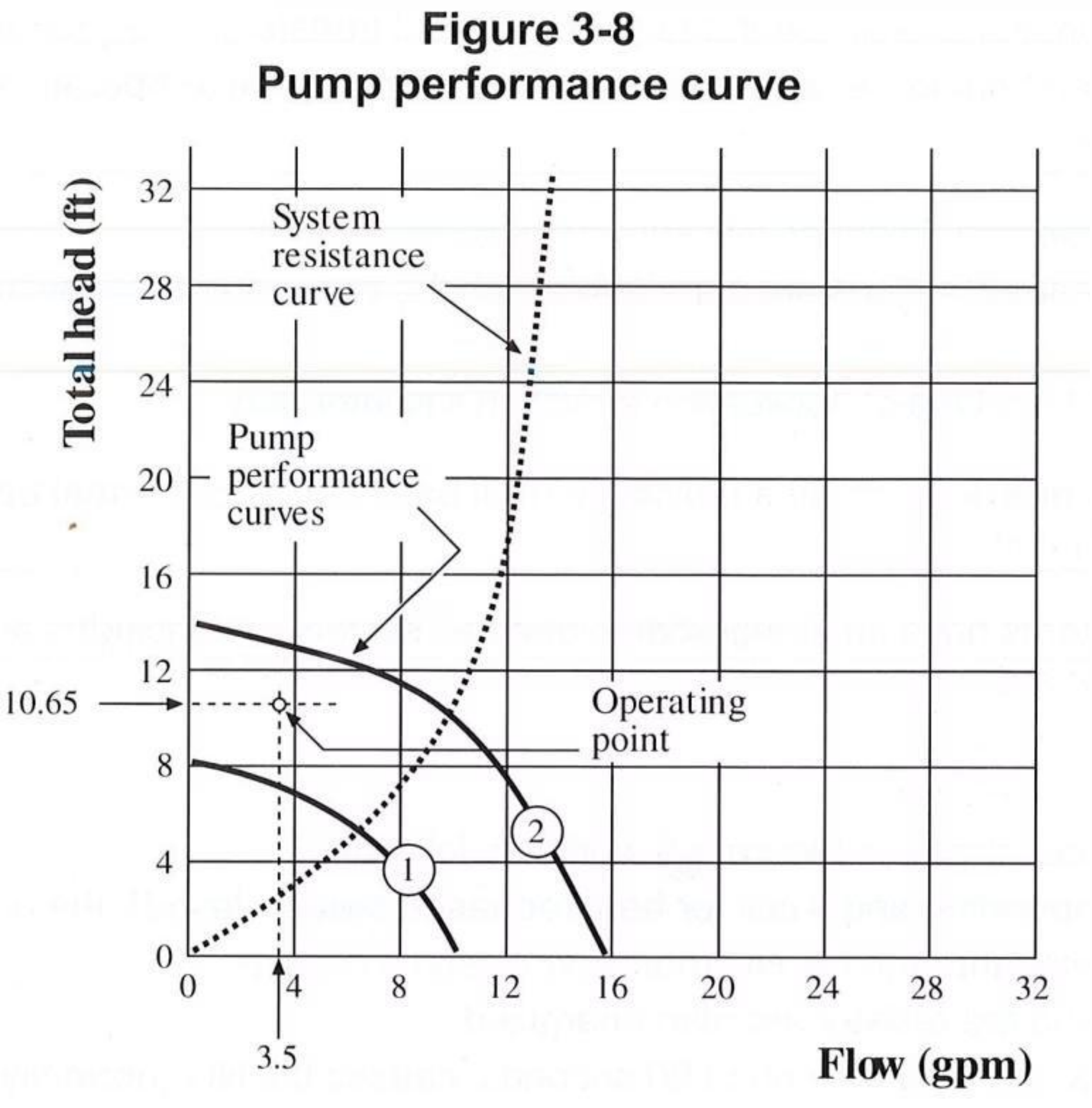
The pump curve should intersect the system curve in or near the area of highest pump efficiency. A pump's highest efficiency region is usually close to the knee of its curve.

Pump Selection Example

System Requirements

If a system has a head loss of 10.65 and requires a flow rate of 3.5 gpm, the operating point would be plotted on the pump performance curve as shown in the diagram.

When comparing the performance curves of pump 1 and pump 2, it's clear that pump 2 is the only suitable pump for the application.



Pump 2 intersects the system operating point, making it the appropriate choice for this application.

Current Draw on Circulator Motor

Effect of Piping Size

Larger piping in the system increases the current draw on the motor.

Effect of Valve Position

Shutting off a valve on the system supply (pump discharge) side decreases the current draw on the motor.

Understanding these conditions is important for proper system operation and troubleshooting electrical issues with circulator motors.

Thermal Balancer Function

Purpose

Many low-mass boilers require minimum circulation to prevent kettling (boiling) in the heat exchanger.

A thermal balancer, or pump delay, is a snap-action, single-pole, double-throw relay that prevents residual boiler heat from tripping the high limit aquastat by delaying circulator shutoff for 60 to 90 seconds after burner shut-off.

This margin of time allows an extended period of heat transfer in the exchanger, recovering the residual boiler heat for heating purposes and balancing the temperature in the system with that of the boiler.

Thermal Balancer Selection

Voltage Compatibility

Ensure that voltage ratings are compatible with the pump and other system components.

Current Ratings

Current ratings must be appropriate for the connected equipment.

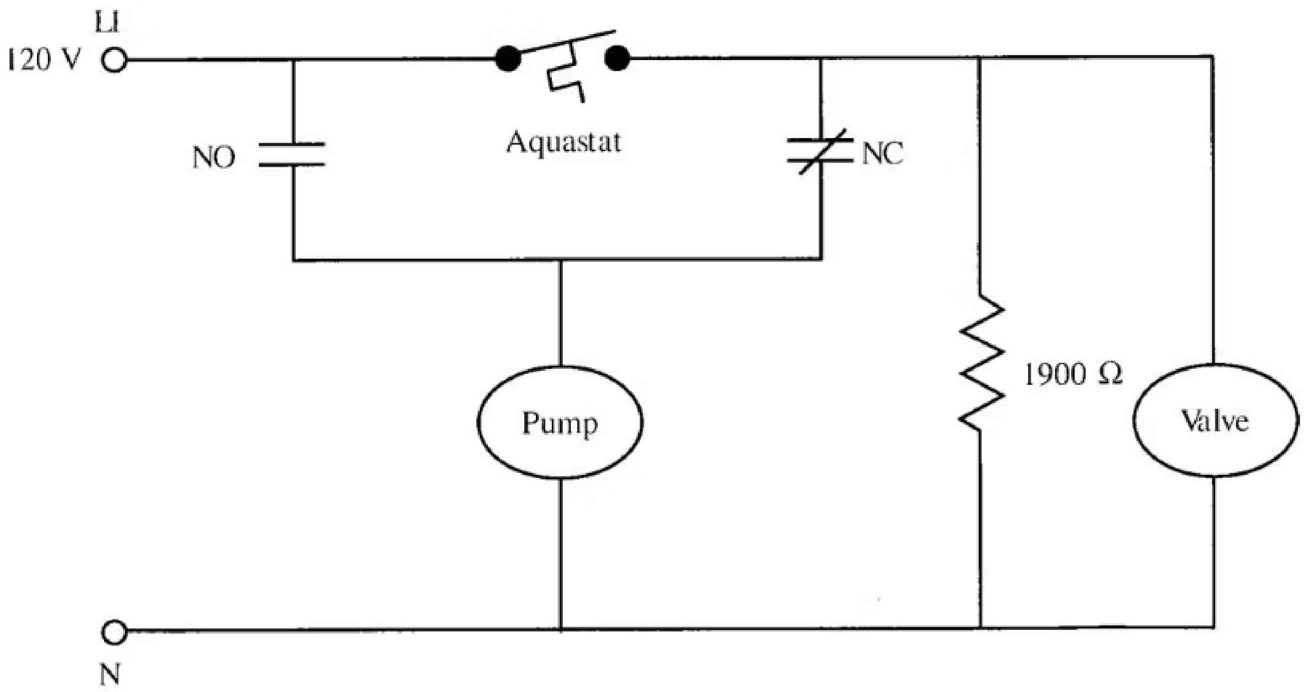
Application Approval

The thermal balancer must be approved for the type of application for which it is intended.

Modern Alternatives

Newer control systems have an integrated electronic system that includes all the functions on the same control board.

Thermal Balancer Wiring and Operation



Operation Sequence

1. During normal operation and a call for heat (aquastat switch closed), the pump is energized by the current passing through the NC (normally closed) contacts.
2. The gas valve and the resistor are also energized.
3. The resistor heats up and after 60 to 90 seconds, causes the NO (normally open) contacts to close, and the NC contacts to open.
4. When the aquastat switch opens, both the resistor and the valve are de-energized.
5. Current continues to flow through the NO contacts until the resistor cools (60 to 90 seconds), causing the NO contacts to open and the NC contacts to close.

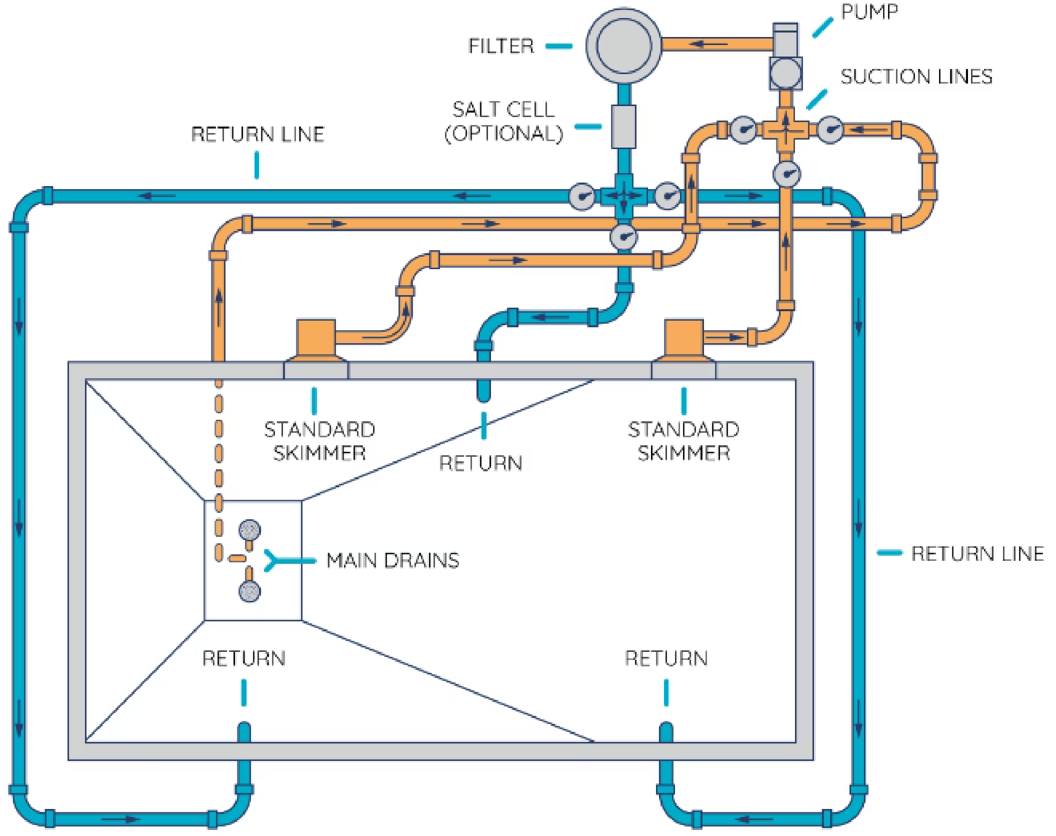
Pool Filter Pump Applications

Basic Pool Recirculation System

In a basic pool recirculation system, the filter pump draws water from the pool through the drain and skimmer.

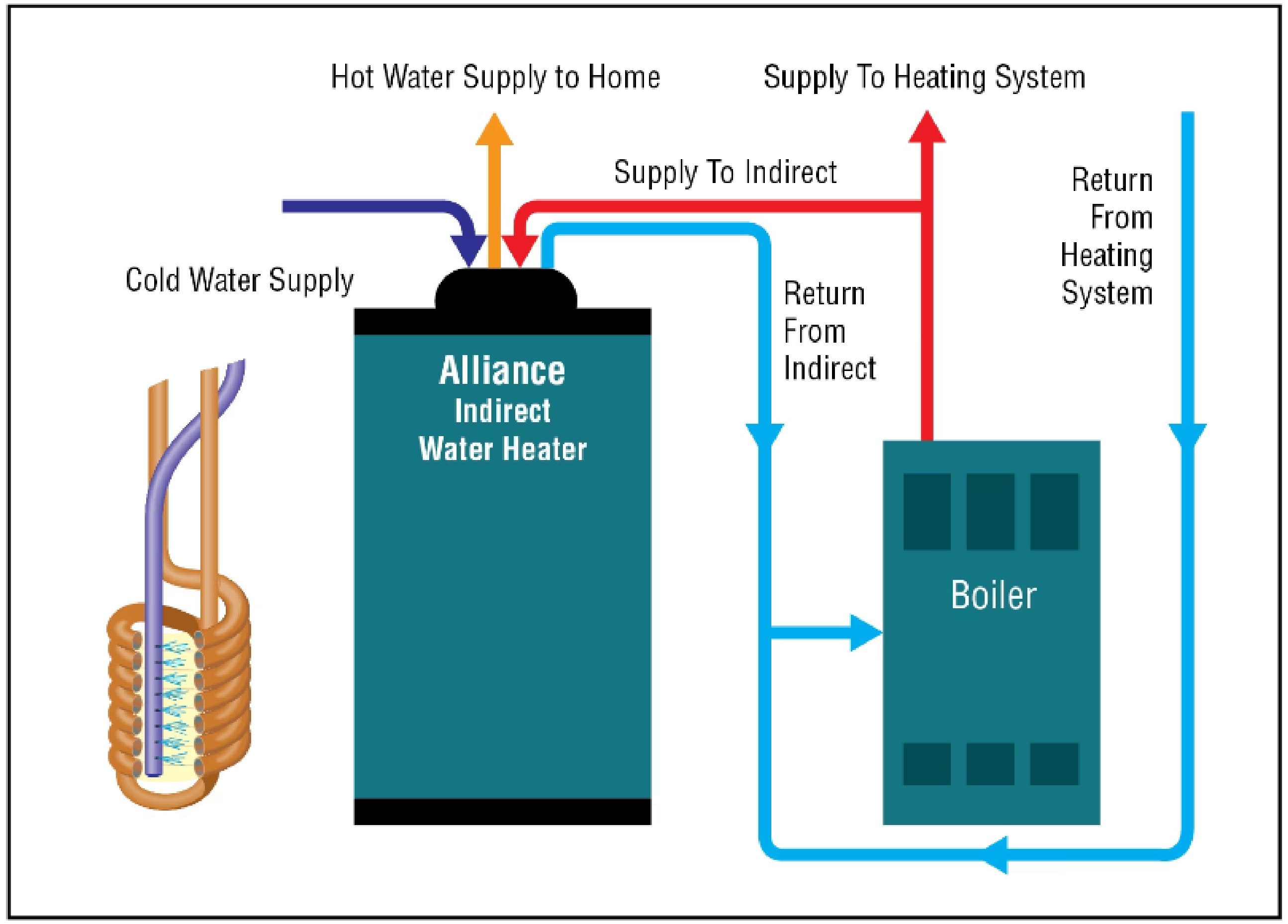
The water then passes through the filter and into the pool heater.

Any necessary chemicals are added to the heated water, which then flows back into the pool.



The filter pump provides all the pressure required to maintain water flow through the recirculation system.

Combo and Hydronic Heating System Circulation



System Configuration

In combination and hydronic heating systems, circulators provide the pressure differential required to maintain fluid flow in the system.

In a simple domestic hot water and space heating combination system, a circulator is installed in the cold water return line adjacent to the water heater or just downstream of the expansion tank.

In a hydronic heating system, a circulator has many options of placement depending on system functionality and variables. Also, independent circulators may control various zones in some systems.

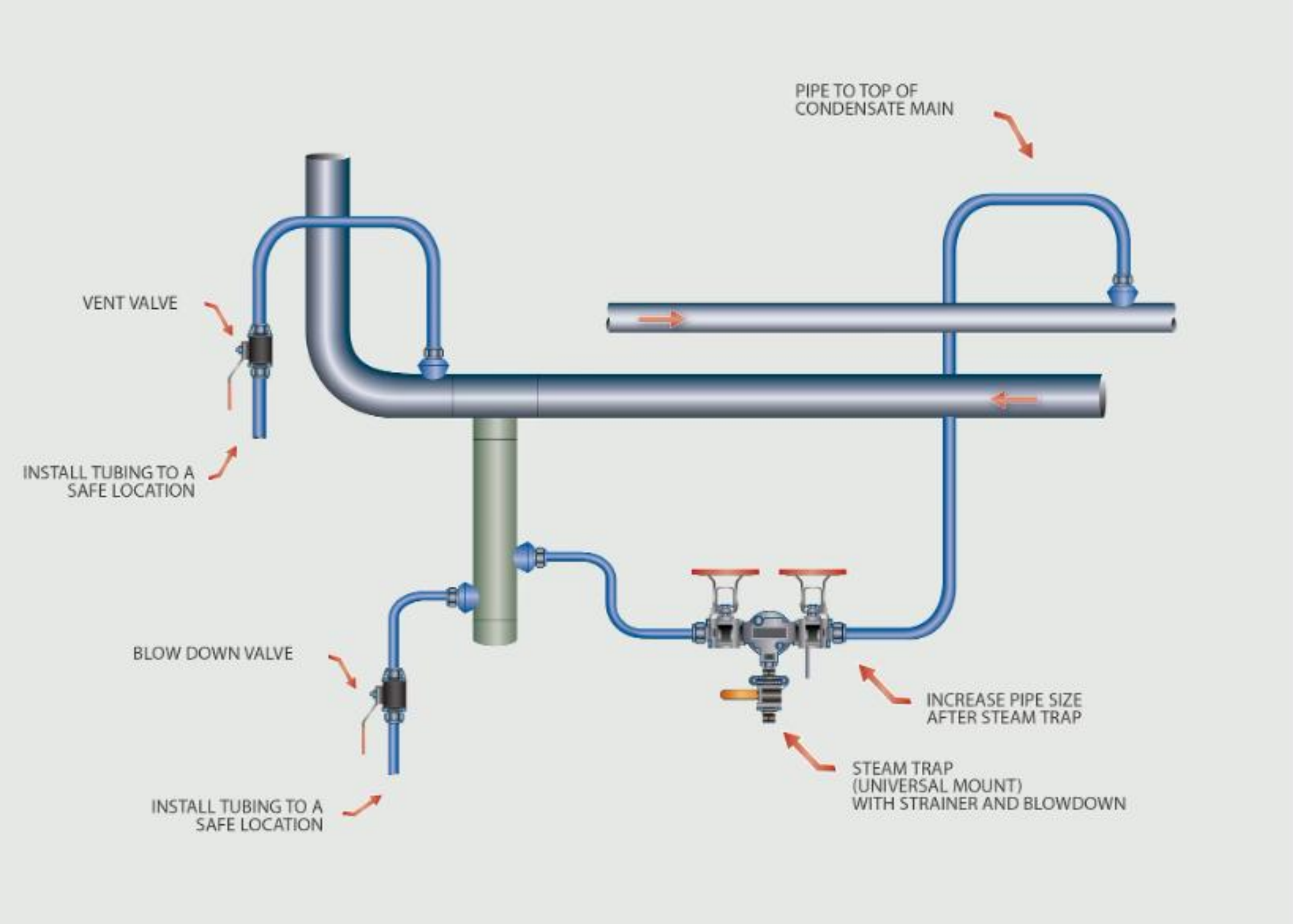
Condensate Pump Applications

Steam Boiler Systems

Some large hydronic systems with steam boilers may have a collection tank for condensate produced in the system.

The condensate is pumped back to the boiler as makeup water.

This recirculation improves system efficiency by recovering both the water and some of the heat energy.



Impeller Maintenance Considerations

Handling Precautions

When replacing a pump impeller, avoid excessive lateral movement of the shaft.

The shaft seal is fragile and may leak if subjected to excessive lateral movement during installation.

Always follow manufacturer's recommendations for impeller replacement procedures.

Check for proper clearance between the impeller and volute after installation.

Coupler Replacement and Alignment

Shaft Inspection

When replacing a pump coupler, also check the pump shaft to make sure it is not out of alignment.

Alignment Importance

Misalignment of the pump shaft can cause premature coupler failure.

Oil Reservoir Position

Pump bearing assemblies contain oil reservoirs, and you must not install them in any way that allows oil to drain from the bearing assembly.

Vibration Prevention

Proper alignment reduces vibration, noise, and wear on bearings and seals.

Isolation Flange Benefits

Service-Friendly Design

An isolation flange allows the unbolting and removal of a circulator from the system with no loss of fluid other than what is left in the pump volute.

This design of flange has a built-in ball valve that you can open or close with a screwdriver. When the ball valves are closed, you can remove the circulator.

Another mounting method that allows isolation of a circulator is the use of standard flanges and a gate valve or ball valve in the piping on each side of the pump.

Wet Rotor Circulator Advantages

Self-Cooling

System fluid acts as a coolant for the motor, preventing overheating during operation.

Self-Lubricating

System fluid lubricates the pump bearings, reducing maintenance requirements.

Quiet Operation

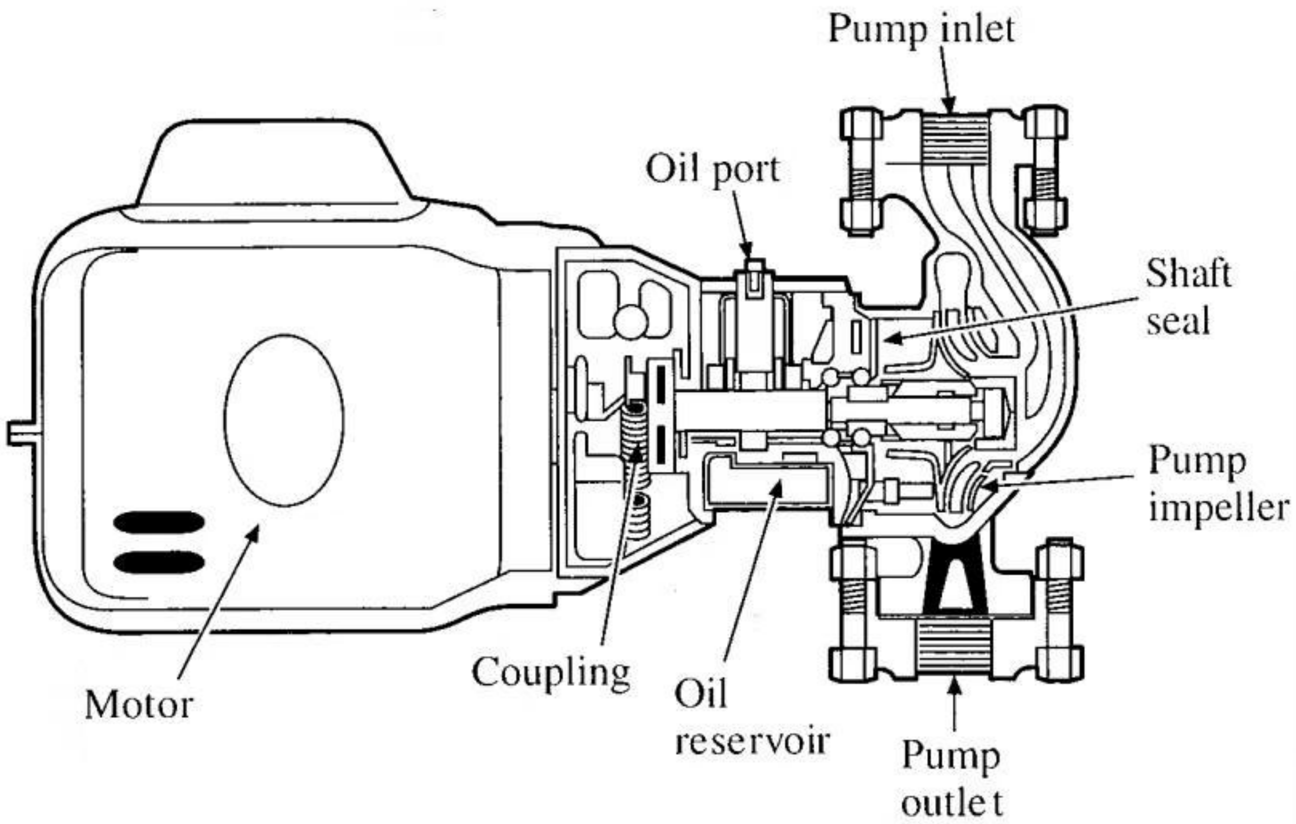
The fluid-filled chamber dampens noise and vibration, resulting in quieter operation.

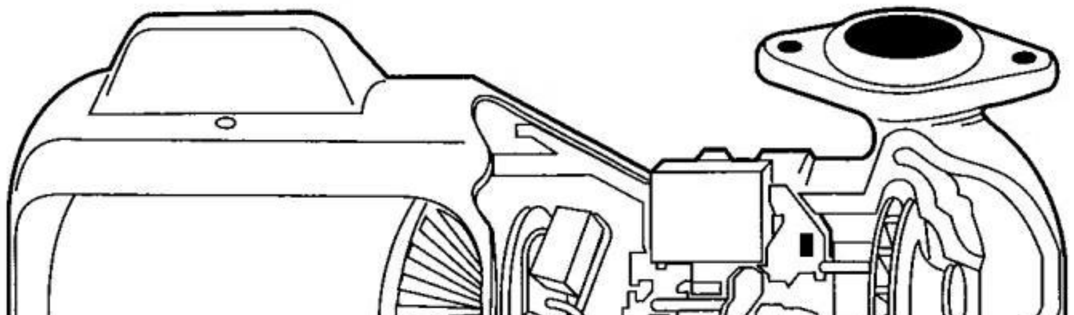
High Temperature Tolerance

Many modern wet rotor circulators can handle fluids at temperatures up to 230°F (110°C).

Three-Piece Circulator Maintenance Benefits

Figure 3-3
Three-piece circulator
Courtesy of ITT Bell and Gossett





Service Advantages

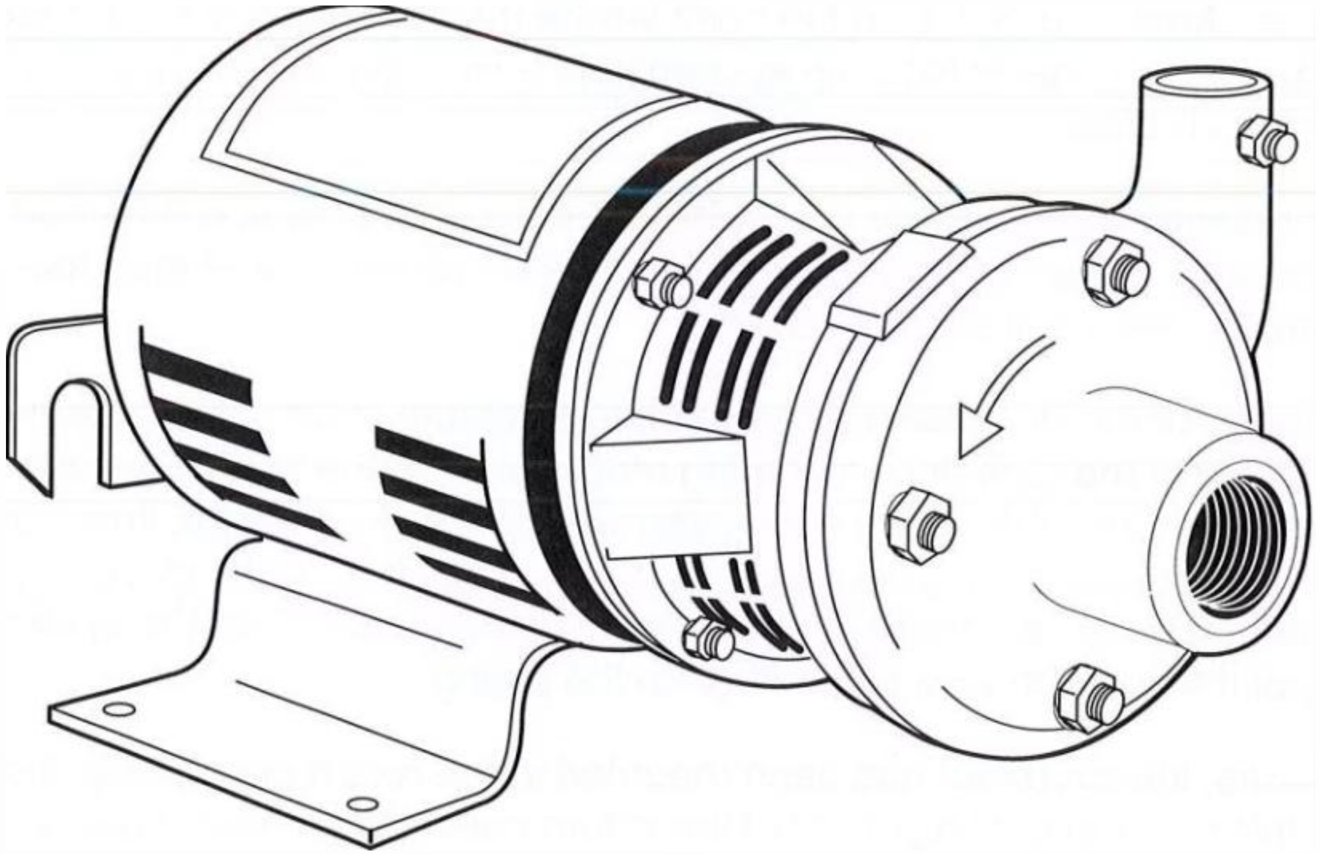
- Motor can be serviced or replaced without disturbing the piping connections
- Coupling can be inspected or replaced without draining the system
- Reduces system downtime during maintenance
- Simplifies troubleshooting of motor electrical issues
- Allows for motor replacement without specialized plumbing skills
- Facilitates upgrading to more efficient motors when needed

End-Suction Pump Applications

Suitable Applications

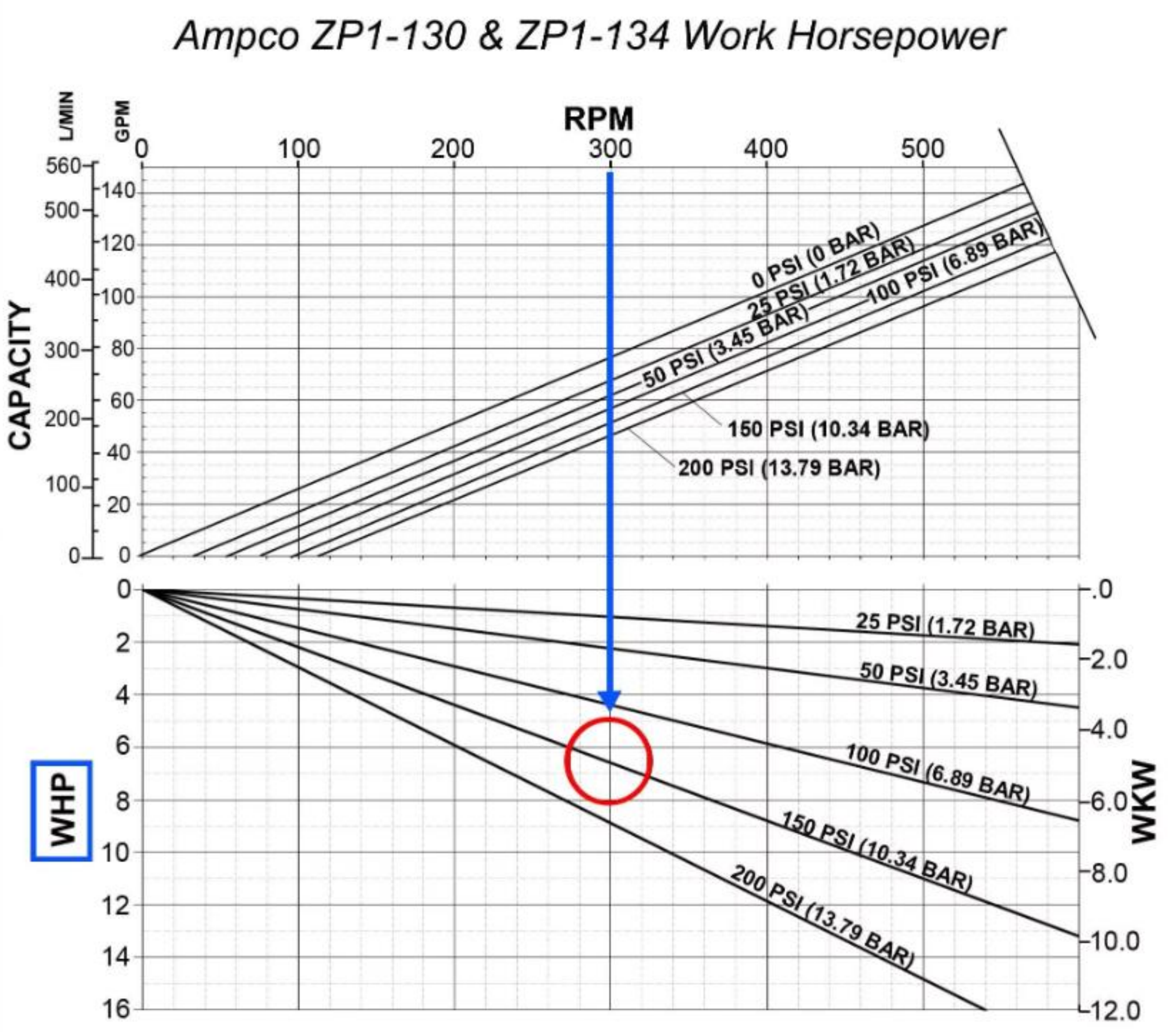
End-suction pumps are often used in:

- Larger commercial hydronic systems
- Applications requiring higher flow rates
- Systems with space for the 90-degree bend in piping
- Installations where the pump needs to be mounted on a base
- Applications requiring easy access to the impeller



Base-mount (end-suction) centrifugal pump

Pump Efficiency Considerations

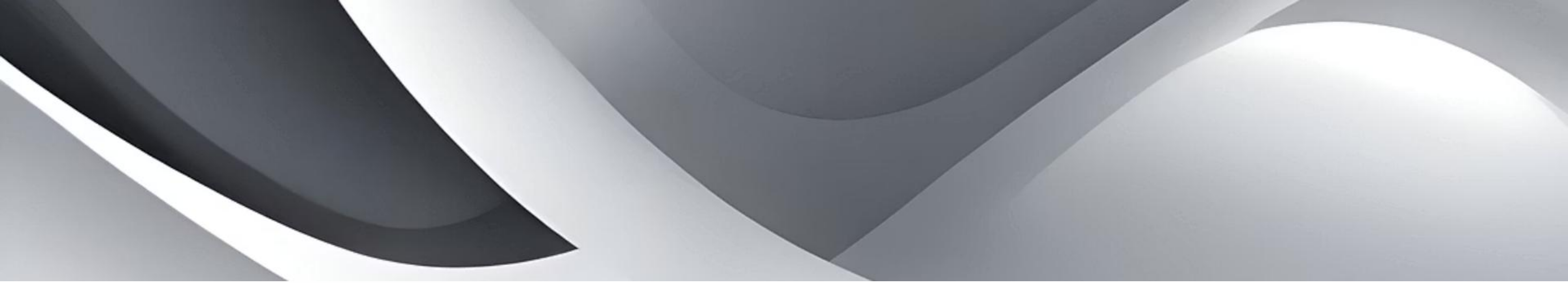


Maximizing Efficiency

For optimal energy efficiency, a pump should operate:

- Near the knee of its performance curve
- At or near its best efficiency point (BEP)
- Within the manufacturer's recommended flow range
- At the appropriate speed for the application
- With properly sized impellers for the specific system requirements

Operating a pump outside its efficiency range can result in higher energy costs, increased wear, and shorter service life.



Environmental Considerations for Pump Selection

Ambient Temperature

The surrounding temperature affects motor cooling and electrical component performance.

Humidity Levels

High humidity environments may require special motor enclosures to prevent moisture damage.

Dust and Contaminants

Dusty environments may require filtered ventilation or sealed motor designs.

Altitude

Higher altitudes affect motor cooling and may require derating of electrical components.

Safety Considerations for Circulator Installation

Electrical Safety

Ensure proper grounding and follow all electrical codes when wiring circulators.

Pressure Ratings

Verify that all components can handle the maximum system pressure.

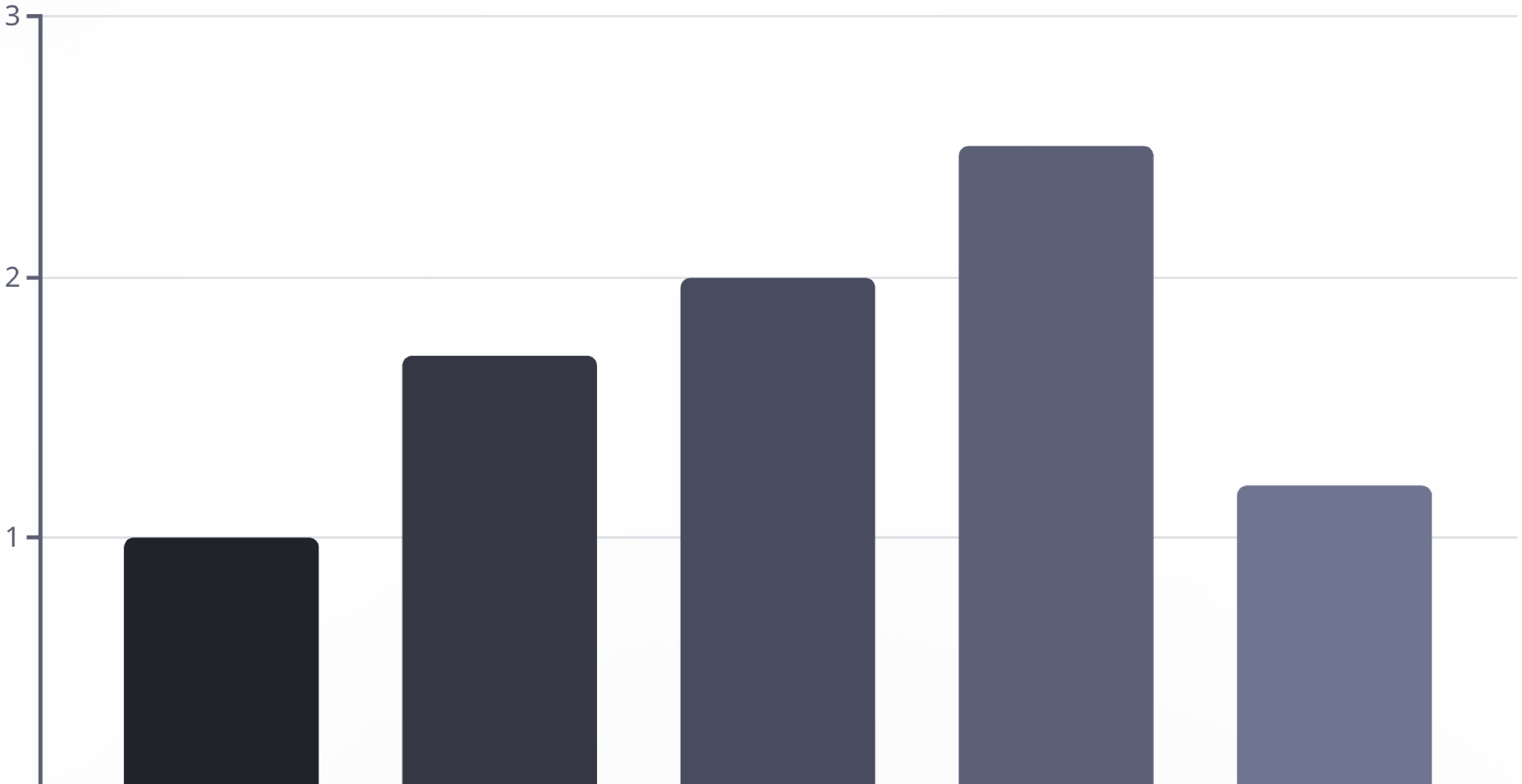
Temperature Limits

Ensure the circulator is rated for the maximum fluid temperature in the system.

Accessibility

Install circulators in locations that allow for safe and easy maintenance access.

Pump Sizing for Different Terminal Units



Factors Affecting Pump Head Requirements

Piping Length

Longer pipe runs create more friction loss, increasing head requirements

Fittings & Valves

Each fitting and valve adds equivalent length to the system

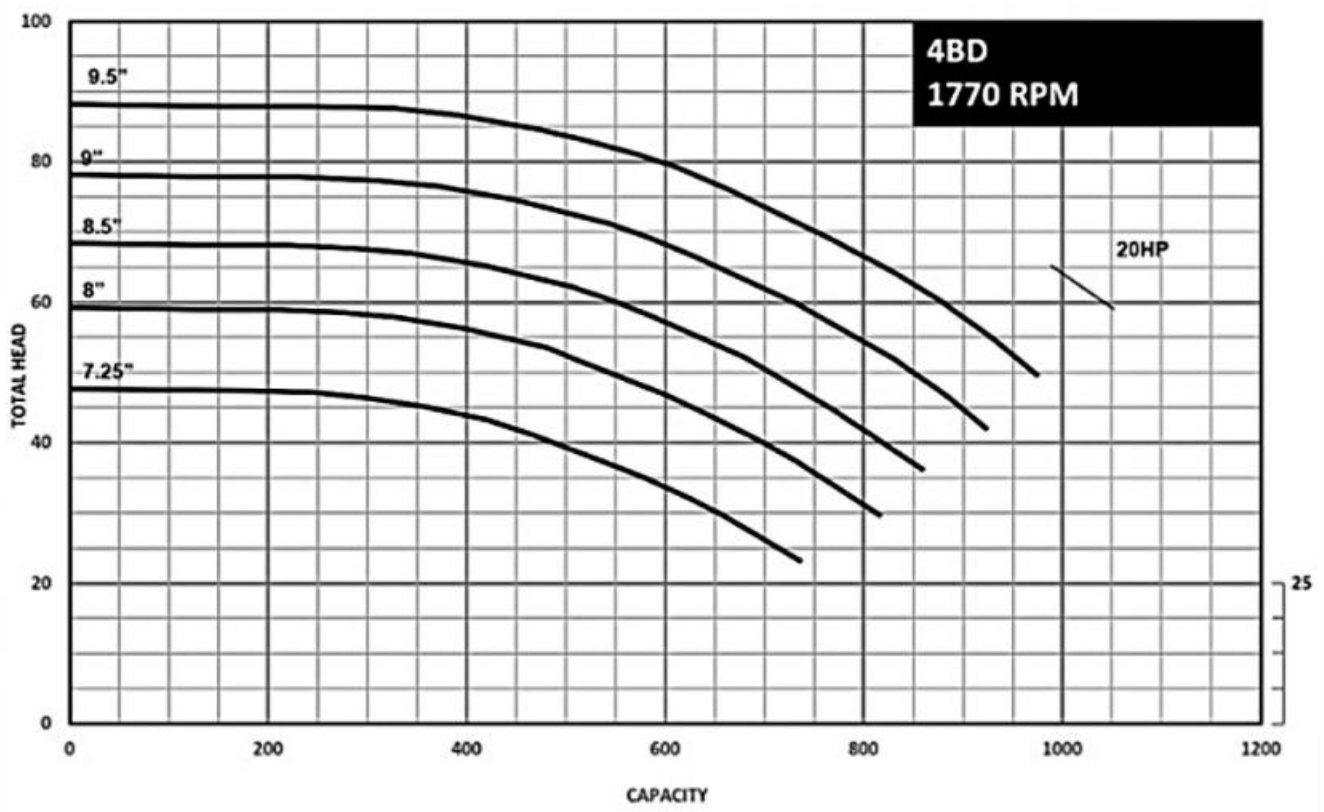
Elevation Changes

Vertical rises require additional head to overcome gravity

Terminal Units

Heat emitters create resistance that must be overcome

Pump Curve Analysis



Reading Pump Curves

A pump curve shows the relationship between flow rate and head for a specific pump model. Understanding how to read these curves is essential for proper pump selection:

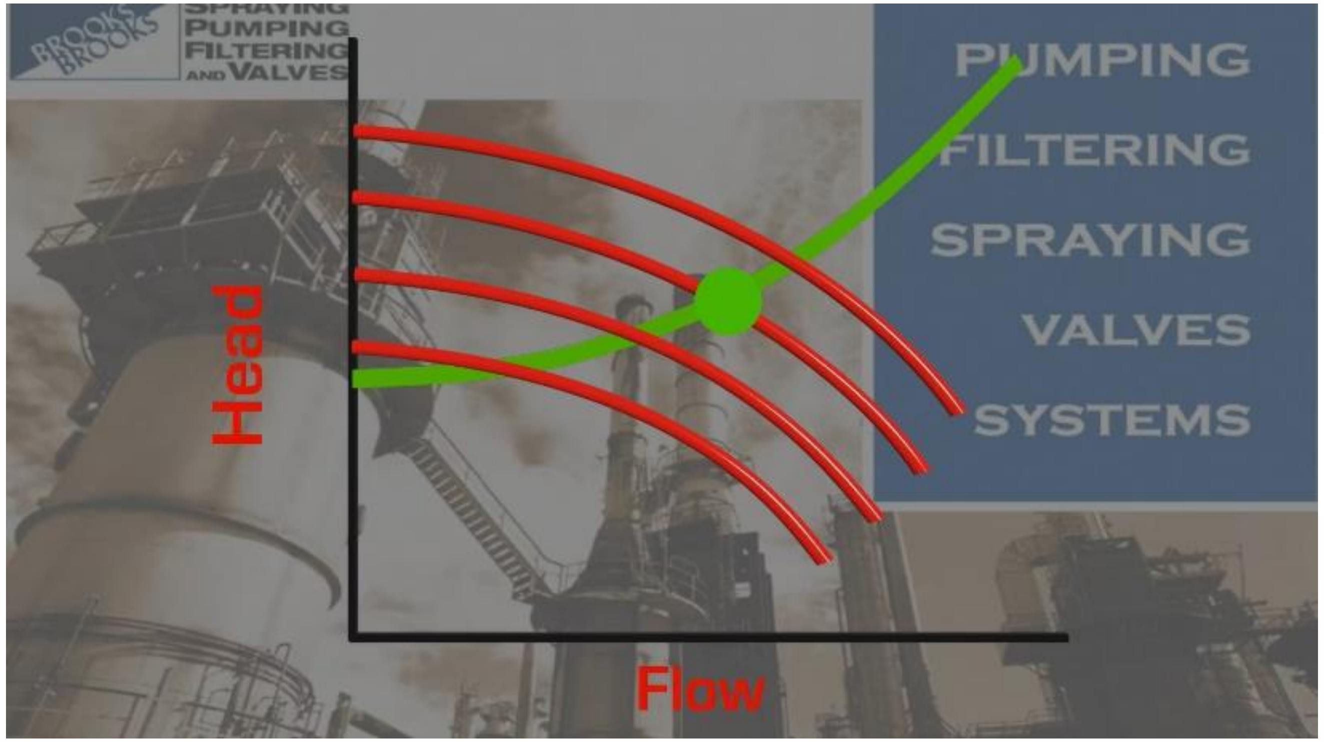
- The x-axis typically shows flow rate in GPM or L/s
- The y-axis shows head in feet or meters
- The curve shows how head decreases as flow increases
- Efficiency islands may be shown as contour lines
- NPSH (Net Positive Suction Head) requirements may be included
- Power consumption curves may be included

System Resistance Curve

Understanding System Curves

The system resistance curve represents the relationship between flow rate and pressure loss in a hydronic system:

- Pressure loss increases with the square of the flow rate
- The curve starts at the origin (0,0)
- The shape is determined by the system's physical characteristics
- The intersection with the pump curve determines the operating point
- Changes to the system (adding zones, closing valves) alter the curve



The intersection of the system curve and pump curve determines the actual flow rate and head at which the system will operate.

Variable Speed Pumping

Benefits of Variable Speed Circulators

Modern hydronic systems often use variable speed circulators that adjust their performance based on system demands:

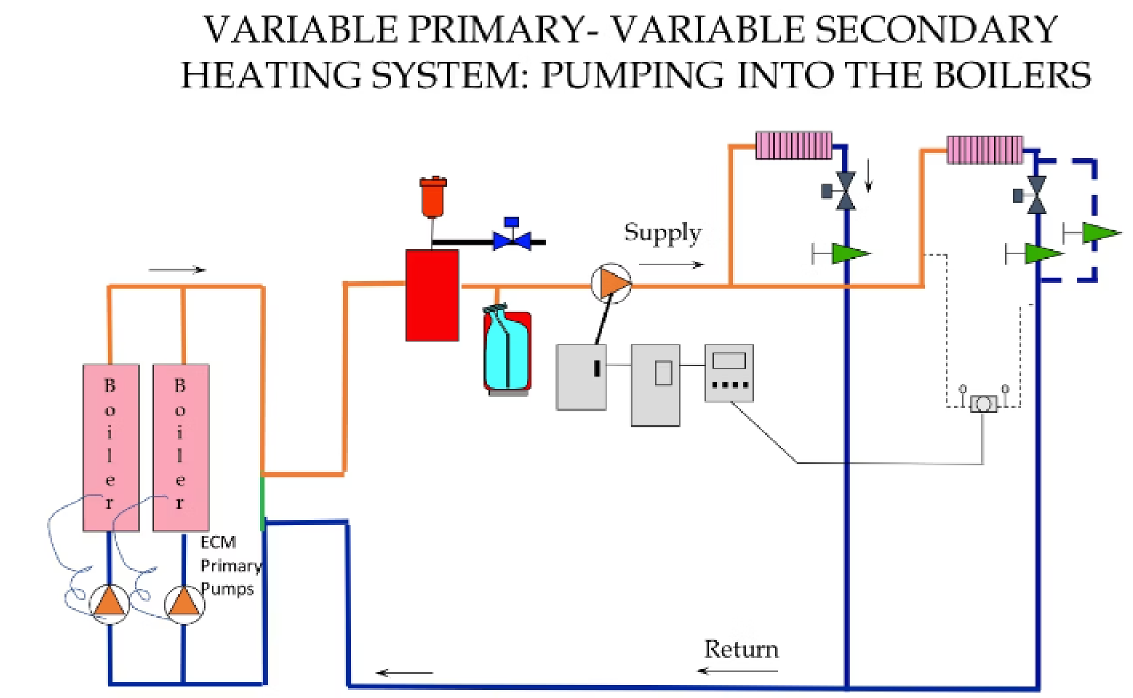
- Energy savings of 50-80% compared to fixed-speed pumps
- Reduced noise during partial load conditions
- Better temperature control throughout the system
- Extended equipment life due to reduced wear
- Ability to maintain delta-T across the heat source
- Elimination of flow noise caused by excessive velocity

Primary-Secondary Pumping

System Configuration

Primary-secondary pumping is a design approach that uses separate circulators for the heat source loop (primary) and distribution loops (secondary):

- Hydraulically separates the loops
- Allows different flow rates in each loop
- Simplifies system control
- Reduces interference between circulators
- Improves heat source efficiency
- Facilitates zoning without affecting the primary loop



The closely spaced tees create a hydraulic separation point between the primary and secondary loops.

Troubleshooting Circulator Issues

No Flow

Check for power to the pump, closed valves, air in the system, or a seized impeller. Verify the pump is rotating in the correct direction.

Insufficient Flow

Look for partially closed valves, clogged strainers, air in the system, or an undersized pump. Check system for excessive resistance.

Noisy Operation

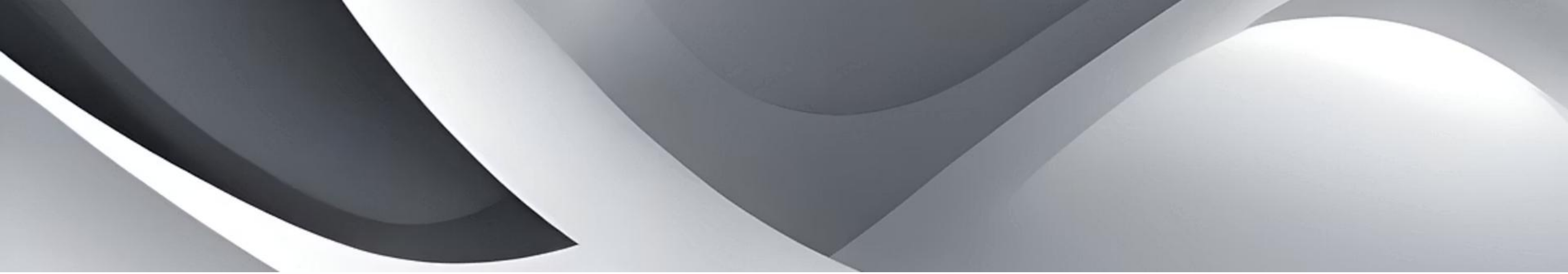
Investigate for air in the system, cavitation due to low inlet pressure, worn bearings, or pump running off its curve.

Overheating Motor

Check for incorrect voltage, high ambient temperature, or excessive load due to system conditions.

Leaking Seals

Inspect for worn seals, excessive pressure, or misalignment of the pump shaft and motor.



Summary of Circulator Principles

4

Common Types

Centrifugal pumps, wet rotor circulators, three-piece circulators, and inline/end-suction configurations

3

Key Applications

Pool filter pumps, hydronic heating systems, and condensate pumping

5+

Selection Factors

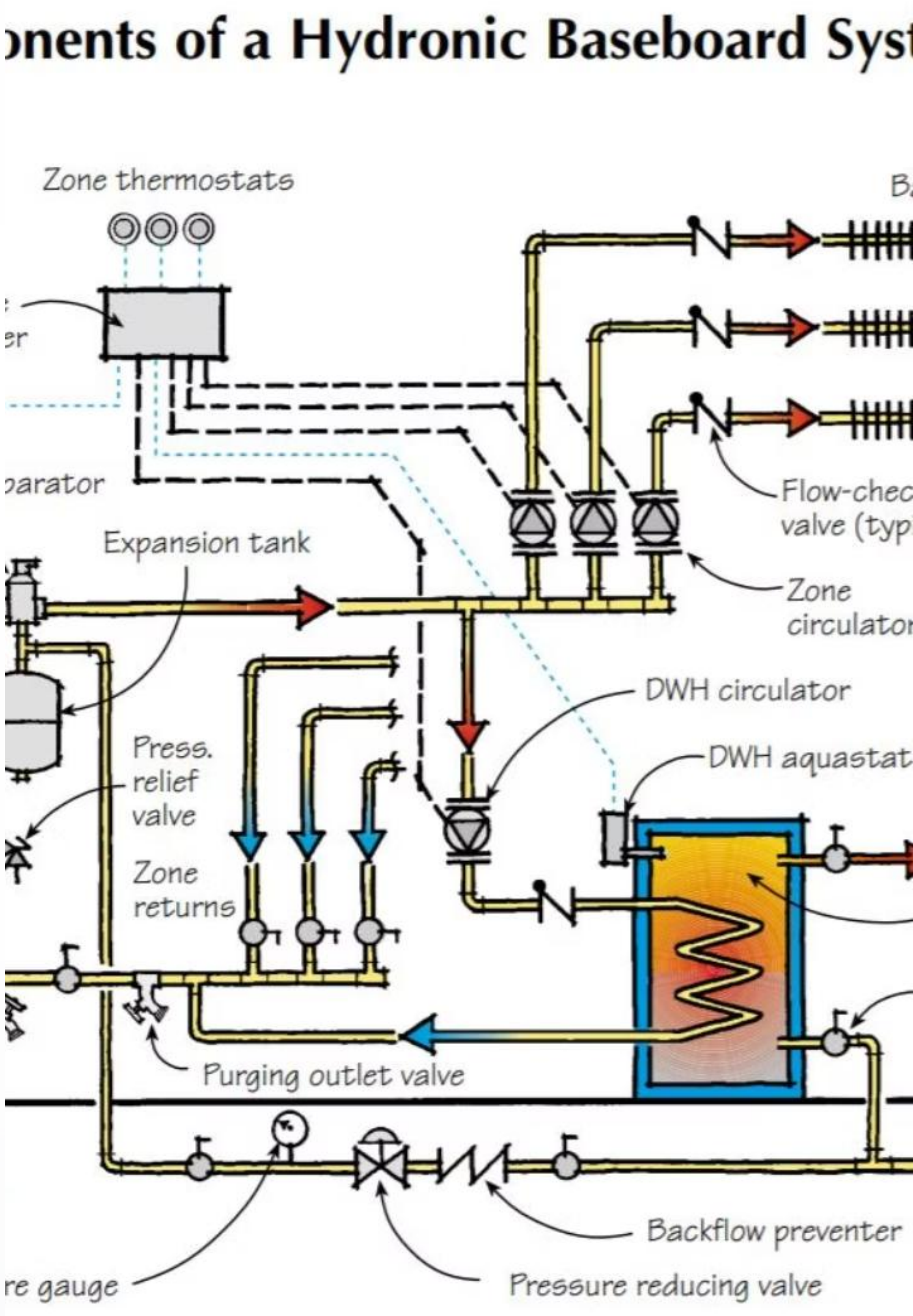
Flow rate, head, efficiency, location, electrical requirements, and environmental conditions

Understanding the principles of circulators is essential for gas technicians and fitters working with hydronic heating systems. Proper selection, installation, and maintenance of circulators ensures efficient system operation, reliable performance, and extended equipment life.

CSA Unit 20

Chapter 4
Hydronic Control System Servicing and Maintenance

An important part of hydronic system servicing and maintenance is making a regular analysis and check of the system's various control valves and devices related to the circulator, boiler, and other mechanical components. The gas technician/fitter must also be familiar with wiring diagrams and operational sequencing.



Objectives and Terminology

Objectives

At the end of this chapter, you will be able to:

- List operation checks
- Describe wiring diagrams and sequence of operation
- Analyze and identify control malfunctions

Key Terminology

- Air eliminator and venting device: Device used to remove air from hydronic systems
- Mixing valve: Valve used to blend two or more incoming streams of fluid to achieve a desired output fluid temperature
- Pressure reducing valve (PRV): Valve that reduces the pressure of water coming into a boiler through a domestic water distribution pipe

Check Valves

Directional Flow

Check valves allow flow in only one direction. You must install all check valves with the arrow on the valve body pointing in the correct direction of flow.

Installation Requirements

When a swing check valve is newly installed or replaced, you must always mount it horizontally and with the bonnet upright. You may mount a spring check valve in any position.

Maintenance Concerns

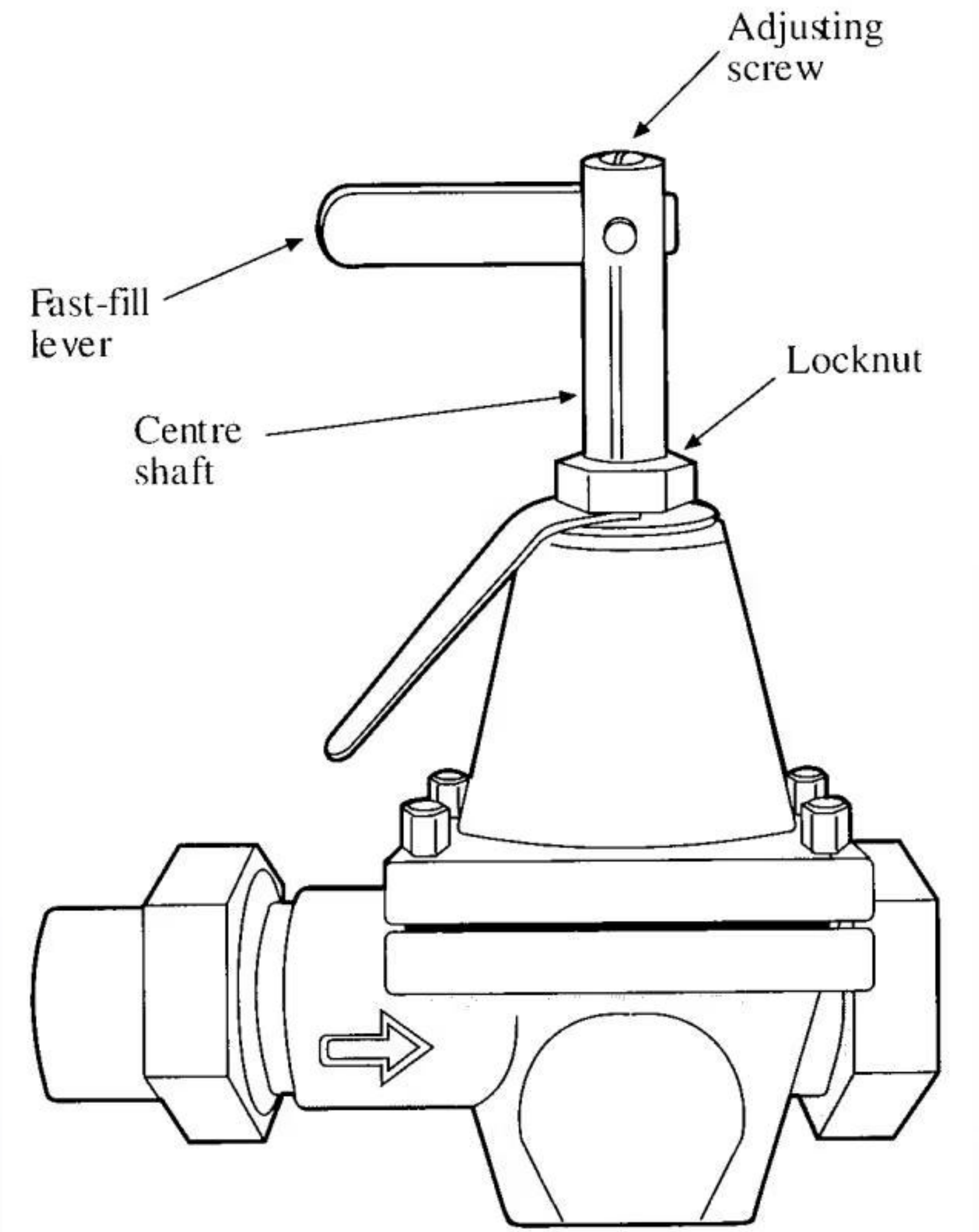
A properly functioning check valve will not allow hot water to migrate back through it. A check valve will require replacement if it does not adequately prevent backflow, or if it "chatters" due to loose components.

Pressure Reducing Valve (PRV)

Function

A pressure reducing valve (PRV), or boiler feed water valve, reduces the pressure of water coming into a boiler through a domestic water distribution pipe. The incoming water is normally at a much higher pressure than required for the boiler.

The PRV maintains the system at a constant pre-set pressure that is high enough to prevent pump cavitation and noise, both of which are symptoms of low system pressure. Typical boiler pressures are 12 to 15 psig (84 to 105 kPa).



Adjustment

To increase the static pressure setting, turn the static pressure screw or centre shaft

Testing the PRV

Lower Water Pressure

Lower the water pressure to below the set-point of the PRV.

Shut Off Water Feed

Close the water feed valve completely.

Turn Water On

Open the water feed valve and observe the pressure gauge.

Check Pressure Response

The water pressure should rise as the PRV is feeding, then stop at the set-point.

If the boiler pressure gauge creeps up to a higher pressure reading over a short time, it may be an indication of a leaking valve seat in the PRV.

Low Water Cut-Off (LWCO)

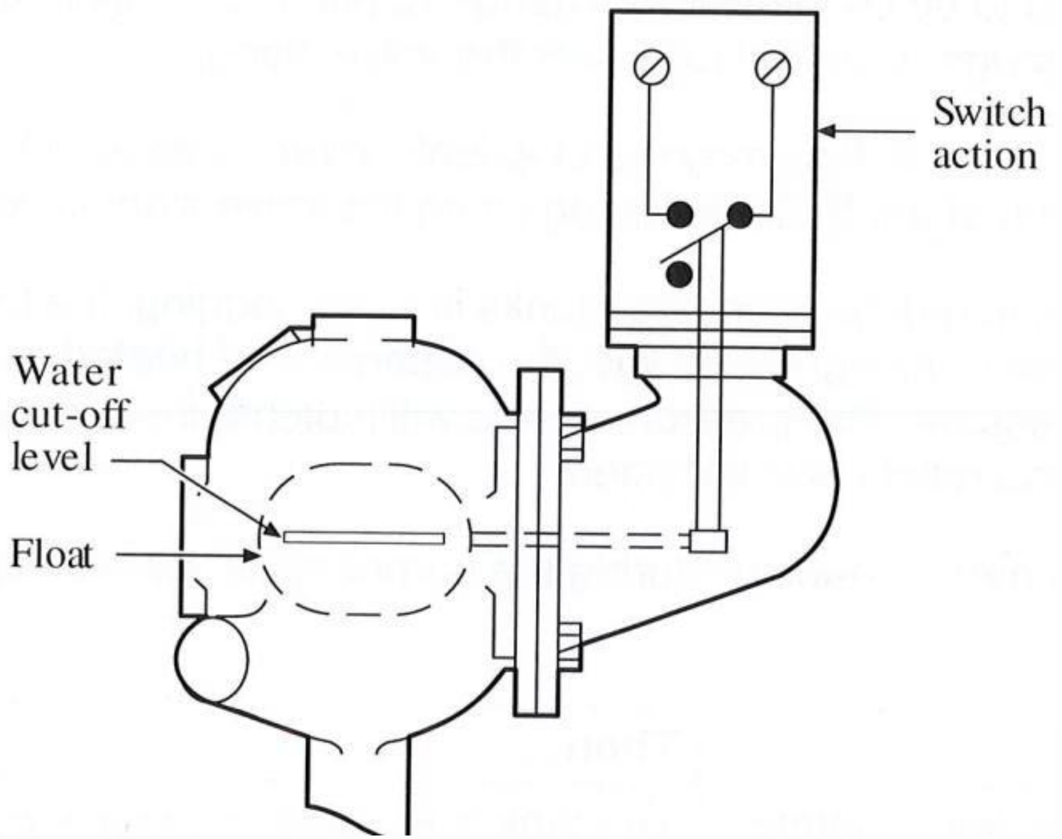
Required Installation

The Codes require that the following types of boilers be equipped with a low water cut-off (LWCO):

- All steam boilers
- Hot water boilers in excess of 400 MBtu/h (120 kw)
- Hot water boilers where the boiler is located above the hot water circulating system

Function

The sole function of the low water cut-off is to shut off the gas supply if there is a low water condition. When the water in the boiler drops to a pre-set level, electrical contacts in the low water cut-off will open, de-energizing the burner and shutting it off.



Testing the Low Water Cut-Off

Drain to Low Water Condition

Allow the boiler to drain to a low water condition. This is a true test, and you should monitor it carefully.

Use Blowdown Fitting

If the low water cut-off has a blowdown or drain fitting, you can drain the water level in the device quickly. This should shut down the burner immediately.

Regular Maintenance

Regular operation of this blowdown is necessary to prevent solids from building up in the device.

Avoid False Tests

If a test button or other form of test is performed without isolating and draining the boiler to below the low water setpoint, consider the test false. You must test the conductivity of the sensing probe, not just the electronic function of the control.

Expansion Tank Types and Function

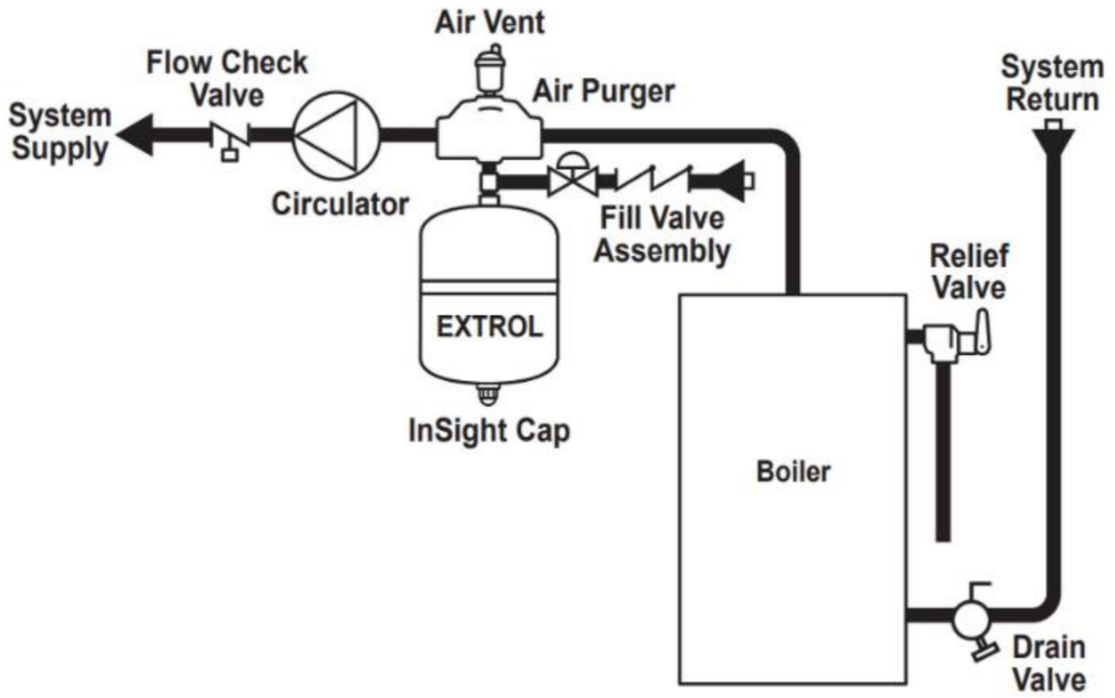
Purpose

An expansion tank allows for the expansion of the volume of water in the system when it undergoes heating. The expansion tank requires sizing to match the size of the system.

Types

The two main types of expansion tank in common use are:

- Diaphragm
- Non-diaphragm



Diaphragm Tank Pressure

In a diaphragm tank, the pressure on the air side of the diaphragm is equal to the system static pressure at that elevation within the system. You must establish the proper air-side pressure before the tank is exposed to system pressure so that the tank can provide maximum effective expansion volume.

Expansion Tank Issues

Diaphragm Leaks

The diaphragm of an expansion tank may develop leaks over a period of time. If the diaphragm is leaking, water will flow out of the Schrader fitting when the valve stem is depressed.

Water-Logging

A common problem with non-diaphragm-type tanks is water-logging. If a tank is water-logged or isolated by a closed valve or plugged inlet line, the expansion of heated water in the system will cause an increase in pressure. The pressure gauge will indicate the pressure increase.

Pressure Indicators

If the pressure increases immediately after the burner comes on, the tank is isolated or water-logged. If the pressure does not increase immediately, the tank is able to absorb some expansion water, but its air space is too small or the tank is partially water-logged.

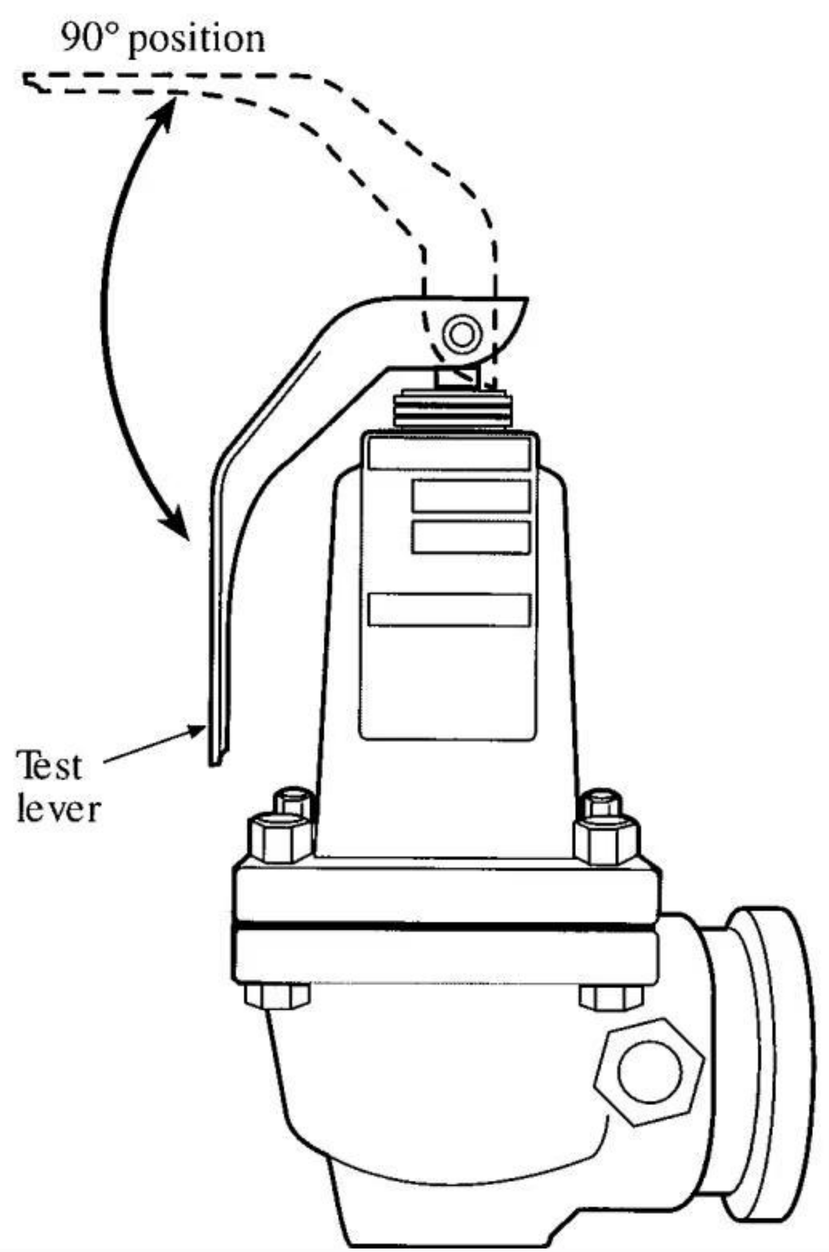
Relief Valves

Purpose

A relief valve prevents dangerously high pressures from developing in the boiler and hydronic system.

Testing Procedure

1. Pull up on the valve's test lever
2. Ensure that the discharge from the valve is directed safely away to prevent personal injury and damage to other equipment
3. The test lever should reset tightly when it is released, with no leakage from the valve's discharge port
4. Operating the lever will loosen the valve seat, but the only check is to perform a "pop" test by isolating the expansion tank and slowly bringing the boiler up to pressure to pop the relief valve



The boiler pressure gauge should never read higher than the pressure setting of the relief valve. Use a water test gauge to determine the actual system pressure.

If system pressure is above relief set pressure, correct the system overpressure and replace the relief

Reducing System Pressure

Shut Off the Boiler

Turn off the boiler completely.

Isolate the Expansion Tank

Close the valve between the expansion tank and the system.

Drain Excess Water

Drain off excess water in the expansion tank.

Re-open Isolation Valve

Re-open the expansion tank isolation valve and recheck the pressure.

Check PRV

If the pressure remains above the normal operating pressure, the pressure reducing valve may need adjustment.

Isolation Valves

Purpose

Isolation valves help close off the piping connected to system components that you may need to open or remove during maintenance and repair operations.

Gate valves are commonly used for isolation. They are always fully open or fully closed.

Common Issues

If a gate valve is left partially open while fluid is flowing through it, it may cause vibration and chatter that will eventually damage the valve.

If a gate valve appears to be leaking when fully closed (off position), check to ensure that it is fully closed. If it still leaks when fully closed, the gate may be damaged, and you will need to replace it.

A gate style valve should turn in about 15 times and then stop. A globe-style valve may turn in and stop but may still not seal if the washer is deteriorated.

Differential Pressure Regulation/Bypass Valves

Purpose

A differential pressure regulation valve is installed in a multi-circuit hydronic system to prevent buildup of large pressure differentials that could cause excessively high flow rates and noise in the system.

Operation

When a differential pressure regulation valve is operating properly, the pressure at the discharge of the circulator does not increase as each zone valve closes.

Adjustment

You can adjust the pressure set point of a differential pressure regulation valve by turning the valve cap. Turning the cap clockwise will increase the setting. Turning the cap counterclockwise will decrease the setting.

Backflow Preventers

Requirement

Backflow prevention is required on boiler systems.

Type Determination

The type of backflow prevention required will vary depending on the local regulating authority, the type of backflow (pressurized or non-pressurized), and the degree of hazard (chemicals in system, etc.).

Testing Requirements

The backflow device installed normally requires testing by a certified backflow prevention tester. Backflow testing requirements depend on the local regulating authority.

Testing Frequency

In addition to a mandatory annual test, testing of backflow devices before the system is put in service and whenever an authorized plumber has repaired it is a must.

Circuit and Bypass Balance Valves

Purpose

Balancing valves are devices for adjusting flow rates in parallel piping circuits. In a multi-zone system, throttling one balancing valve will increase water flow into the other zones.

Common Issues

If one zone or circuit in the system is not getting sufficient heat, you should open the circuit balancing valve and monitor the temperature to see if it increases.

If a balancing valve leaks when it is in the fully closed position, you should replace it.

Aquastats

Function

An aquastat is a temperature-actuated operated switching device. It senses the temperature of the fluid in a hydronic system and turns the heat source burner on and off as required to maintain the temperature of the fluid within pre-set upper and lower limits.

Troubleshooting

If an aquastat appears to be malfunctioning, check first its wire connections and electrical contacts for corrosion or other faults. When checking the contacts, maximum voltage will be indicated when the switch is open and zero voltage when it is closed.

If an aquastat is operational, turning its dial to a higher temperature will turn the burner on.

Aquastat Calibration and Issues

Calibration Check

You can check aquastat calibration by observing the actual fluid temperature by means of a thermometer and comparing it to the temperatures at which the aquastat cycles the burner on and off.

Response Issues

Many times, an aquastat will not respond accurately to limit temperatures due to poor heat transfer, which can occur if the aquastat's sensor bulb is coated with insulating debris or is not properly positioned in the system.

Modern Replacements

Many aquastats have been replaced by electronic controllers, which operate the system in the same sequence by using a temperature sensor to transmit the temperature of the medium to the controller.

High Limit Testing Procedure

Raise Temperature Control

Raise temperature control to maximum setting.

Verify Burner Operation

Observe that burner lights.

Lower High Limit Setting

Lower high limit setting to a setting just above system water temperature.

Allow Heating

Allow boiler to heat up to high limit setting.

Verify Burner Shutdown

Observe that burner shuts off at high limit setting.

Restore Settings

Return high limit setting to original setting and observe that burner lights. Return temperature control to original setting.

Temperature-Activated Valves

Types

Temperature-actuated activated valves include internal temperature-sensed:

- Mixing valves
- Thermostatic radiator valves

Mixing Valve

A mixing valve helps blend two or more incoming streams of fluid to achieve a desired output fluid temperature.

A three-way mixing valve that is internal temperature-sensed is used to reduce temperature of the radiant panel.

You can check valve operation and performance by observing changes in thermometer readings while changing the valve setting.

Thermostatic Radiator Valve

Function

Thermostatic radiator valves facilitate accurate control of individual radiant heating units (radiators) within desired temperature limits.

Testing

You can check thermostatic valve operation by first turning up the room or zone thermostat to create a demand for heat, then measuring the temperature at the radiator to see if it increases to the set level.

If there is little or insufficient heat, there may be too little water getting to the radiator or it may be air locked. Before proceeding further, the radiator valve setting should be increased and the temperature measured again after a demand for heat.

Air Eliminators

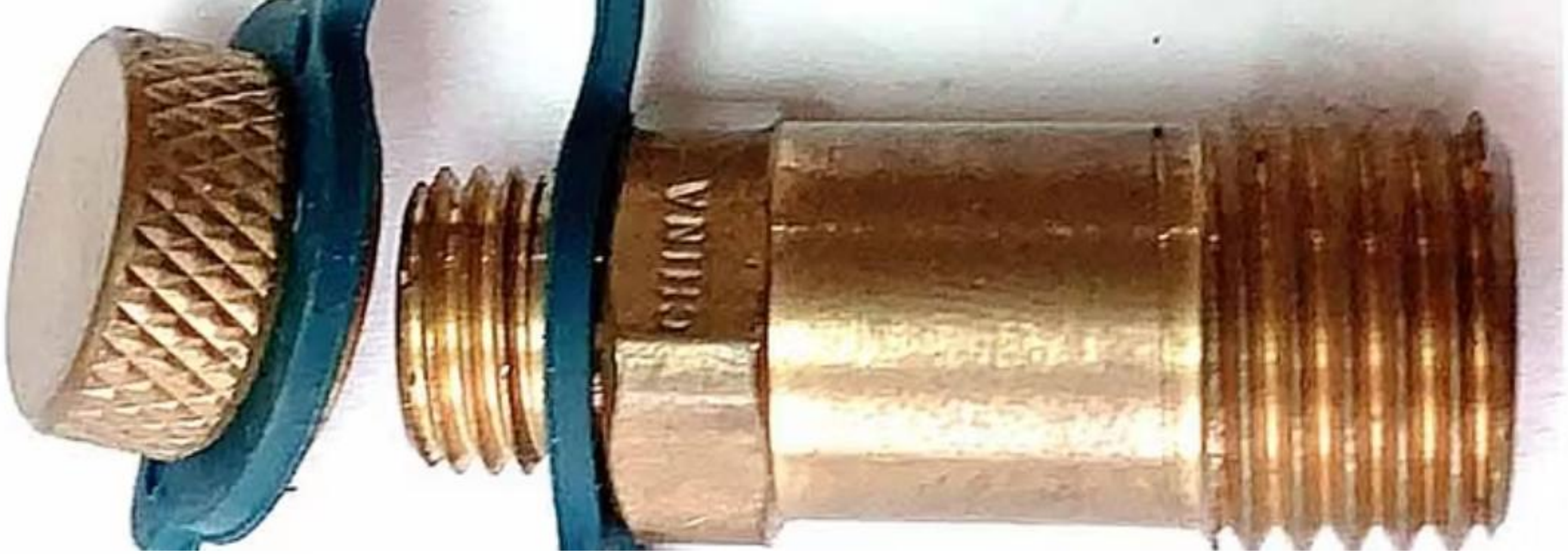
Purpose

Air eliminators and venting devices are for removing air from hydronic systems. A common indication of the presence of air is noise in one or more zones of the system.

Troubleshooting

The first thing to do is ensure that there are no air locks in the radiators or zone piping. You can do this by opening the manual vents to expel any accumulated air and by checking the operation of automatic air vents.

You can clear air locks in individual radiators by operating the radiator's manual air release vent or by venting air through vents at the high points in the distribution circuit.



Manual Vent

Common Issues

A manual vent may sometimes leak water around its threaded connection or through its bleed valve.

Repair

Tightening the vent connection may stop the leak. Otherwise, you must isolate the vent before removing it from the system and replacing or repairing it.

Maintenance

The bleed valve may become fouled with debris from the fluid in the system and require cleaning.

Float Vent

Testing

You can check a float-type air vent for proper operation by depressing the stem of its Schrader valve.

If the valve is working properly, water will flow out of the valve fitting. If a substantial amount of air is released, the vent is not working properly.

Troubleshooting

If the vent is malfunctioning, isolate it from the system before removing it for repair or replacement.

A common problem is a sticking float assembly caused by debris in the system fluid.

Air Purger/Air Scoop

Installation Location

Air purgers should always be located as close to the boiler as possible on the supply main, where the system fluid is the hottest.

Installation Orientation

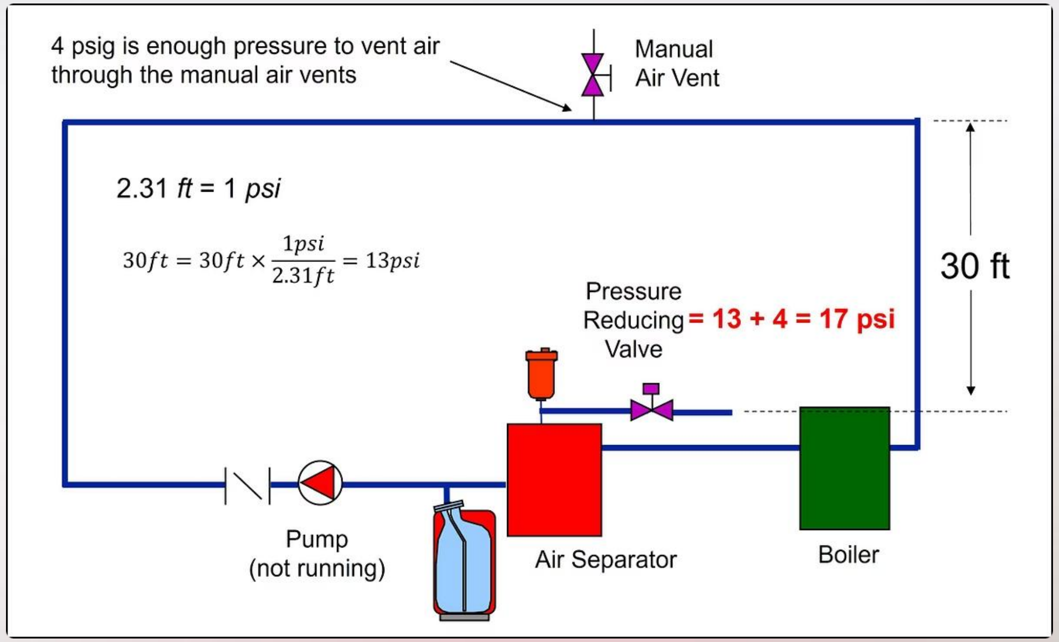
Air purgers must be installed horizontally, with the arrow on the purger body pointing in the direction of system fluid flow.

Troubleshooting

If an air purger is suspected to be malfunctioning, the first thing to check is the operation of its float valve. The float valve assembly is subject to sticking caused by debris in the system fluid.

Repair

If the purger is malfunctioning, isolate it from the system before removing it for repair or replacement.



Air Separator

Installation

A microbubble air separator must be installed vertically and oriented to the proper direction of flow.

Common Issues

Like the float-type air vent, the vent valve and float assembly of an air separator can also become fouled by system debris.

Perform operational checks as for a float-type vent.

Pump-On Check

Raise Temperature Control

Raise temperature control to maximum setting.

Verify Burner Operation

Observe burner lights.

Lower ON Setpoint

Lower the ON setpoint of the pump control until the pump motor starts.

Note: Do not force the control beyond the maximum or minimum setpoint.

Raise Setpoint

Raise the setpoint until the pump motor stops.

Wait for Temperature

Wait for temperature to reach set point. Pump should start.

Restore Settings

Return pump control and operating control to original settings.

Pump-Off Check

Turn Off Gas

Turn off gas to main burner.

Raise Pump Control

Raise pump control until pump motor shuts off.

Lower Pump Control

Lower pump control until pump motor starts.

Set Control

Set pump control just above water temperature.

Wait for Setpoint

Wait for pump control to reach set point. Pump motor should stop.

Restore Gas and Settings

Turn on gas to main burner. Return pump to original settings.

Hot Water Boiler Flow Switch

Function

The flow switch shuts off the boiler burner(s) if water flow is below the setpoint too low. Water flowing through the system moves a paddle or activates a pressure control, which operates the switch.

Testing Procedure

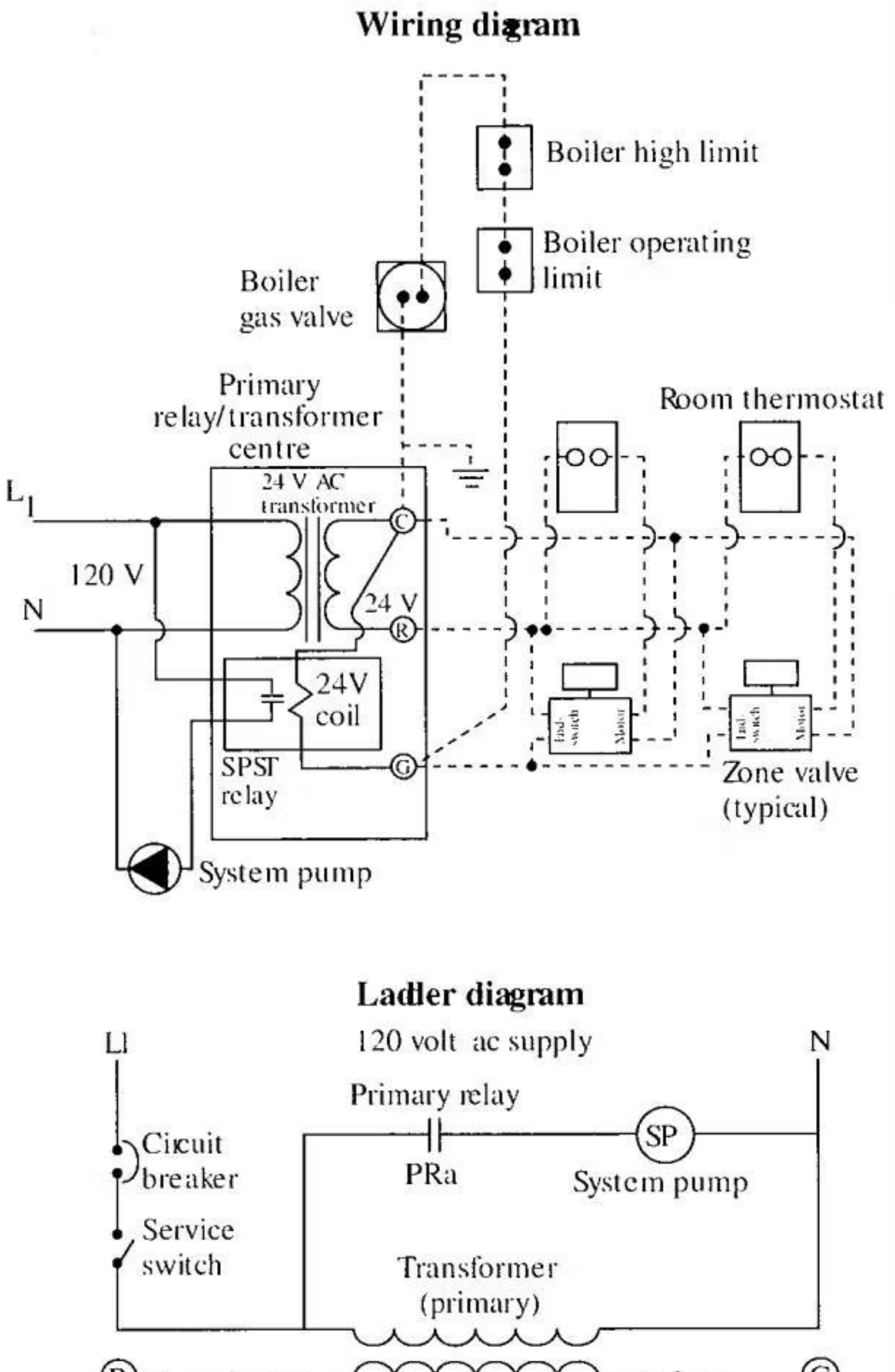
1. Raise the temperature control to the maximum setting
2. Observe the burner lights
3. Turn off power to the boiler
4. Remove the pump motor neutral wire and ensure it is safely isolated
5. Turn on power to the boiler
6. Observe that the burner does not light
7. Turn off power to the boiler
8. Reinstall pump motor neutral wire
9. Turn on power to the furnace
10. Observe that the burner lights
11. Return temperature control to original setting

Wiring Diagrams and Sequence of Operation

Purpose

Wiring diagrams and ladder diagrams can be useful for determining the operating sequence of hydronic system components and controls.

These drawings, which are supplied by equipment manufacturers, work as installation guides for field wiring external system controls. You may also use them for analyzing and troubleshooting service problems.



Sequence of Operation

Power Supply

With the circuit breaker and service switch closed, the 120 V supply energizes the 24 V AC transformer.

Thermostat Demand

On a demand for heat from a particular zone, the room or zone thermostat closes and 24 V is supplied from terminal R to open the zone valve.

Zone Valve Operation

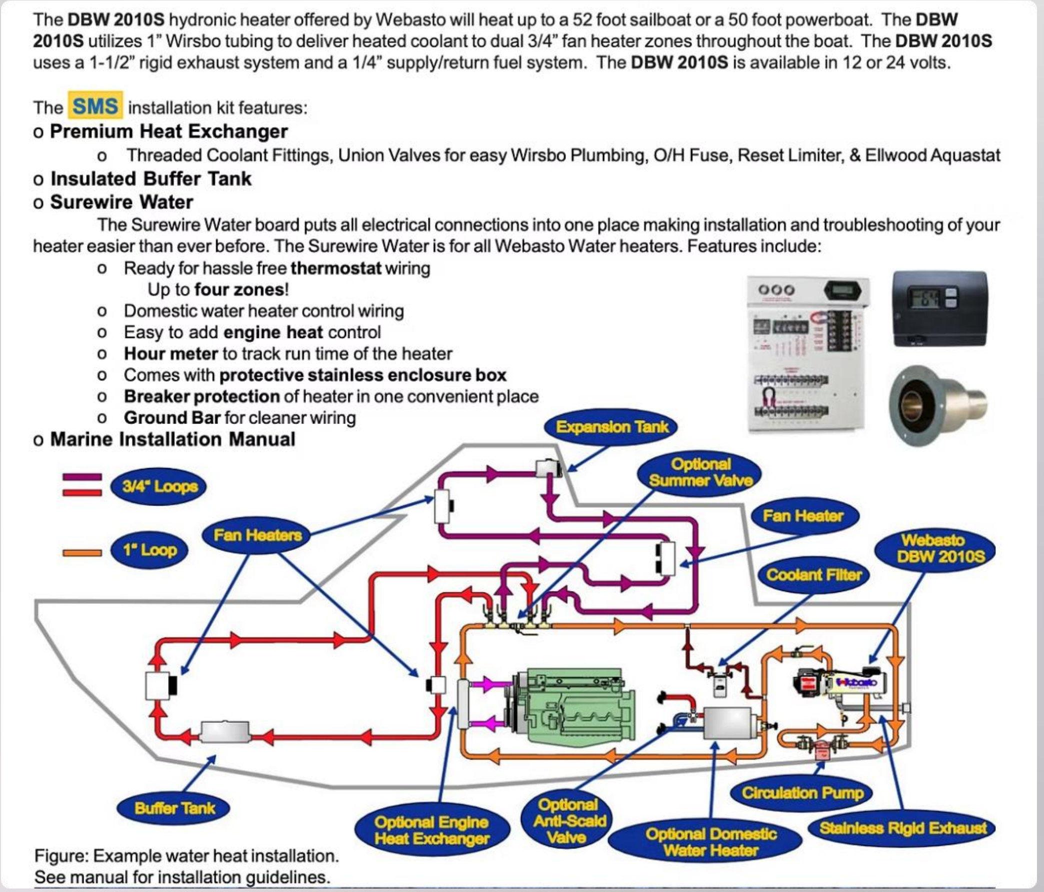
Some zone valves contain an end switch, which is a switch that is activated by the opening of the zone valve. When the zone valve opens, its end switch closes, and 24 V from terminal R is supplied to terminal G to actuate the primary relay.

Pump and Burner Activation

This closes the circuit that energizes the pump circuit and burners. If the aquastat and any other burner interlocks are closed, the automatic burner gas valve is energized.

Burner Ignition

The gas valve opens and gas flows into the burner, where it is ignited to heat the water in the boiler.



The **DBW 2010S** hydronic heater offered by Webasto will heat up to a 52 foot sailboat or a 50 foot powerboat. The **DBW 2010S** utilizes 1" Wirsbo tubing to deliver heated coolant to dual 3/4" fan heater zones throughout the boat. The **DBW 2010S** uses a 1-1/2" rigid exhaust system and a 1/4" supply/return fuel system. The **DBW 2010S** is available in 12 or 24 volts.

The **SMS** installation kit features:

- **Premium Heat Exchanger**
  - Threaded Coolant Fittings, Union Valves for easy Wirsbo Plumbing, O/H Fuse, Reset Limiter, & Ellwood Aquastat
- **Insulated Buffer Tank**
- **Surewire Water**

The Surewire Water board puts all electrical connections into one place making installation and troubleshooting of your heater easier than ever before. The Surewire Water is for all Webasto Water heaters. Features include:

- Ready for hassle free **thermostat** wiring
  Up to **four zones**!
- Domestic water heater control wiring
- Easy to add **engine heat** control
- **Hour meter** to track run time of the heater
- Comes with **protective stainless enclosure box**
- **Breaker protection** of heater in one convenient place
- **Ground Bar** for cleaner wiring

- **Marine Installation Manual**

Figure: Example water heat installation.
See manual for installation guidelines.

Analyzing and Identifying Control Malfunctions

Circulator Problems

Circulator problems that are particular to hydronic systems include system resistance and flow rate, and heat output and temperature difference.

Boiler Problems

The following conditions can result from boiler system malfunctions: carbonizing, condensation, corrosion, liming, and underfiring and overfiring.

Mechanical Problems

Mechanical malfunctions can cause problems such as insufficient heat in one or more rooms or zones or throughout the building, and noise in the system.

System Resistance and Flow Rate

Relationship

As resistance increases in the system, the pressure increases, and the flow rate decreases. Excessive resistance in the system caused by scaling or other restrictions will cause the pump to work harder to maintain flow.

Impact

Too much resistance in the system will reduce the flow rate to the point where system efficiency is affected.

Flow rate can also be too slow if the pump motor does not have sufficient horsepower and rpm to maintain an effective flow rate. Selecting pump of adequate horsepower and rpm is required to maintain proper flow rate.

Heat Output and Temperature Difference

Pump Performance

The boiler heat output and the temperature difference between the supply and return water affect pump performance. The circulating pump must be able to maintain a flow rate sufficient to meet the heat output and temperature differential of the appliance and system.

Calculation Basis

One Btu is required to raise the temperature of one pound of water 1°F. One US gallon of water weighs 8.33 pounds.

Calculating Boiler Output Rate

Type	Formula
Imperial	Boiler output(Btu/h) = 8.33 lbs (ΔT) 60 minutes = 500 (ΔT) Where: ΔT = hydronic system temperature differential(°F)
Metric	Boiler output(kW) = 0.263 (ΔT) Where: ΔT = hydronic system temperature differential(°C)

For example, the number of Btu/h required to maintain a 20°F temperature differential is calculated as follows:

Boiler output(Btu/h) = 500 × 20 = 10,000 (Btu/h)

Calculating Flow Rate

Type	Formula
Imperial	Flow rate(US gpm) = Boiler output (Btu/h) ÷ (500)ΔT Where: △T = hydronic system temp. differential(°F)
Metric	Flow rate(L/s) = Boiler output (kW) ÷ (4.19)△T Where: △T = hydronic system temp. differential(°C)

For example, a system with 250,000 Btu/h output and a system temperature differential of 20°F would require a pump that could maintain a flow rate of 25 US gpm:

250,000 = (500×20) = 25 US gpm

Inputs			**Calculations**		
Pipe diam, D_1	15	in	Pipe diam, D_1	1.25	ft
Constricted diam, D_2	5	in	Constricted diam, D_2	0.416667	ft
Measured pressure diff., $P_1 - P_2$ (psi)	1.2	lb/in^2	Constricted area, A_2	0.1364	ft^2
			Diam. Ratio, β (= D_2/D_1)	0.333	
Fluid density, ρ	1.94	$slugs/ft^3$			
Meter Coefficient, C	0.6		Measured pressure diff., $P_1 - P_2$ (psf)	172.8	lb/ft^2
			Pipe Flow Rate, Q	1.10	cfs

Boiler Problems: Carbonizing

Causes

Flame impingement, which results from too long a burner flame or from excessive water flow in the fin tube boilers, primarily causes carbonizing or sooting on heat source surfaces.

Adjustments to Reduce Sooting

- Yellow tipping of burner flames due to incorrect primary air adjustment
- Scale or lint blocking the burner's ports
- Input (incorrect burner port loading)

Boiler Problems: Condensation

Cause

Condensation in the boiler's combustion chamber usually occurs as a result of low flue gas temperatures.

Factors Leading to Low Flue Gas Temperatures

- An under-sized or under-fired boiler
- Excessive water flow
- Use of a night set-back thermostat
- Large volume radiation equipment

Condensing type boiler is specially designed to take advantage of condensing gases and should not be confused with non-condensing applications.

Boiler Problems: Corrosion

Internal Corrosion

Internal corrosion may result from low flue gas temperatures or air in the system, which will cause oxidation (rusting).

Air can enter the system in one of two ways:

- In the boiler makeup water
- Through leaks in the system

To reduce air infiltration, equip the system with adequate air venting devices and check it for leaks on a regular basis.

External Corrosion

Corrosive chemicals in the combustion air such as solvents, paint thinners, bleaches, chlorine or fluorine vapours can cause external corrosion. Chlorine are present in chemicals or processes such as printing ink, paint stripping solutions, refrigerants, and permanent wave solutions among others.

Boiler Problems: Underfiring and Overfiring

Importance of Proper Firing Rate

It is important for efficient system operation to maintain the proper boiler firing rate. A boiler's firing rate is specified on the rating plate.

Underfiring

Underfiring is not necessarily a problem if the boiler and venting system was designed to allow for a lesser input. However, the boiler will not be operating to its full level of efficiency, and flue gas temperatures may be low.

Overfiring

Overfiring a boiler can result in problems such as incomplete combustion and excessively high flue gas (stack) temperatures. When a boiler is overfiring, check the input by clocking the gas meter. If the input is incorrect, check the manifold pressure and adjust it, or change the burner orifice size.

Mechanical Problems: Insufficient Heat Output

Common Causes

Insufficient heat output is generally a result of:

- Insufficient or no flow in the system
- Incorrect temperature settings

Potential Faults

These problems can be a cause of a number of faults, including:

- Faulty or misadjusted manual isolation, zone, check, mixing, or balancing valves
- Lack of pressure (insufficient head pressure)
- Air or air locks in the system
- Undersized or scaled piping
- Incorrect temperature settings on mixing valves

Mechanical System Problems and Causes

Problems/symptoms	Possible causes
Insufficient heat throughout building during cold weather; Boiler fires but cycles on/off on limit control	Limit set below system design temperature; Air flow restricted to radiation equipment; Radiation equipment inadequately sized; Pumping or flow restriction problem
No heat in upper floor of building	Air in system due to problem with water feed regulator
One cold radiator (manual air bleed)	Air locked; Needs to be purged
Gurgling sound in pipes (manual air bleed)	Air bubbles; Shut down pump and bleed all radiators; Advise customer to repeat process regularly
Circulator making loud rattling noise	Check for broken pump coupler or pump cavitation
Flow switch keeps boiler burner from firing but activates when shaken	Pump size incorrect; Line restriction; Incorrect installation of flow switch in relation to the pipe size and fittings; Incorrect installation of flow switch sensing paddles

Noise in the System

Air in System

Air in the system produces gurgling noises.

Valve Installation

Zone valves installed backwards will cause water hammer when they slam shut.

Pump Issues

Pumps that are undersized or that operate at excessive rpm cause increased flow velocity, which then creates noise in the system.

Piping Problems

Poorly secured piping supports permit noise-generating vibration. Inadequate expansion and contraction clearances between piping and the building structure may result in noise when the piping rubs against the structure.

Cavitation

Pump cavitation can be a major source of noise.

Pump Cavitation

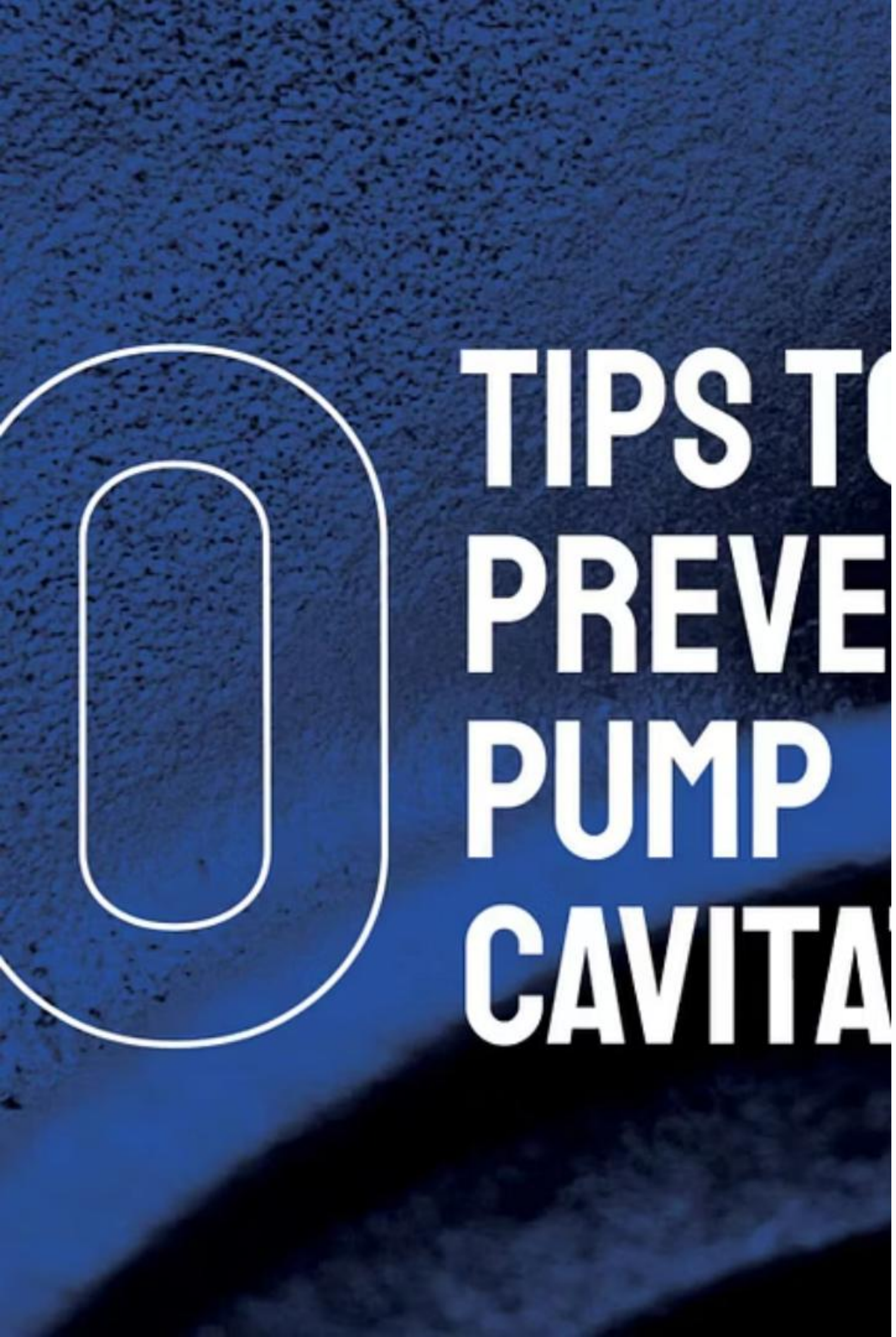
Definition

Cavitation is the formation of bubbles in a liquid by pressure variation, heating, or vibration. Pump cavitation is characterized by gurgling or popping sounds, vibration, and erratic flow.

Reducing Cavitation

You can reduce or eliminate pump cavitation in hydronic systems by:

- Keeping system static pressure as high as possible
- Keeping system fluid temperature as low as possible
- Locating the expansion tank as near to the inlet of the pump as possible
- Installing the pump at as low a point in the system as possible to increase static pressure at the pump inlet



Additional Measures to Reduce Pump Cavitation

Proper Piping

Installing the pipe leading to the pump inlet as a straight run, at least ten pipe diameters in length

Air Removal

Equipping the system with adequate air removal devices

Pump Placement

Placing high-head or multiple pump installations to ensure that the greater pressure differentials they produce do not cause cavitation

Hydronic System Maintenance Checklist

Regular Inspection

Check all valves, controls, and mechanical components for proper operation

Preventative Maintenance

Clean and service components before they fail

Repair and Replace

Address any malfunctioning components promptly

System Testing

Verify proper pressure, temperature, and flow rates

Importance of Regular Maintenance

15%

Energy Savings

Properly maintained systems use less fuel

30%

Extended Lifespan

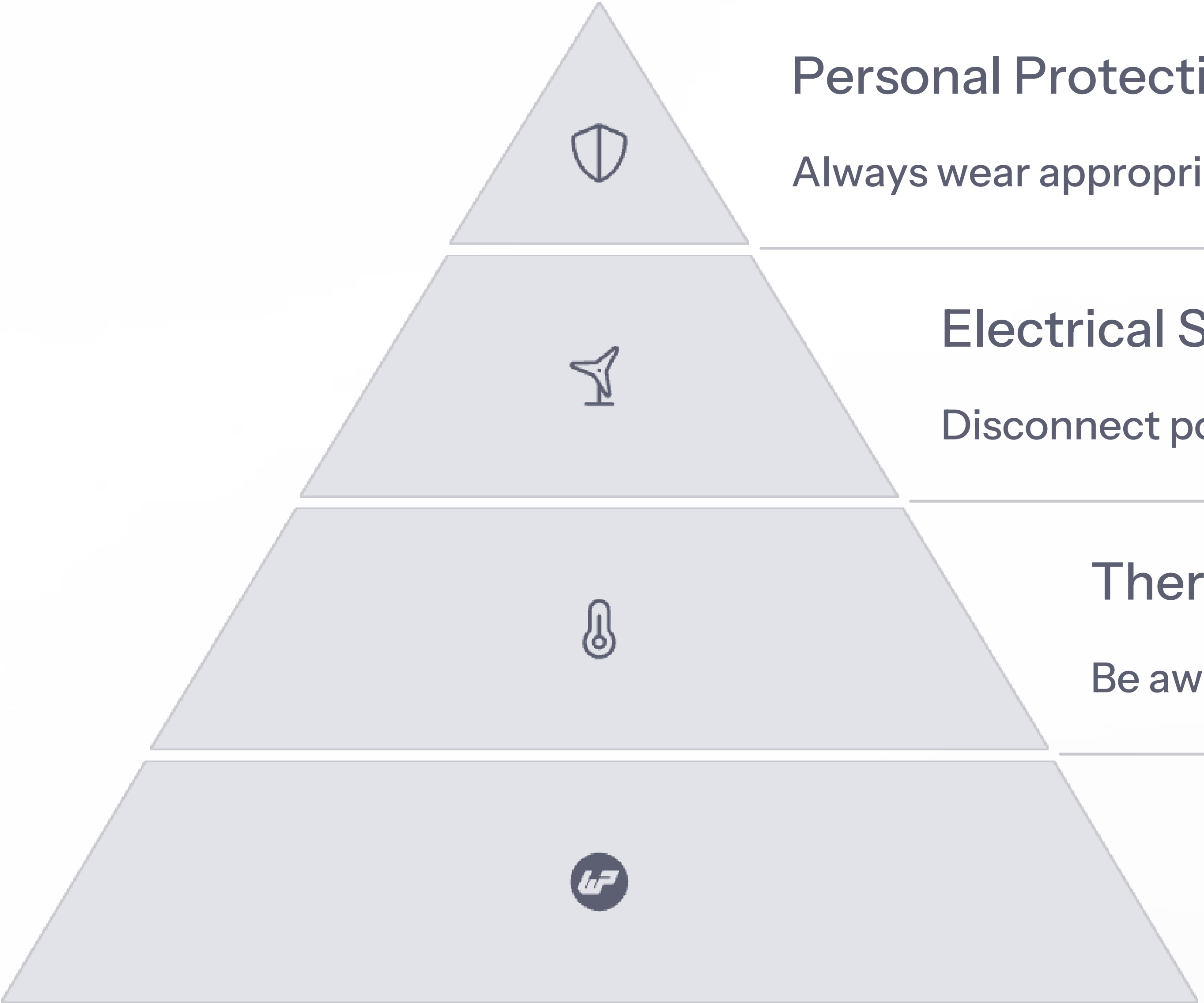
Regular maintenance increases system longevity

50%

Fewer Breakdowns

Preventative maintenance reduces emergency repairs

Safety Considerations in Hydronic Maintenance



Personal Protection

Always wear appropriate PPE

Electrical Safety

Disconnect power before servicing electrical components

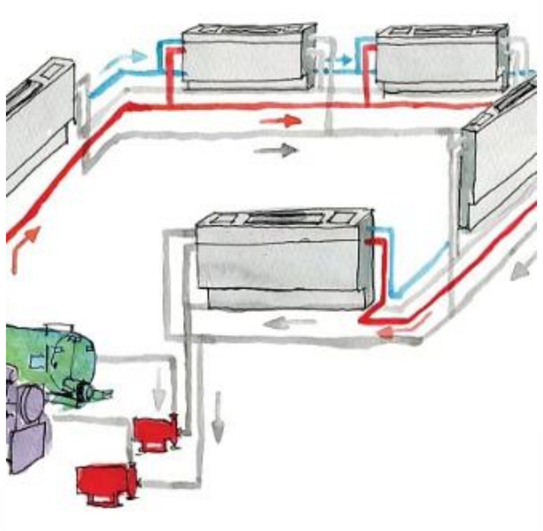
Thermal Hazards

Be aware of hot surfaces and water

Pressure Safety

Relieve system pressure before opening components

Tools for Hydronic System Maintenance



Essential tools for proper hydronic system maintenance include pressure gauges, thermometers, multimeters for electrical testing, pipe wrenches, air vent keys, and flow meters. Having the right tools ensures accurate diagnosis and efficient repairs.

Seasonal Maintenance Schedule

Pre-Heating Season

Complete system check before cold weather

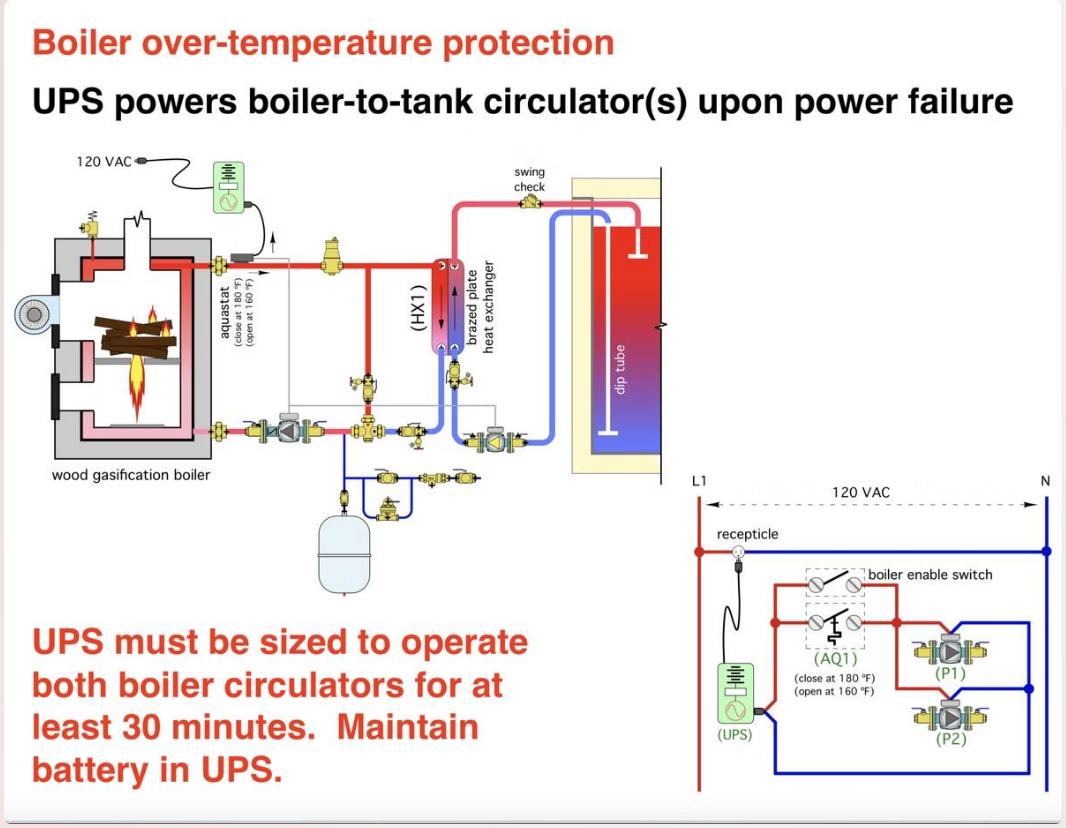
Mid-Season Check

Verify operation during peak usage

End of Season Service

Address any issues before shutdown

A well-planned maintenance schedule ensures your hydronic system operates efficiently throughout the heating season. The most critical maintenance should be performed before the heating season begins, with follow-up checks during peak usage periods and a thorough inspection at the end of the season to identify any issues that need addressing before the next heating cycle.



Documentation and Record Keeping

System Specifications

Keep detailed records of all system components, including model numbers, installation dates, and manufacturer information.

Maintenance History

Document all maintenance activities, including dates, work performed, and parts replaced.

Performance Data

Record system pressures, temperatures, and flow rates during each maintenance visit to track changes over time.

Warranty Information

Maintain files of all warranty documentation for system components to ensure coverage when needed.

Common Hydronic System Control Issues

Advanced Troubleshooting Techniques

Systematic Approach

When troubleshooting complex hydronic systems, always follow a systematic approach:

1. Gather information about the problem from the user
2. Verify the complaint by observing system operation
3. Check the simplest potential causes first
4. Test components in a logical sequence
5. Verify the repair by testing system operation

Diagnostic Tools

Advanced diagnostic tools can help pinpoint issues more quickly:

- Infrared thermometers to identify temperature differentials
- Ultrasonic flow meters for non-invasive flow measurement
- Data loggers to track system performance over time
- Combustion analyzers for boiler efficiency testing
- Electronic pressure and temperature sensors for precise readings

Water Quality and System Longevity

pH Balance

Maintain proper pH levels (typically 7.5-8.5) to prevent corrosion and scaling in the system.

Filtration

Install and maintain proper filtration to remove particulates that can damage pumps and valves.

Chemical Treatment

Use appropriate inhibitors and treatments to prevent corrosion, scaling, and biological growth.

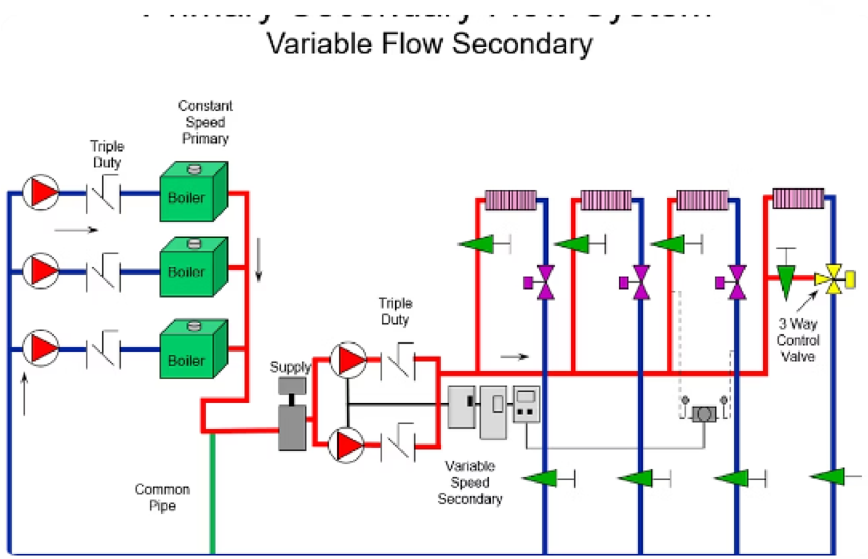
Regular Testing

Test water quality parameters regularly and adjust treatments as needed to maintain optimal conditions.

Energy Efficiency Improvements

Outdoor Reset Controls

These controls adjust boiler water temperature based on outdoor temperature, reducing energy consumption during milder weather while maintaining comfort.



Variable Speed Pumps

Modern ECM pumps adjust their speed to match system demand, consuming significantly less electricity than traditional fixed-speed pumps.

Zone Controls

Proper zoning allows heating only the areas that need it, when they need it, reducing overall energy consumption and improving comfort.

Future Trends in Hydronic Control Systems

Smart Controls

Internet-connected controls allow remote monitoring and adjustment, predictive maintenance, and integration with home automation systems.

Low-Temperature Systems

Systems designed to operate at lower temperatures improve efficiency and compatibility with renewable heat sources like heat pumps and solar thermal.

Advanced Analytics

Data-driven systems that continuously optimize performance based on usage patterns, weather forecasts, and energy prices.

Hybrid Systems

Integration of multiple heat sources (conventional boilers, heat pumps, solar) managed by sophisticated controls for maximum efficiency.

Summary: Hydronic Control System Servicing

Regular Inspection

Systematic checks of all components

Proper Maintenance

Preventative service to avoid failures

Effective Troubleshooting

Systematic diagnosis of issues

Professional Service

Qualified technicians ensure safety and efficiency

Proper servicing and maintenance of hydronic control systems is essential for ensuring efficient operation, preventing costly breakdowns, and extending system lifespan. By following the guidelines outlined in this presentation, technicians can provide high-quality service that maintains system performance while ensuring safety and reliability.

CSA Unit 20

Chapter 5
Pool Heating Systems

Pool heating systems have their own system components and requirements for installation, sizing, and maintenance. The gas technician/fitter must be familiar with Code requirements for pool systems, as well as have the ability to troubleshoot burner and ignition systems for pool heaters.

Learning Objectives

Installation Requirements

Describe the proper installation requirements for pool heating systems

System Components

Identify and describe the various components that make up a pool heating system

System Sizing

Understand how to properly size pool heating systems

Maintenance

Describe cleaning and winterizing procedures

Troubleshooting

Effectively troubleshoot burner and ignition system issues

Key Terminology

Term	Abbreviation (Symbol)	Definition
Backwashing		A reversal of the flow path through the pool filter bed to wash the accumulated debris out of the system
Heater actuator		See Pressure switch
Pressure switch		Switch that turns the pool heater off and on
Turnover time		The length of time (in hours) required to circulate all the water in the pool once through the filter

Common Boiler Issues

Burner Will Not Fire

Check the following components first:

- Aquastats
- Water supply
- Venting system
- Air vents

Incomplete Combustion

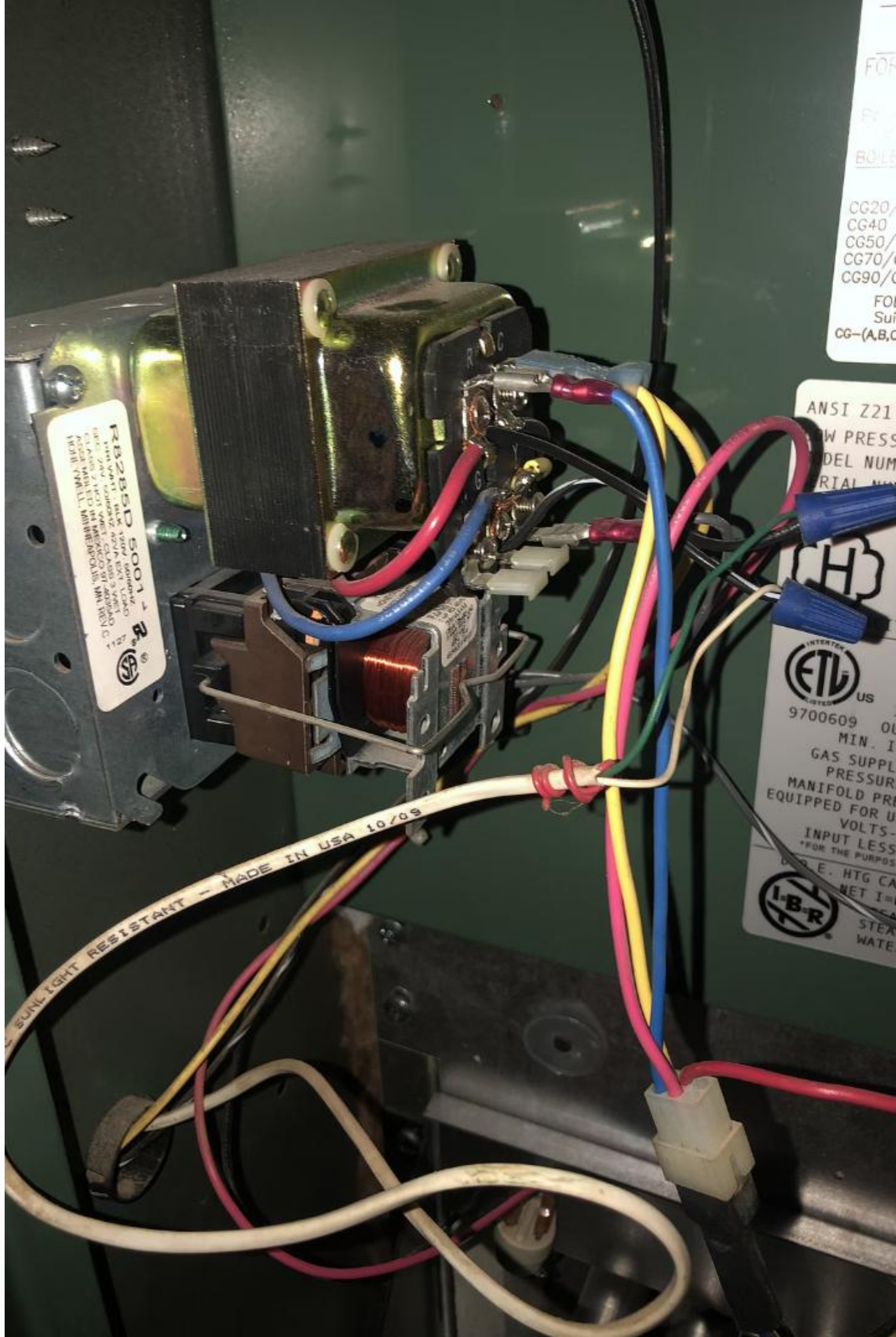
Likely causes include:

- Air in the system
- Low water condition
- Over-firing the burner
- High water pressure

Air in the System

Can create common problems such as:

- Noise
- High velocities
- Condensation
- High flue temperatures



System Maintenance Personnel

Certified Tester

Can test a backflow preventer

Gas Technician

Installs and maintains gas equipment

Homeowner

Limited maintenance capabilities

Plumber

Handles water system components

Hydronic System Issues

Pressure Increases After Burner Activation

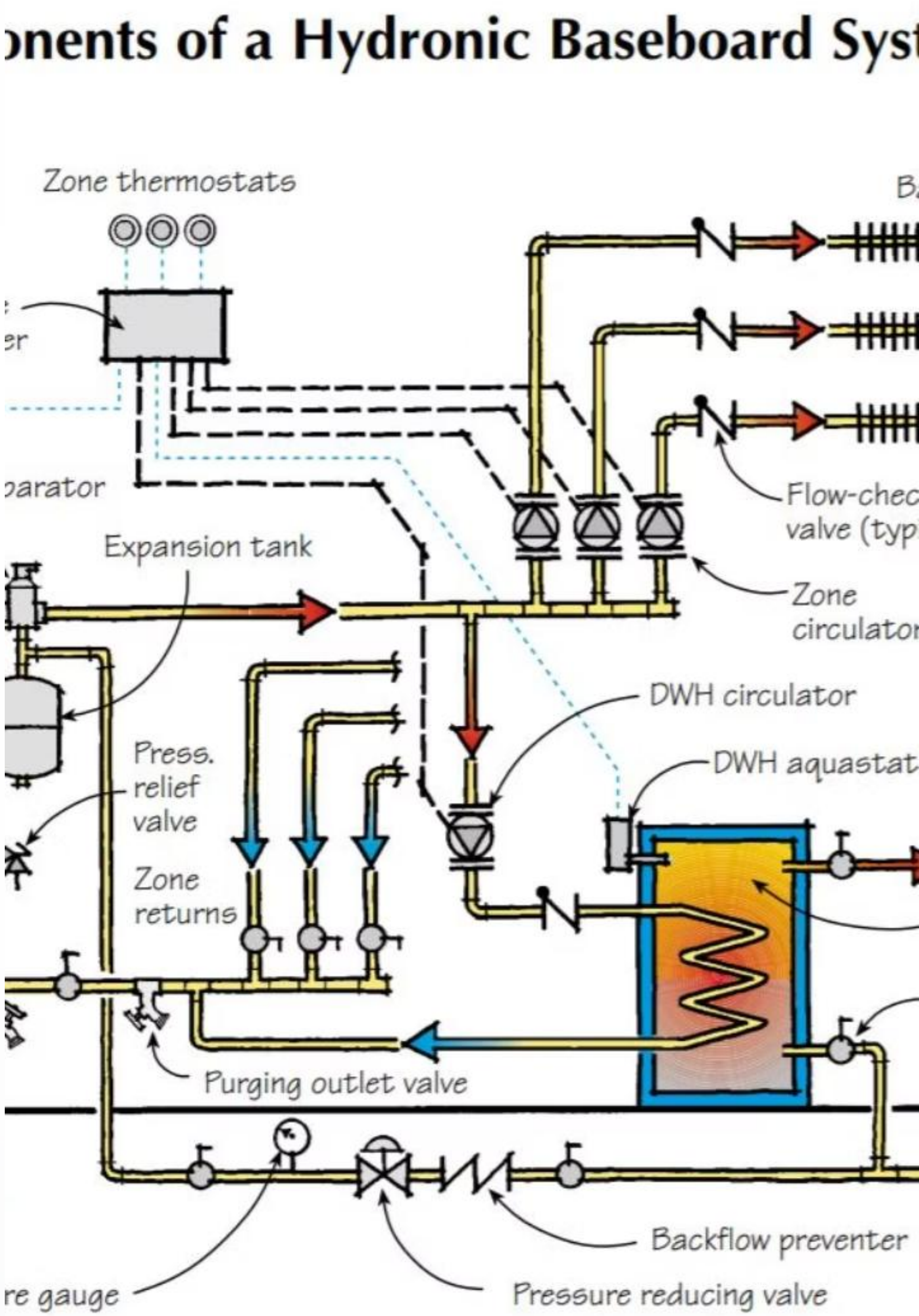
Cause: Expansion tank is water-logged

Zone Valve End Switch Failure

Result: Burner will not fire

No Heat in Top Floor

Most likely cause: Air lock in system



Modern Pool Heaters

Preferred Heating Methods

Natural gas-fired and propane-fired heaters are today's method of choice for heating pools. Innovative technological advances have resulted in highly efficient systems.

Efficiency Improvements

Modern pool heaters feature improved heat exchanger design, forced-draft combustion systems, and pilot-less ignition, resulting in units that are up to 95% efficient.

The gas technician/fitter must consider many factors when planning a pool heater installation. In all cases, compliance with applicable Code requirements and manufacturer's installation instructions are of primary importance.

Code Requirements

1. **CSA B149.1 Section 7**

   Contains specific requirements for pool heater installations

2. **Base Material and Levelling**

   Proper foundation requirements for pool heaters

3. **Location Restrictions**

   Guidelines for appropriate placement of equipment

4. **Clearance to Combustibles**

   Required safety distances from flammable materials

Heater Placement Considerations

Combustion Air

Adequate supply of air for proper combustion

Venting

Sufficient venting for exhaust gases

Electrical Access

Proximity to electrical distribution system

Gas Supply

Accessibility to gas distribution system

Water Quality Effects

Water Type Requirements

Pool heaters must only be used with potable water

pH Level Maintenance

Maintain pH level at 7.5 for proper operation

Corrosion Prevention

Regular inspection and deposit removal required

Pool heaters are not designed for use with mineral water, sea water, saltwater, or other non-potable water supplies. Using a pool heater with non-potable water will adversely affect heater operation, damage the heat exchanger, and probably void the warranty.

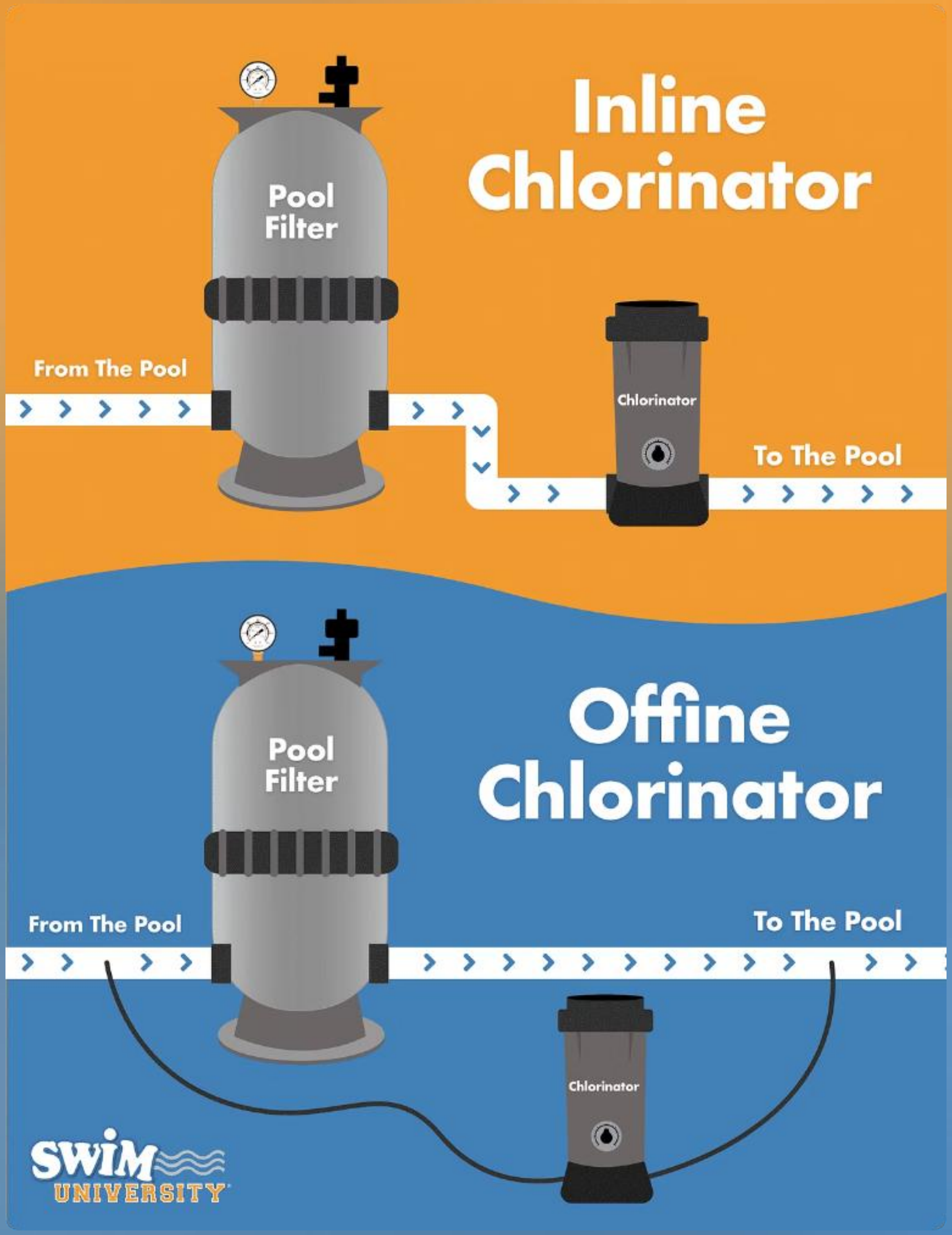
Mineral Deposits and Liming

Effects of Liming

Pool heaters are more susceptible to corrosion and the formation of lime deposits (liming) than other pool components. The insulating and flow restricting effects of liming will impair heater output and overwork the pump, lowering energy efficiency and increasing operating costs.

Causes of Mineral Buildup

High concentrations of minerals eventually precipitate out of the pool water, forming deposits in the heat exchanger tubes and on other pool component surfaces. The concentration of naturally occurring minerals in the water increases daily due to evaporation. The addition of algae- and bacteria-killing chemicals such as chlorine and bromine further increases the mineral content.



Chlorine Effects

Chlorine Addition

Chlorine added to pool water

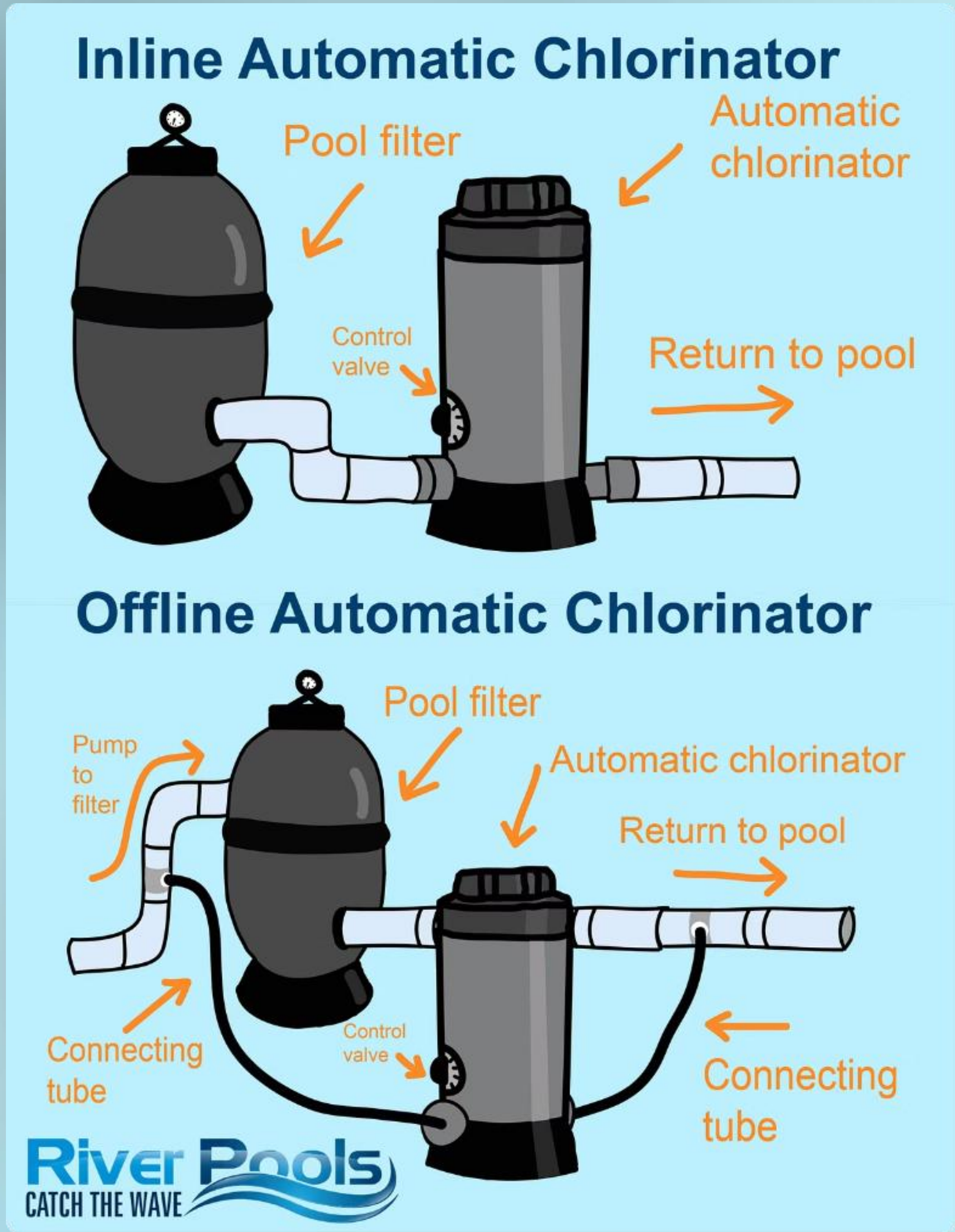
Acid Formation

Forms hydrochloric acid in water

Component Damage

Can damage heater components

When chlorine is added to the pool water, it forms hydrochloric acid, which can damage heater components. If a pool is equipped with a chlorinator, the chlorinator must be installed so that it injects the chlorine into the circulation system downstream of the heater.



Chlorinator Installation

1 Downstream Placement

Chlorinator must inject chlorine into circulation system downstream of the heater

2 Elevation Requirements

Injection point should be at a lower elevation than the heater outlet fitting

3 Anti-Siphon Device

Must be equipped with an anti-siphon device to eliminate backsiphoning

4 Wiring Configuration

Chlorinator should have wiring so that it operates only when the filter pump is operating

Chemical Safety

Exposure Risks

Exposure to pool chemicals can be harmful to your eyes and lungs.

Safety Precautions

When handling pool treatment chemicals, follow all applicable health and safety precautions and procedures.

Safety Data Sheets

Be sure to know and understand the information contained within the safety data sheet (SDS) for any hazardous products that you may encounter.

Critical Information

The product information, first-aid measures, and other critical information for a hazardous product are included in the SDS.

WHMIS and Safety

WHMIS

Unit 1 Safety, Chapter 3. Hazardous materials covers the Workplace Hazardous Materials Information System (WHMIS), the updated WHMIS 2015 legislation, and safety data sheets (SDS).

Personal Protective Equipment

Always use appropriate personal protective equipment when handling pool chemicals and performing maintenance on pool heating systems.

System Materials Considerations

Plastic Protection

Protect piping and other components made of plastic from overheating due to back-siphoning of hot water from the heater

Backflow Prevention

To prevent backflow of hot water, install a check valve and "heat sink" pipe between the heater and the filter unit

Plastic Connection Warning

Never connect plastic (PVC) piping directly to heater headers

Electrolytic Corrosion

When galvanized pipe is connected to copper pipe or tubing, ensure that the joint must have a dielectric insulating fitting to prevent electrolytic corrosion

Pool Heating System Components

Piping Runs

Connect all system components

Heater Bypass Valve

Ensures proper flow through heater

Controls

Operating and safety controls

Pressure Switch

Turns heater on/off based on water flow

Filter

Removes debris from water

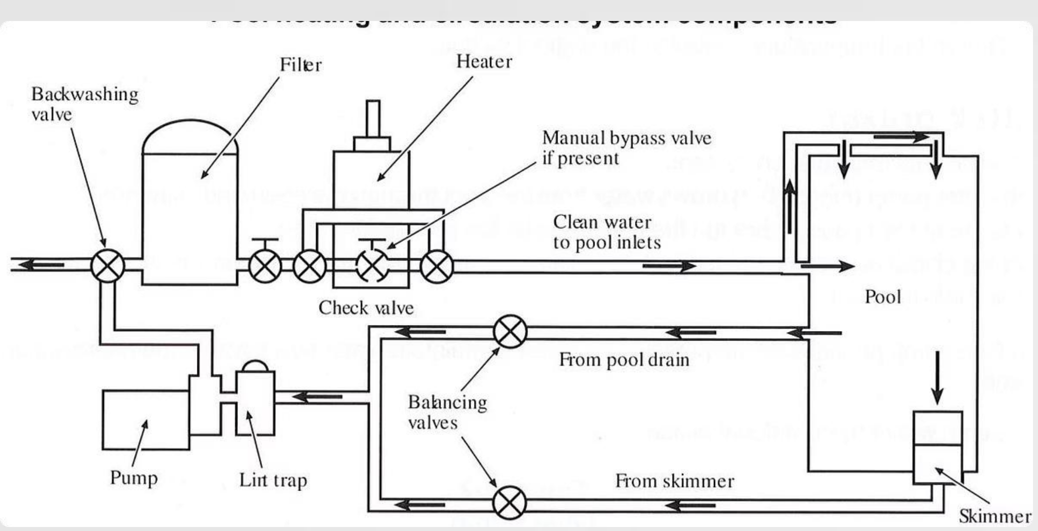
Filter Pump

Circulates water through the system

Piping System Layout

Figure 5-1 shows the piping runs and components for a typical pool water heating and treatment system. Water circulates continuously through the system in the direction(s) that the arrows indicate. However, water does not flow in all pipes at the same time.

The diagram illustrates the complete circulation path from the pool through the skimmer, pump, filter, heater, and back to the pool, with all necessary valves and components.



Heater Bypass Valve

Purpose

The bypass valve ensures proper flow through the heater. A manual bypass is required on systems with a flow rate of more than 125 US gpm (8 L/s). On some systems with flow rates less than 125 US gpm (8 L/s), a manual bypass is not required. An automatic bypass valve is built into some pool heaters.

Function

The function of the bypass valve is to reduce condensation by allowing water to bypass the fin tube coil when pump rates are high. The operation of the bypass valve depends on a spring-loaded valve seat, which opens when pressure behind the valve reaches a critical point. This causes cold water to bypass the heater coil keeping the coil warmer.

Pressure Switch

Definition

The pressure switch, or heater actuator, turns the heater off and on.

Primary Function

It only switches the heater on when the filter pump is running to ensure adequate flow through the heater.

Specifications

The pressure switch is normally a component within the pool heater and is typically set to 2 psig (14 kPa).

Protection

Prevents damage to the fin tube from low or no water flow through the heater.

If the heater were to operate without proper circulation, the water in the heat exchanger would quickly boil off, resulting in damage to the unit. You can adjust the setting of the pressure switch to compensate for different water levels in the pool.

Testing the Pool Heater Pressure Switch

Raise Temperature Control

Raise the temperature control to the maximum setting.

Observe Burner

Observe that the burner lights.

Adjust Gas Valve

Turn the gas valve to the pilot position.

Interrupt Water Flow

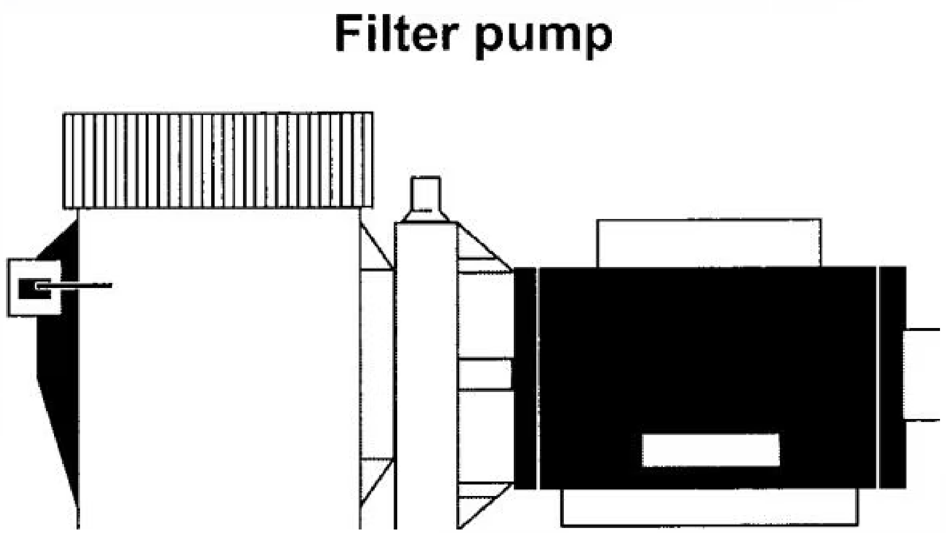
Turn off power to the pump or restrict the water flow.

Return Gas Valve

Turn the gas valve to the on position.

Observe that the main burner does not light. Restore power to the pump or restore the water flow. Observe that the main burner lights. Return the temperature control to the original setting.

Filter Pump



Basic Recirculation System

In a basic pool recirculation system, the filter pump draws water from the pool through the drain and skimmer. The water then passes through the filter and into the pool heater. At the chlorinator, any necessary chemicals are added to the heated water, which then flows back into the pool.

Pump Function

The filter pump provides all the pressure required to maintain water flow through the recirculation system. The pump works by centrifugal action, creating the necessary pressure to move water through all components of the system.

Valves in Pool Systems

Check Valve

Some filter pumps have a built-in check valve in front of the strainer. If the pump is located above the water level of the pool, the check valve prevents water draining from the suction pipe when the strainer is opened.

Gate Valve

When a pump does not have a check valve, install a gate valve in the suction line to prevent it from draining when the strainer is opened.

Return Line Valve

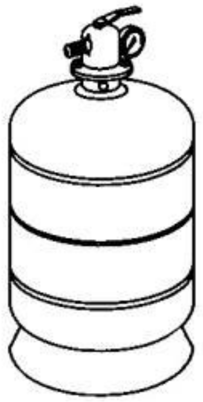
Install a gate valve in the pool return piping to prevent draining of the strainer due to siphoning through the filter.

System Priming

The proper placing of valves in a pool piping system ensures that the system will remain full of water and not require re-priming after maintenance.

Pool Filter

Figure 5-3
Filter



Filter Operation

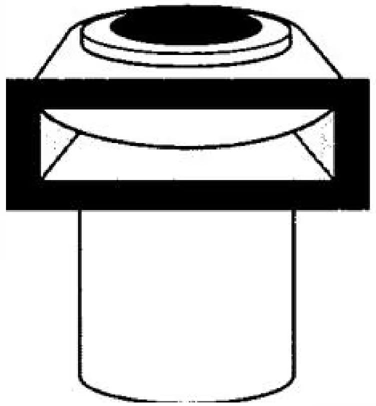
Water flows downwards through the filter bed where dirt and debris collect in the sand filter. As dirt accumulates in the filter bed, water flow through it is gradually restricted. Eventually, cleaning the filter bed will require backwashing (flushing).

Backwashing Process

Backwashing is basically a reversal of the flow path through the filter bed to wash the accumulated debris out of the system. This process cleans the filter media and restores proper water flow.

Skimmer

Figure 5-4
Skimmer



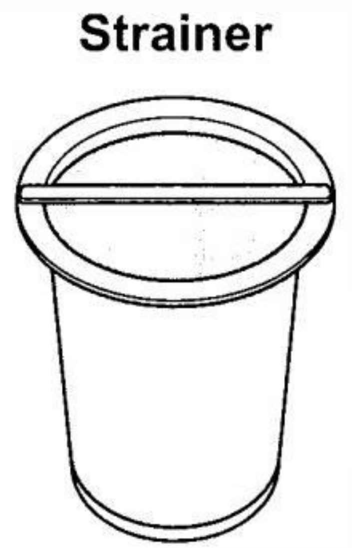
Location and Connection

The skimmer is mounted in the wall of the pool at water level and is connected directly to the filter pump suction piping, between the drain and the pump.

Function

The vacuum created by the skimmer's suction action pulls in water from the pool's surface layer, removing floating dust, debris, leaves, and any oil film that has accumulated on the surface. This prevents the accumulation of deposits on the bottom and walls of the pool.

Strainer



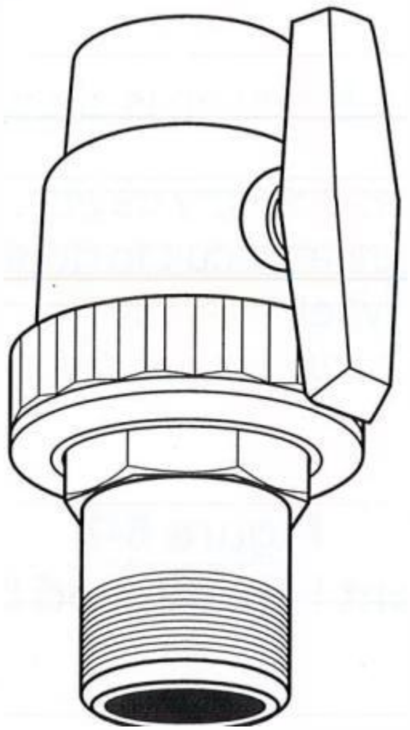
Purpose

Strainers are screens that prevent large pieces of debris from damaging the pump and creating blockages in the system.

Installation Locations

They are installed at the skimmer and filter pump inlet to catch debris before it can enter the pump mechanism.

Drain and Hydro Relief Valve



Drain Valve Location

The drain valve is located on the filter pump suction piping connected to the drain in the bottom of the pool. It is opened to drain the pool for maintenance purposes.

Hydro Relief Valve

For in-ground pools, a drain that incorporates a hydro relief valve for admitting water to an empty pool is recommended. This is because if there is ground water pressure below the pool, the hydro relief valve will open, allowing the ground water to enter than pushing against the bottom of the pool.

Operating and Safety Controls

Thermostat

Controls water temperature

High Limit Aquastat

Prevents water overheating

Pilot Safety

Controls gas flow

Ignition Control

Manages burner ignition

In addition to the pressure switch, which acts as a safety device, a pool heater system has these operating and safety controls to ensure proper and safe operation.

Thermostat/Aquastat

Mounting

Most pool heaters have a mechanical aquastat that is mounted on the heater unit.

Adjustment

You can adjust the aquastat, which usually has a maximum setting of 100°F (38 °C), to the desired water temperature.

Function

The aquastat cycles the heater on and off as required to maintain the desired water temperature in the pool.

Operation

You can leave the aquastat at the desired setting and use the ON-OFF switch to shut the heater off when it is not required.

High Limit Aquastat

Safety Requirement

All pool heaters must have a high limit aquastat to limit the water temperature to 140°F (60 °C) to prevent scalding.

Installation Location

The high limit aquastat is usually installed in the heat exchanger outlet header.

Temperature Threshold

If the outlet water temperature exceeds 140°F (60 °C), the aquastat will switch the heater off.

Pilot Safety Devices

Types of Pilot Safety Devices

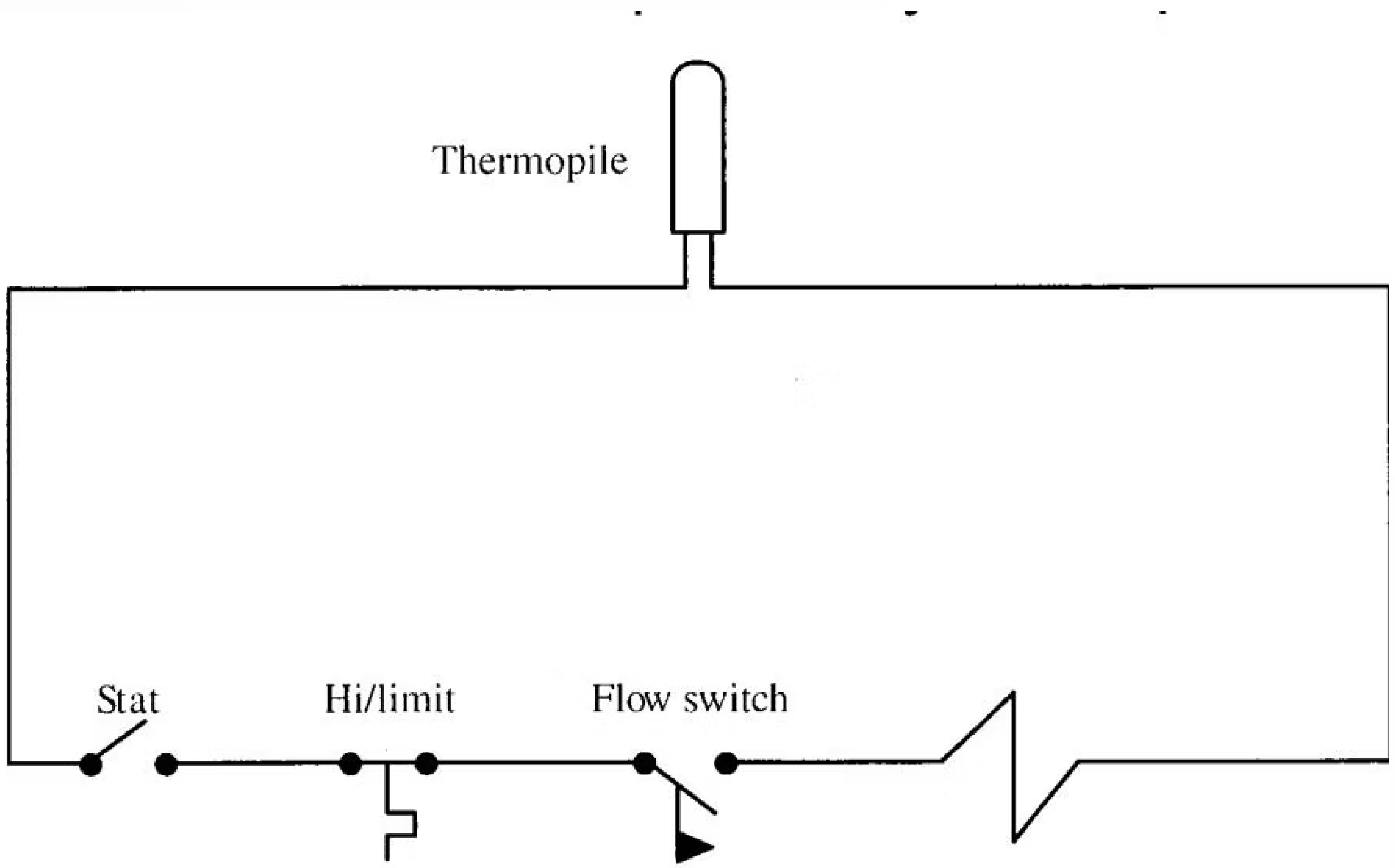
There are two types of pilot safety devices used in pool heating systems:

- Self-energizing (millivolt)
- Electronic ignition

Purpose

These devices ensure that gas is only supplied to the burner when a proper pilot flame is present, preventing dangerous gas accumulation if the pilot is extinguished.

Millivolt System



Operation

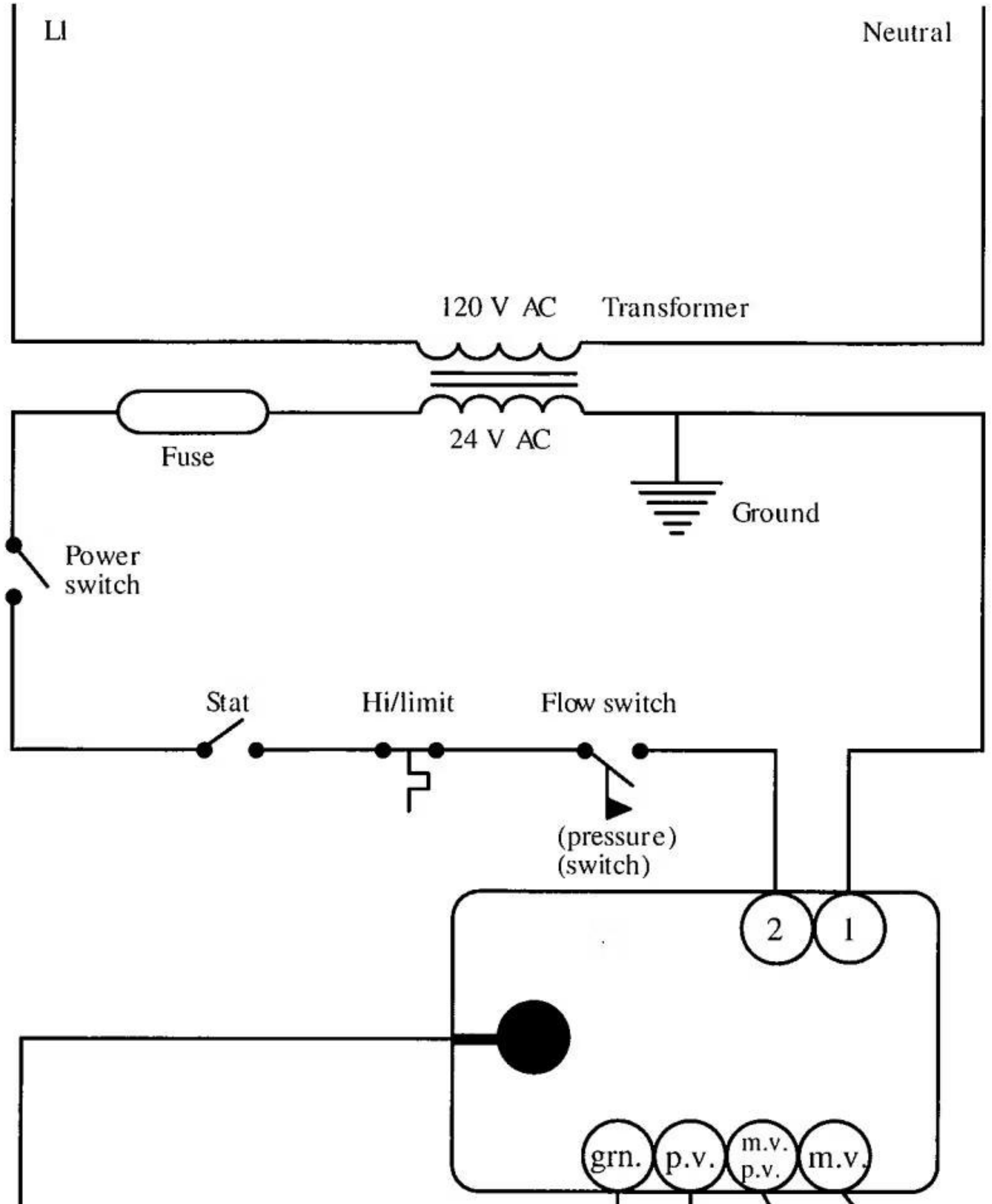
In a self-energizing millivolt system, a thermopile, or pilot generator, produces the electrical current that operates the gas valve.

Safety Function

This type of pilot system also functions as a safety device. If the pilot flame is extinguished, the thermopile will cool off, opening an electrical circuit to de-energize the gas valve and shut down gas flow to the pilot and heater burner. When this occurs, relight the pilot burner manually before operating the heater.

Unit 12 Basic electricity for gas fired equipment, Chapter 5. Millivolt systems covers this in detail.

Electronic Ignition



System Sizing Overview

Pool Heater

Sized based on pool surface area and temperature requirements

Gas Pipe

Follows standard gas pipe sizing procedures

Vent

Sized according to manufacturer specifications

Pump

Sized based on flow requirements and turnover time

Filter

Sized according to filter type and flow rate

Pool Heater Sizing Factors

Key Sizing Factors

Pool heaters are sized according to:

- The surface area of the pool
- The difference between the desired pool temperature and average local air temperature

Surface Area Importance

Surface area is used instead of water volume because pools with the same surface area have approximately the same volume and surface area also takes the heating effect of direct sunlight into account.

16x32	13,400	15,400	17,300	19,200
18x36	17,000	19,400	21,900	24,300
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Heat Calculation Basics

BTU Definition

One Btu is the amount of heat required to raise the temperature of one pound of water 1°F.

Imperial Gallon Calculation

Raising one imperial gallon (ten pounds) of water by 1°F requires 10 Btu.

Volume Consideration

Knowing the volume of the pool and the temperature rise of the heater, you can determine the size of the heater required.

Pool Heater Sizing Procedure

Calculate Surface Area

Calculate the area of the pool surface in square feet.

Determine Desired Temperature

Determine the temperature desired for the water in the pool.

Find Average Temperature

Determine the average temperature for the coldest month of pool use. This information is available from the local weather service office.

Calculate Temperature Rise

Subtract the coldest month average temperature from the desired pool temperature to get the required temperature rise.

Apply Sizing Formula

Use the formula to determine the required output of the heater in Btu/h (KW).

Heater Sizing Formula

Imperial Formula

Heater Output(Btu/h) = Pool Area(sq ft) × Temperature Rise(°F) × 12

Metric Formula

Heater Output(kW) = Pool Area(m^2) × Temperature Rise(°C) × 0.07

The formula above is based on a temperature rise of 1 - 1.25°F per hour (0.55 - 0.7 °C per hour) and an average wind speed of 3.5 mph (5.8 kph) at the pool surface. Factors such as exposure to sun and wind, relative humidity, and cooler night-time temperatures affect a pool's heating load.

Sizing Example

Measurement	Formula	Imperial	Metric
Pool Size		40ft × 20ft = 800sq ft	12.1m×6.05m = 73.2m^2
Temperature Rise		15° temperature rise	8.3°C temp.rise
Heater Output	Area × Temp Rise × Factor	800 × 15° × 12 = 144 Mbtu/h	73.2 × 8.3° × 0.07 = 42.2 kW

The example is based on a pool with an average depth of 5.5 feet (1.66 m).

Other System Sizing Considerations

Gas Pipe Sizing

Sizing of the gas piping for a pool heater installation conforms with normal pipe sizing procedures, which are detailed in Unit 10 Piping and tubing systems for industrial and commercial applications.

Vent Sizing

Vent sizing, materials, and other installation requirements are specified in the pool heater manufacturer's instructions. In all cases, venting must conform to all applicable Codes.

Pump and Filter Sizing

Pump Sizing

Pump (circulator) sizing is covered in more detail in Chapter 2. Distribution and control systems, including:

- Filter type and flow rate
- Pool water turnover time

Follow the manufacturer's requirements for pool pumping systems.

Filter Sizing

Pool filter sizing is based on:

- Filter type and flow rate
- Pool water turnover time

Filter Types and Flow Rates

Filter type	Flow rate
Diatomaceous earth	1 – 2 US gpm (0.065 – 0.126 L/s)
Rapid sand	3 - 5 US gpm (0.189 - 0.315 L/s)
High-rate sand	15 – 20 US gpm (0.945 – 1.26 L/s)
Fabric cartridge	0.5 - 1 US gpm (0.031 - 0.063 L/s)

Pool filters are classified according to their filter media. Flow rate differs for each type of filter media and is measured in US gpm per square foot of filter area.

Turnover Time and Filter Sizing

Turnover Time Definition

Turnover time is the length of time (in hours) required to circulate all the water in the pool once through the filter.

Determining Filter Size

Filter manufacturer's catalogues usually specify filter sizes based on the relationship between pool capacity and turnover time, calculated as follows:

1. Filter rate = pool capacity (US gal) ÷ (turnover time × 60)
   = pool capacity (Liters) ÷ (turnover time × 3600)
2. Filter area = filter rate ÷ flow rate
3. From the manufacturer's catalogue, select the size and number of filters required to match the filter area.

Cleaning and Winterizing

Regular Maintenance

Regular cleaning of heat exchanger tubes and preparation of the pool equipment for winter are important pool heater maintenance and service items.

Heat Exchanger Vulnerability

The inside surfaces of a pool heater's heat exchanger tubes are vulnerable to scale accumulation. Soot from incomplete combustion and corrosion products can accumulate on the exterior surfaces of the tubes.

Cleaning Heat Exchanger Tubes

Exterior Cleaning

In most cases, you can remove soot and corrosion on the exterior surfaces of heat exchanger tubes using a wire brush. You may also use a high-velocity water spray if the heat exchanger is removed from the heater. Using water for cleaning with the heat exchanger in place may damage the combustion chamber and heater insulation.

Interior Cleaning Methods

You can clean the inside surfaces of heat exchanger tubes in two ways:

- Acid cleaning
- Reaming

Safety Precautions for Cleaning

Safety Requirements

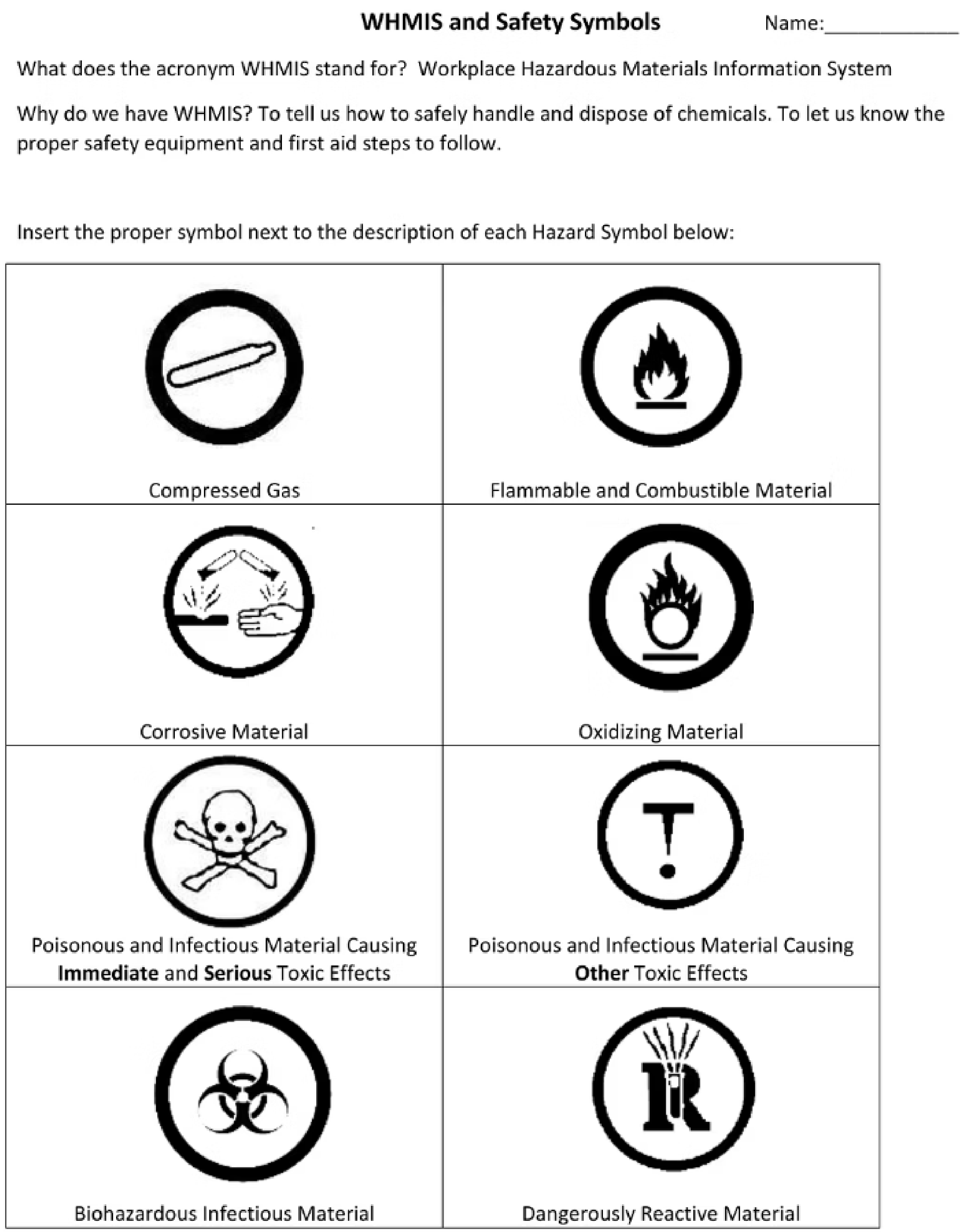
Technicians/fitters must always follow proper WHMIS/WHMIS 2015 and other recommended procedures and use the prescribed protective clothing and safety equipment when performing cleaning operations.

Personal Safety

In Unit 1 Safety, Chapter 1. On-the-job safety measures details information on personal safety and personal protective equipment (PPE).

Hazardous Materials

Chapter 3. Hazardous materials covers information on handling hazardous products.



WHMIS and Safety Symbols Name:____________

What does the acronym WHMIS stand for? Workplace Hazardous Materials Information System

Why do we have WHMIS? To tell us how to safely handle and dispose of chemicals. To let us know the proper safety equipment and first aid steps to follow.

Insert the proper symbol next to the description of each Hazard Symbol below:

Compressed Gas	Flammable and Combustible Material
Corrosive Material	Oxidizing Material
Poisonous and Infectious Material Causing **Immediate** and **Serious** Toxic Effects	Poisonous and Infectious Material Causing **Other** Toxic Effects
Biohazardous Infectious Material	Dangerously Reactive Material

Acid Cleaning Procedure

Remove Heat Exchanger

Remove the heat exchanger tube assembly from the heater in accordance with the manufacturer's instructions.

Prepare Acid Solution

Immerse the tube assembly in a solution of three parts water to one part muriatic acid.

Monitor Cleaning Process

Observe the action of the acid solution on the tube assembly. When the tubes appear to be clean, remove the assembly from the acid solution.

Rinse Thoroughly

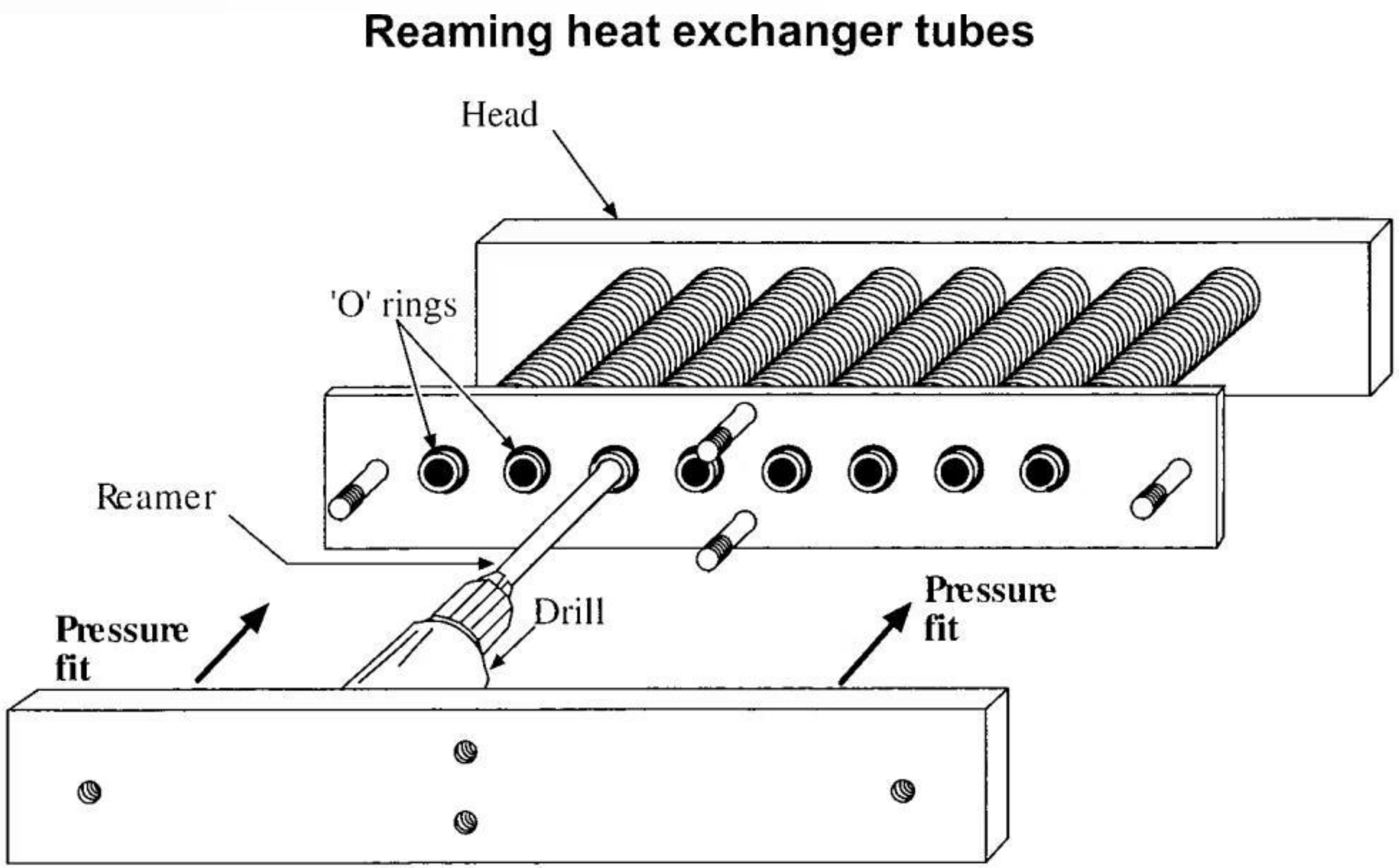
Thoroughly rinse the assembly with a soda-ash solution, then with clean water.

Dry and Protect

Let the assembly dry thoroughly and then apply heat-resistant, rust-inhibiting paint in accordance with manufacturer's instructions.

Reassemble the heat exchanger and heater. Dispose of the acid and soda-ash solutions in accordance with WHMIS/WHMIS 2015 and applicable environmental regulations.

Reaming Procedure



Remove Heat Exchanger

Remove the heat exchanger tube assembly from the heater in accordance with the manufacturer's instructions.

Dry Thoroughly

Thoroughly dry the heat exchanger -- this makes the tubes easier to ream out.

Select Proper Reamer

Measure the inside diameter of the tubes and select a carbide-tipped reamer of the same diameter.

Ream Tubes

Ream the inside of the tubes, removing the reamer frequently to clear powdered scale and debris and prevent binding.

Winterizing

Seasonal Preparation

In areas where a pool will not be used during the winter months, it must be winterized.

Winterizing Process

Winterizing generally includes:

- Draining all water from the pool heater, circulation equipment, and piping system
- Removing or weatherproofing of electrical and mechanical equipment that could be damaged by exposure to winter conditions
- Closing off pool and equipment openings to prevent accumulation of debris and provide protection from rain and snow

Draining the System

Open Drain Valves

Open all drain valves.

Remove Drain Plugs

Remove all drain plugs.

Allow Gravity Drainage

Allow as much water as possible to drain from the system by gravity.

Use Compressed Air

Any water left in the system can be blown out by means of compressed air or inert gases.

It is important to ensure that no water is left in the heat exchanger of the pool heater. Even during short periods of freezing temperatures, stagnant water in the exchanger tubes can form ice which will expand and split the tubes.

Freezing Damage Prevention

Freezing Risk

If water can remain in pool equipment and piping during below-freezing conditions, it will freeze and expand, splitting pipes and otherwise damaging the equipment.

Seasonal Startup Caution

Take care when attempting to ignite the burner of a pool heater for the first time in a season. Pool heaters are more dangerous than other types of boilers because spiders may crawl into burner throats and pilot heads and it is difficult to hear the burner gas flowing or the click of the millivolt valve over the sound of the nearby pump.

Troubleshooting Overview

Table 5-1 outlines common pool heater burner and ignition problems and their causes. Understanding these issues and their remedies is essential for proper maintenance and repair of pool heating systems.

Common Problems

- Delayed ignition
- Heater will not operate
- Pilot will not light or remain lit
- Slow heater output
- Heater will not shut off

Diagnostic Approach

When troubleshooting pool heater issues, it's important to systematically check each potential cause before moving to the next. This ensures that the true problem is identified and properly addressed.

Delayed Ignition Issues

Corroded Burner

Due to system fluid leakage - Inspect and repair burner

Accumulated Debris

Around burner assembly - Clean burner area

Blocked Air Flow

Materials stored around heater exterior - Remove materials blocking air flow

Inadequate Gas Flow

To pilot burner or pilot burner misaligned - Inspect and repair

Heater Operation Problems

Heater Will Not Operate

- No gas flow - Turn on gas supply
- Main gas valve turned off - Turn on main gas valve
- Pilot extinguished - Re-light pilot
- No electrical power - Check electrical system, including all electrical controls in series with the gas valve
- Pool water temperature higher than thermostat setting - Adjust setting as necessary
- Pump not operating or has lost its prime - Check pump operation and re-prime as necessary
- Dirty filter - Clean filter

Pilot Will Not Light or Remain Lit

- No gas at pilot burner - Turn on gas supply, clean pilot orifice if dirty
- Weak pilot generator - Replace pilot generator
- Draft extinguishes pilot - Protect pilot from drafts
- Condensation extinguishes pilot - Protect pilot from condensation

Heater Performance Issues

Slow Heater Output

- Soot accumulation in heater - Remove soot as necessary
- Air in system - Bleed air from system
- Filter pump too small - Install larger capacity pump
- Heater too small - Install larger capacity heater
- Limit control set too low - Adjust limit control
- Low pressure in system - Increase system pressure

Heater Will Not Shut Off

- Defective gas valve - Shut off main gas supply
- Short circuit - Check all electrical system wiring, components, and connections for shorts

Heater Cycling Problems

High Limit Switch Set Too Low

Remedy: Adjust high limit setting

Low Water Flow Due to Scaling

Remedy: Clean heat exchanger

Manual Bypass Valve Open Too Far

Remedy: Adjust manual bypass valve

Air Leak in Suction Line

Remedy: Repair leaks as necessary

Incorrect Pressure Switch Setting

Remedy: Adjust pressure setting

Weak Pilot Generator

Remedy: Replace pilot generator

Gas and Combustion Issues

Gas Pressure Problems

Gas pressure too high or too low - Adjust gas pressure

Hot Spots

Hot spot in heater - Check combustion chamber for damage

Air Supply

Insufficient combustion air - Increase air supply

System Noise Issues

Air in System

Remedy: Bleed air from system

Filter Pump Too Large

Remedy: Install smaller pump

Inadequate Piping Support

Remedy: Repair or replace supports

Low Water Pressure or Flow

Remedy: Increase water pressure or flow as required

Pump Coupler Broken

Remedy: Repair or replace coupler

Faulty Pump Impeller or Bearing

Remedy: Repair or replace parts

Soot Accumulation Problems

Gas Flow Issues

Too little or too much gas - Adjust gas flow rate

Draft Conditions

Poor draft conditions - Adjust draft as necessary

Condensation

Condensation on heat exchanger - Protect heat exchanger from effects of condensation

Additional Troubleshooting Issues

Heater Not Properly Levelled

Remedy: Level heater

Insufficient Combustion Air

Remedy: Increase combustion air

Debris on Heat Exchanger

Remedy: Remove debris

Draft Hood Wrong Length

Remedy: Adjust draft hood

Incorrect Burner Assembly

Remedy: Replace burner assembly

Leaking Heat Exchanger

Remedy: Repair or replace heat exchanger