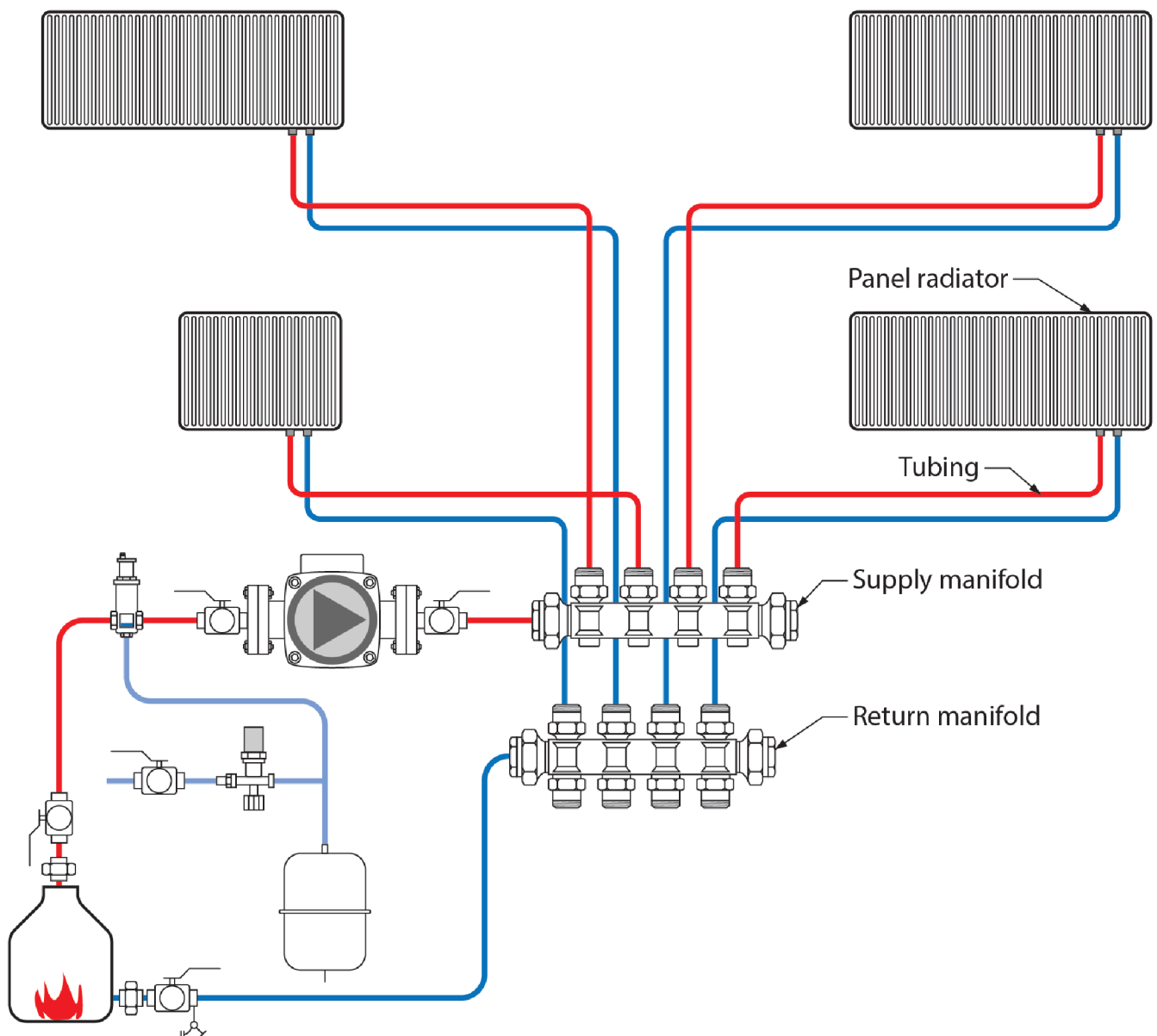


Block B: Heating & Cooling Systems



Block B: Heating & Cooling Systems

BC Plumbing Apprenticeship, Level 2

SKILLED TRADES BC

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

TRU OPEN PRESS
KAMLOOPS



Block B: Heating & Cooling Systems Copyright © 2025 by Skilled Trades BC, TRU Open Press is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License (<https://creativecommons.org/licenses/by-nc-sa/4.0/>), except where otherwise noted.

Original material © SkilledTradesBC, All Rights Reserved. The original material provided by SkilledTradesBC has been adapted and modified with permission. ©COPYRIGHT TRU, 2025. Licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (**CC BY-NC-SA 4.0** (<https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en>)) licence.

This licence allows you to retain, reuse, copy, redistribute, and revise this resource — in whole or in part — for **non-commercial purposes**, provided that the adapted version is released under the same licence and the original creators are properly attributed as follows:

Block B: Heating & Cooling Systems (<https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/>) by SkilledTradesBC, revised by the BC Articulation Curriculum Subcommittee, Rod Lidstone, Audrey Curran, and TRU Open Press, is used under a **CC BY-NC-SA 4.0** (<https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en>) licence. **Download for free at:** <https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/>

Suggested citation (APA style, 7th Edition):

Block B: Skilled Training BC. (2025). Block B: Heating & Cooling Systems (Rev. ed.; adapted by Rod Lidstone, the BC Articulation Curriculum Subcommittee, & TRU Open Press). TRU Open Press, Thompson Rivers University.
<https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/> (<https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/>)

Cover Art Attribution: Skilled Trades BC (2021)

This book was produced with Pressbooks (<https://pressbooks.com>) and rendered with Prince.

Contents

Block B: Heating & Cooling Introduction	vii
Acknowledgments	xi
Accessibility	xvi
B-4 Hydronic Heating Piping and Components	
B-4 Hydronic Heating Piping and Components Introduction	159
B-4.1 Hydronic Distribution System Components	162
B-4.2 Hydronic System Valves	202
B-4.3 Distribution Systems	237
B-4.4 Distribution System Installation	251
Self-Test B-4.1 Hydronic Distribution System Components	269
Answer Key: Self-Test B-4.1	272
Self-Test B-4.2 Hydronic System Valves	273
Answer Key: Self-Test B-4.2	275
Self-Test B-4.3 Distribution Systems	276
Answer Key: Self-Test B-4.3	279
Self-Test B-4.4 Distribution System Installation	280
Answer Key: Self-Test B-4.4	283
Plumbing Apprenticeship & Trade Resources in BC	298
Version History	301

Block B: Heating & Cooling Introduction

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

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

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

Plumbing Apprenticeship Program Level 2 Series

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

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

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

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

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

Block C: Install Fixtures and Appliances

(<https://c-plumbfixappliance-bcplumbingapprlz.pressbooks.tru.ca/>)

C-1: Plumbing Fixtures and Trim

C-2: Plumbing Appliances

Block D: Drainage Systems

(<https://d-drainagesystems-bcplumbingapprlz.pressbooks.tru.ca/>)

D-1: Sanitary Drain, Waste and Vent Systems

D-2: Planning and Installation of DWV Systems

D-3: Storm Drainage Systems

D-4: Test and Drainage Systems

D-5: Drainage System Maintenance and Repairs

Plumbing Apprenticeship Program Overview and Upcoming Resources

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

Disclaimer

The materials in these Learning Guides are intended for use by students and instructional staff. They have been compiled from sources believed to be reliable and to represent the best current opinions on these subjects. These manuals are designed to serve as a starting point for good practices and may not cover all minimum legal standards. No warranty, guarantee, or representation is made by the BC Piping Trades Articulation Committee, the Skilled Trades BC authority, or the King's Printer of British Columbia regarding the accuracy or sufficiency of the information contained in these publications. These manuals aim to provide basic guidelines for piping trades practices. Therefore, do not assume that all necessary warnings and safety precautions are included, and additional measures may be required.

Safety Advisory

The current Standards and Regulation in BC can be obtained at the WorkSafeBC (<http://www.worksafebc.com>) website:
<http://www.worksafebc.com>

Please note that it is always the responsibility of any person using these materials to inform themselves about the Occupational Health and Safety Regulation pertaining to their areas of work.

Symbol Legend



Important Information



Potentially Toxic/ Poisonous Situation



Required or Optional Resources



Potentially Flammable Situation



Complete a Self-Test



Possibly Explosive Situation



Use Protective Equipment



Potential Electric Shock

Acknowledgments

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



The Open Press

The Open Press combines TRU's open platforms and expertise in learning design and open resource development to support the creation and reuse of open educational resources, while encouraging open scholarship and research.

Resource Development Team 2024/2025

Content Review, Revision, and Development: BC Plumbing Articulation Curriculum Subcommittee and Rod Lidstone

Final Content Review and Revisions: Audrey Curran

Project Lead (TRU Plumbing Trades): Paul Simpson, Curriculum Subcommittee Chair

Publishing Manager: Dani Collins, MEd

Copy Editing: Kaitlyn Meyers, BA

Production: Jessica Obando Almache, BCS

- Co-op Students:
 - Greg Vilac
 - Riley Phillips
 - Vansh Sethi
 - Jesse Perkins

Resources

Content adapted from:

- ©2019, Skilled Trades BC (Harmonized)

- Open School BC
- Trades Training BC

Skilled Trades BC website: <https://skilledtradesbc.ca> (<https://skilledtradesbc.ca>)

To order printed copies of Program Outlines or learning resources (where available) for BC Trades, contact:

Crown Publications, Queen's Printer

Web: www.crownpub.bc.ca

Email: crownpub@gov.bc.ca

Toll Free: 1 800 663-6105

The following suppliers have kindly provided copyright permission for selected images throughout these Plumbing Apprenticeship resources:

- Caleffi idronics/ Caleffi S.p.A. (<https://idronics.caleffi.com/>)
- Canadian Standards Association (CSA Group Org) (<https://www.csagroup.org/>)
- Gas Fired Products, GFP INC (Spaceray) (<https://spaceray.com/commercial-industrial-heaters/>)
- International Association of Certified Home Inspectors® (InterNACHI) (<https://www.nachi.org>)
- International Organization for Standardization (<https://www.iso.org/>)
- MHS Radiators (<https://www.mhsradiators.co.uk/>)
- Natural Resources Canada, 2021 (ENERGY STAR) (<https://natural-resources.canada.ca/energy-efficiency/energy-star>)
- NIBCO, Inc. (<http://www.nibco.com>)
- Province of British Columbia (Building and Safety Standards Branch (<http://www.gov.bc.ca/buildingcodes>))
- Rod Lidstone, ERICOL HOLDINGS LTD. (was LIDSTECH HOLDINGS)
- SkilledTradesBC (<https://skilledtradesbc.ca/>)
- Xylem, Inc. (<https://www.xylem.com/en-us/>)
- Greg Wirachowsky [Skilled Trades BC]

Any additional adapted versions of this content would require additional copyright permissions from the rights holders.

Creative Commons and Site License images:

- Comparison of the various temperature scales ([https://commons.wikimedia.org/wiki/File:Temperature_scales_comparison_\(K,R,C,F\).svg](https://commons.wikimedia.org/wiki/File:Temperature_scales_comparison_(K,R,C,F).svg)) is by Stephen Baltakatei Sandoval (2023) via Wikimedia and is used under a CC BY-SA 4.0 (<https://creativecommons.org/licenses/by-sa/4.0/deed.en>) licence.
- Outdoor boiler with baffles visible (https://commons.wikimedia.org/wiki/File:Herscheid_H%C3%BCinghausen_-_Bahnhof_-_MME_20_ies.jpg) by Frank Vincentz via Wikimedia Commons is used under a CC BY-SA 3.0 (<https://creativecommons.org/licenses/by-sa/3.0/deed.en>)
- Water-tube boiler (https://commons.wikimedia.org/wiki/File:Water_tube_boiler-en.svg) by Jooja, via Wikimedia Commons, was previously adapted by Skilled Trades BC (2021), used under a CC BY-SA 4.0 (<https://creativecommons.org/licenses/by-sa/4.0/deed.en>) license.
- Heat Recovery Ventilator (<https://stock.adobe.com/ca/images/heat-recovery-ventilator-as-indoor-hot-air-temperature-usage-outline-diagram-labeled-educational-physical-principle-for-home-ventilation-system-device-for-climate-control-economy-vector-illustration/461693074>) image from VectorMine (2023); found on Adobe Stock and used under the Adobe Stock Standard free trial license (<https://stock.adobe.com/ca/license-terms>).
- Tyresö slott, interiör, detaljer (<https://digitaltmuseum.se/021016859452/tyreso-slott-interior-detaljer>) by Karolina Kristensson, via DigitaltMuseum, is used under a CC BY-NC-ND 4.0 (<https://creativecommons.org/licenses/by-nc-nd/4.0/deed.en>) license.
- Underfloor heating pipes (https://commons.wikimedia.org/wiki/File:Underfloor_heating_pipes.jpg) by H. Raab (User:Vesta), via Wikimedia Commons, is used under a CC BY-SA 3.0 (<https://creativecommons.org/licenses/by-sa/3.0/deed.en>) licence.
- Collector terra radiant i tubs (https://commons.wikimedia.org/wiki/File:Col%C2%B7lector_terra_radiant_i_tubs.JPG) by Chixoy, via Wikimedia Commons, is used under a CC BY-SA 3.0 (<https://creativecommons.org/licenses/by-sa/3.0/deed.en>) liense.
- Tyresö slott, interiör, detaljer (<https://digitaltmuseum.se/021016859452/tyreso-slott-interior-detaljer>) by Karolina Kristensson, via DigitaltMuseum, is used under a CC BY-NC-ND 4.0 (<https://creativecommons.org/licenses/by-nc-nd/4.0/deed.en>) license.

All symbol icons are from the Noun Project and are used under a CC BY license:

- Important by Larea from Noun Project (<https://thenounproject.com/browse/icons/term/important/>) (CC BY 3.0 (<https://creativecommons.org/licenses/by/3.0/deed.en>))
- Skull and Crossbones by Luis Prado from Noun Project (<https://thenounproject.com/browse/icons/term/skull-and-crossbones/>) (CC BY 3.0 (<https://creativecommons.org/licenses/by/3.0/deed.en>))
- Resources by popcornarts from Noun Project (<https://thenounproject.com/browse/icons/term/resources/>) (CC BY 3.0 (<https://creativecommons.org/licenses/by/3.0/deed.en>))
- Flammable by yogi rista from Noun Project (<https://thenounproject.com/browse/icons/term/flammable/>) (CC BY 3.0 (<https://creativecommons.org/licenses/by/3.0/deed.en>))
- Checkbox by ims.icon from Noun Project (<https://thenounproject.com/browse/icons/term/checkbox/>) (CC BY 3.0 (<https://creativecommons.org/licenses/by/3.0/deed.en>))
- Explosive Materials by Ervin Bolat from Noun Project (<https://thenounproject.com/browse/icons/term/explosive-materials/>) (CC BY 3.0 (<https://creativecommons.org/licenses/by/3.0/deed.en>))

- Work gloves by perilous graphic from Noun Project (<https://thenounproject.com/browse/icons/term/work-gloves/>) (CC BY 3.0 (<https://creativecommons.org/licenses/by/3.0/deed.en>))
- Danger by Alice Design from Noun Project (<https://thenounproject.com/browse/icons/term/danger/>) (CC BY 3.0 (<https://creativecommons.org/licenses/by/3.0/deed.en>))
- Electricity by Alice Design from Noun Project (<https://thenounproject.com/browse/icons/term/electricity/>) (CC BY 3.0 (<https://creativecommons.org/licenses/by/3.0/deed.en>))



TRU Wolves (<https://www.flickr.com/photos/thompsonrivers/52667199689/>) (Thompson Rivers University/Flickr) CC BY-NC-SA 2.0 (<https://creativecommons.org/licenses/by-nc-sa/2.0/>)

Land Acknowledgement

Thompson Rivers University (TRU) campuses are situated on the ancestral lands of the Tk'emlúps te Secwépemc and the T'exelc within Secwepemcúl'ecw, the ancestral and unceded territory of the Secwépemc. The rich tapestry of this land also encompasses the territories of the St'át'imc, Nlaka'pamux, Tšilhqot'in, Nuxalk, and Dakelh. Recognizing the deep histories and ongoing presence of these Indigenous peoples, we express gratitude for the wisdom held by this land. TRU is dedicated to fostering an inclusive and respectful environment, valuing education as a shared journey. TRU Open Press, inspired by collaborative learning on this land, upholds open principles and accessible education, nurturing respectful, reciprocal relationships through the shared exchange of knowledge across generations and communities.

If you are using a printed copy, you can scan the QR code with your digital device to go directly to the video: Introducing SkilledTradesBC (<https://www.youtube.com/watch?v=OQgwdP0rNog>)



Starting December 1, 2022, Industry Training Authority was officially renamed to SkilledTradesBC. Hear more in this video from SkilledTradesBC CEO, Shelley Gray, on what this means for the trades industry and British Columbians. Closed captioning and transcripts are available with this video, Introducing Skilled Trades BC (<https://www.youtube.com/watch?v=OQgwdP0rNog>) (2022) on YouTube.



One or more interactive elements has been excluded from this version of the text. You can view them online here: [#oembed-1](https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=23#oembed-1) (#oembed-1)

References

- Skilled Trades BC. (2021). Book 1: Fuel gas systems, Heating and cooling Systems. Plumber apprenticeship program level 2 book 1 Harmonized. Crown Publications: King's Printer for British Columbia.
- SkilledTradesBC. (2022, December 1). Introducing Skilled Trades BC. YouTube. <https://www.youtube.com/watch?v=OQgwdP0rNog>
- Trades Training BC. (2021). A-1: Introduction to gas-fired appliances. In: *Plumber Apprenticeship Program: Level 2*. Industry Training Authority, BC.

Accessibility

The web version of Block B: Heating & Cooling Systems (<https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/>) has been designed to meet Web Content Accessibility Guidelines 2.0 (<https://www.w3.org/TR/WCAG20/>), level AA. In addition, it follows all guidelines in Appendix A: Checklist for Accessibility (<https://opentextbc.ca/accessibilitytoolkit/back-matter/appendix-checklist-for-accessibility-toolkit/>) of the Accessibility Toolkit – 2nd Edition (<https://opentextbc.ca/accessibilitytoolkit/>).

Includes:

- **Easy navigation.** This resource has a linked table of contents and uses headings in each chapter to make navigation easy.
- **Accessible videos.** All videos in this resource have captions.
- **Accessible images.** All images in this resource that convey information have alternative text. Images that are decorative have empty alternative text.
- **Accessible links.** All links use descriptive link text.

Accessibility Checklist

Element	Requirements	Pass
Headings	Content is organized under headings and subheadings that are used sequentially.	Yes
Images	Images that convey information include alternative text descriptions. These descriptions are provided in the alt text field, in the surrounding text, or linked to as a long description.	Yes
Images	Images and text do not rely on colour to convey information.	Yes
Images	Images that are purely decorative or are already described in the surrounding text contain empty alternative text descriptions. (Descriptive text is unnecessary if the image doesn't convey contextual content information.)	Yes
Tables	Tables include row and/or column headers with the correct scope assigned.	Yes
Tables	Tables include a title or caption.	Yes
Tables	Tables do not have merged or split cells.	Yes
Tables	Tables have adequate cell padding.	Yes
Links	The link text describes the destination of the link.	Yes
Links	Links do not open new windows or tabs. If they do, a textual reference is included in the link text.	Yes
Links	Links to files include the file type in the link text.	Yes
Video	All videos include high-quality (i.e., not machine generated) captions of all speech content and relevant non-speech content.	Yes
Video	All videos with contextual visuals (graphs, charts, etc.) are described audibly in the video.	Yes
H5P	All H5P activities have been tested for accessibility by the H5P team and have passed their testing.	Yes
H5P	All H5P activities that include images, videos, and/or audio content meet the accessibility requirements for those media types.	Yes
Font	Font size is 12 point or higher for body text.	Yes
Font	Font size is 9 point for footnotes or endnotes.	Yes
Font	Font size can be zoomed to 200% in the webbook or eBook formats.	Yes
Mobile Check	Layout displays properly on smaller screen sizes and is mobile-friendly.	

(Accessibility Table originally created by the Rebus Community (<https://press.rebus.community/the-rebus-guide-to-publishing-open-textbooks/back-matter/accessibility-assessment/>) and shared under a CC BY 4.0 License) (<https://creativecommons.org/licenses/by/4.0/>).

Known Accessibility Issues and Areas for Improvement

- Images in H5P self-tests lack alt text, attributions, and licenses to avoid revealing answers.
- Some tables may use merged cells, but they have been structured to work properly with screen readers and there may be long descriptions included in each section if readers prefer to see the table data in a bulleted list.
- These videos do not have edited captions (auto-generated):
 - Introducing SkilledTradesBC (<https://www.youtube.com/watch?v=OQgwdP0rNog>) by Skilled Trades BC (2022)
 - How Rinnai I-Series Boilers Work (<https://www.youtube.com/watch?v=TvCc3noYin4>) by Rinnai America Corporation (2021)

Adapted from the Accessibility Toolkit – 2nd Edition (<https://opentextbc.ca/accessibilitytoolkit/>) by BCcampus, licensed under CC-BY (<https://creativecommons.org/licenses/by/4.0/>).

Other Formats Available

In addition to the web version, this book is available in a number of file formats, including PDF, EPUB (for eReaders), and various editable files. The Digital PDF has passed the Adobe Accessibility Check.

Are you having an issue accessing this resource?

If you have problems accessing this resource, or if you have an idea for how to make this resource more accessible, please contact us to let us know!

Please include the following information:

- The name of the resource
- The location of the problem by providing a web address or page description.
- A description of the problem
- The computer, software, browser, and any assistive technology you are using that can help us diagnose and solve your issue (e.g., Windows 10, Google Chrome (Version 65.0.3325.181), NVDA screen reader)

Contact OpenPress@tru.ca (<mailto:OpenPress@tru.ca>).

B-4 HYDRONIC HEATING PIPING AND COMPONENTS

Plumber Apprenticeship Program – Level 2



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

B-4 Hydronic Heating Piping and Components

Introduction

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

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

Learning Objectives

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

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

Terminology

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

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

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

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

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

B-4.1 Hydronic Distribution System Components

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

Circulating Pumps

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

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

Types of Circulators

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

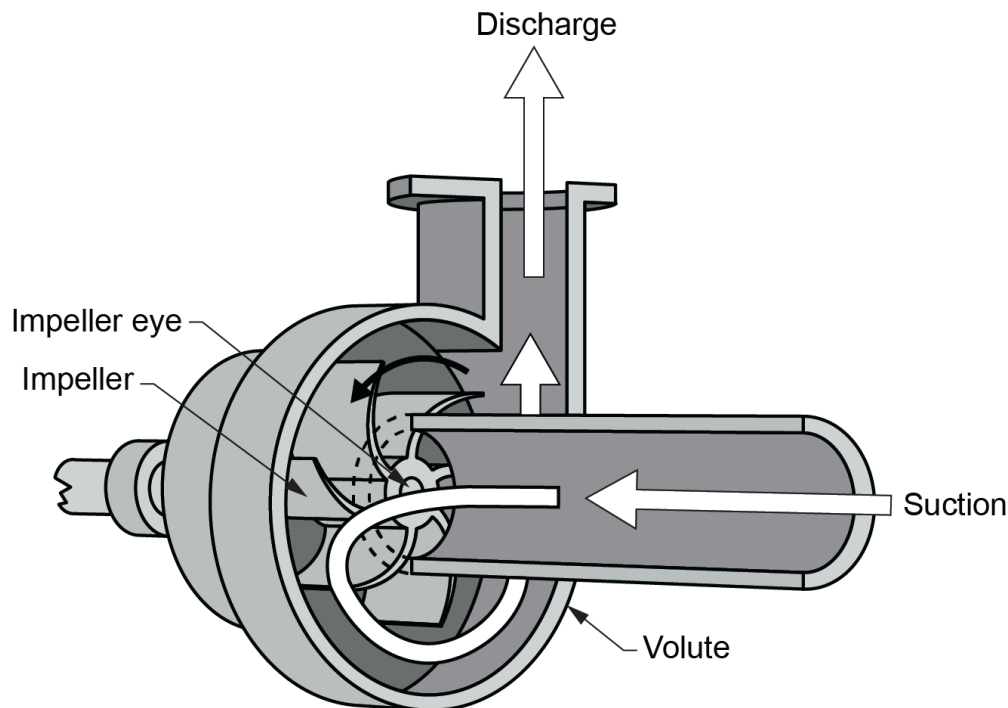


Figure 1 Centrifugal pump showing the impeller eye and the volute. (Skilled Trades BC, 2021) Used with permission.

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

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

Wet-Rotor and Three-Piece Circulators

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

Wet-Rotor Circulators

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

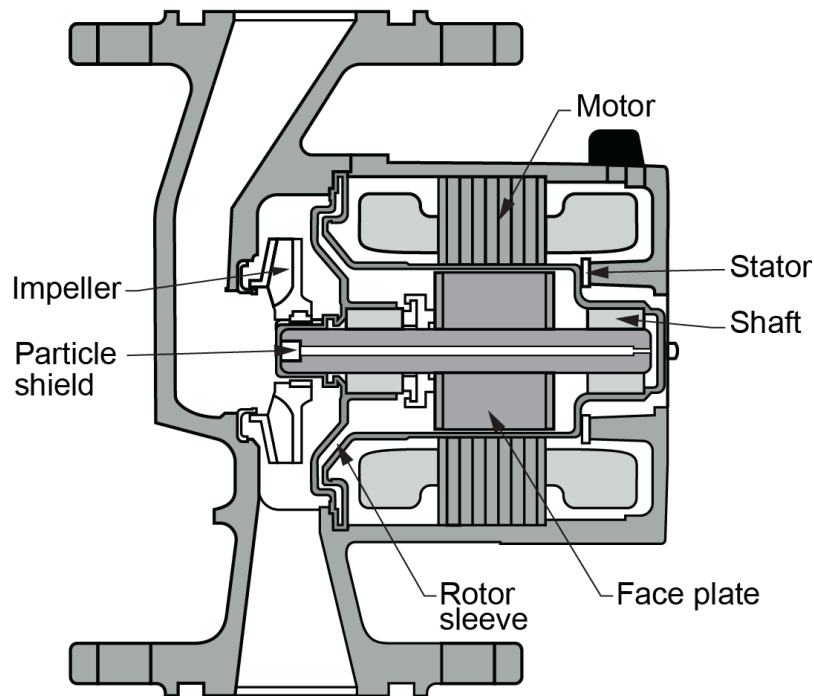


Figure 2 Wet-rotor circulator cutaway. (Skilled Trades BC, 2021) Used with permission.

Dry Rotor Circulators

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

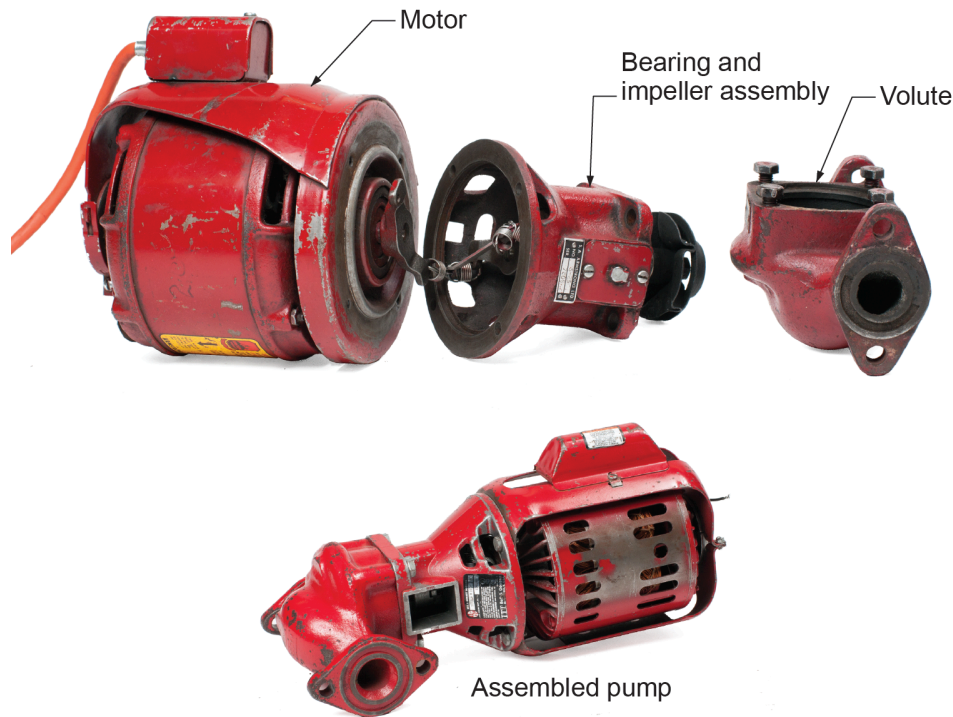


Figure 3 Three-piece circulator. (Skilled Trades BC, 2021) Used with permission.

Pump Location

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

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

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

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

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

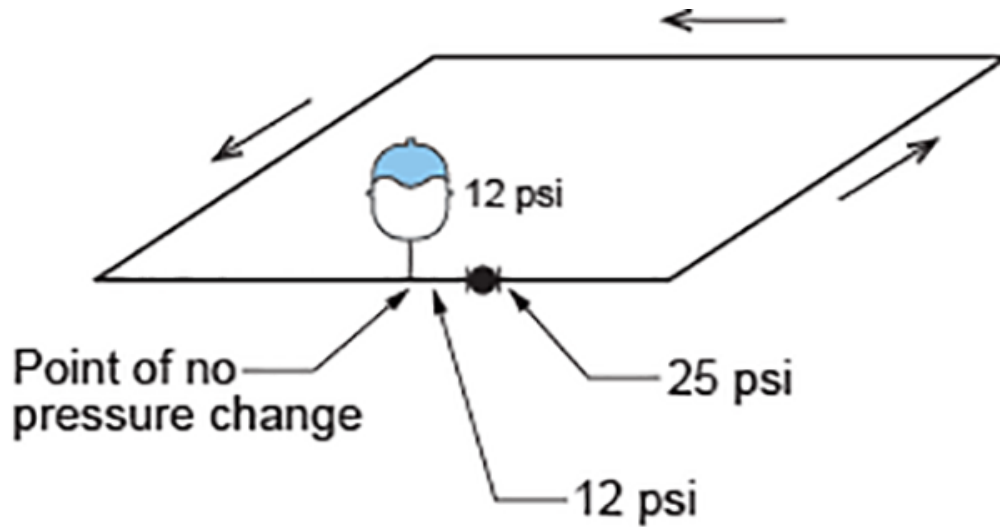


Figure 4 Pump installed downstream of the point of no pressure change. (Skilled Trades BC, 2021) Used with permission.

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

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

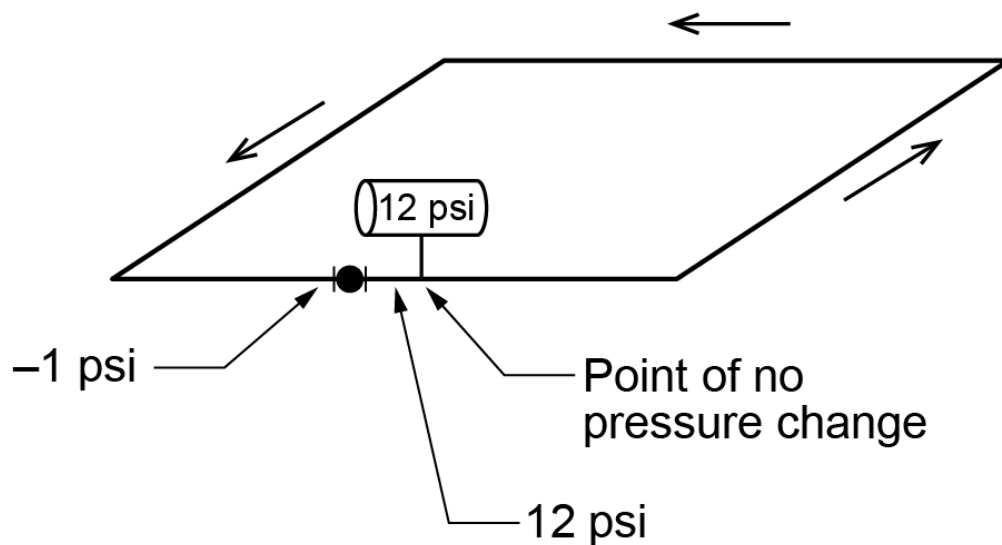


Figure 5 Pump installed upstream of the point of no pressure change. (Skilled Trades BC, 2021) Used with permission.

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

The total pressure at the outlet will therefore be:

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

The total pressure at the inlet will be:

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

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

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

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

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

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

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

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

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

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

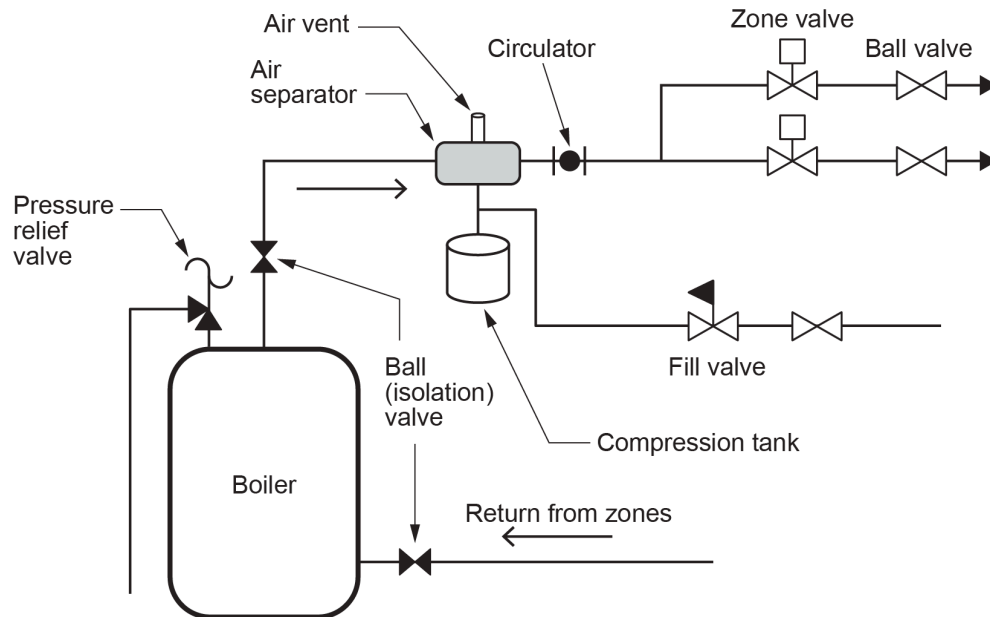


Figure 6a Installation of one pump with respect to other components. (Skilled Trades BC, 2021) Used with permission.

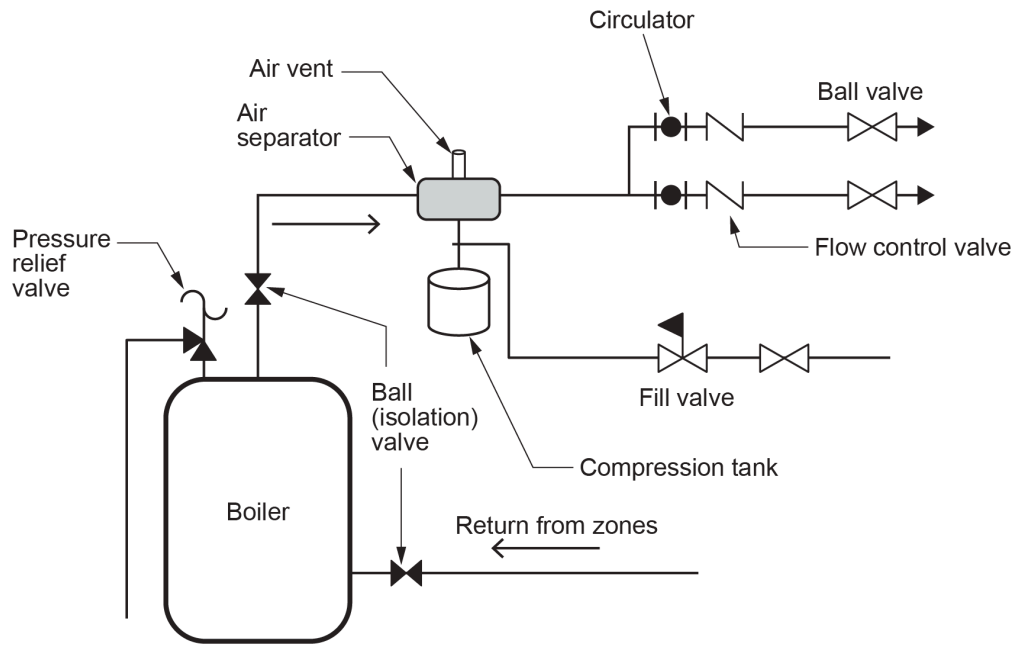


Figure 6b Installation of two pumps with respect to other components. (Skilled Trades BC, 2021) Used with permission.

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

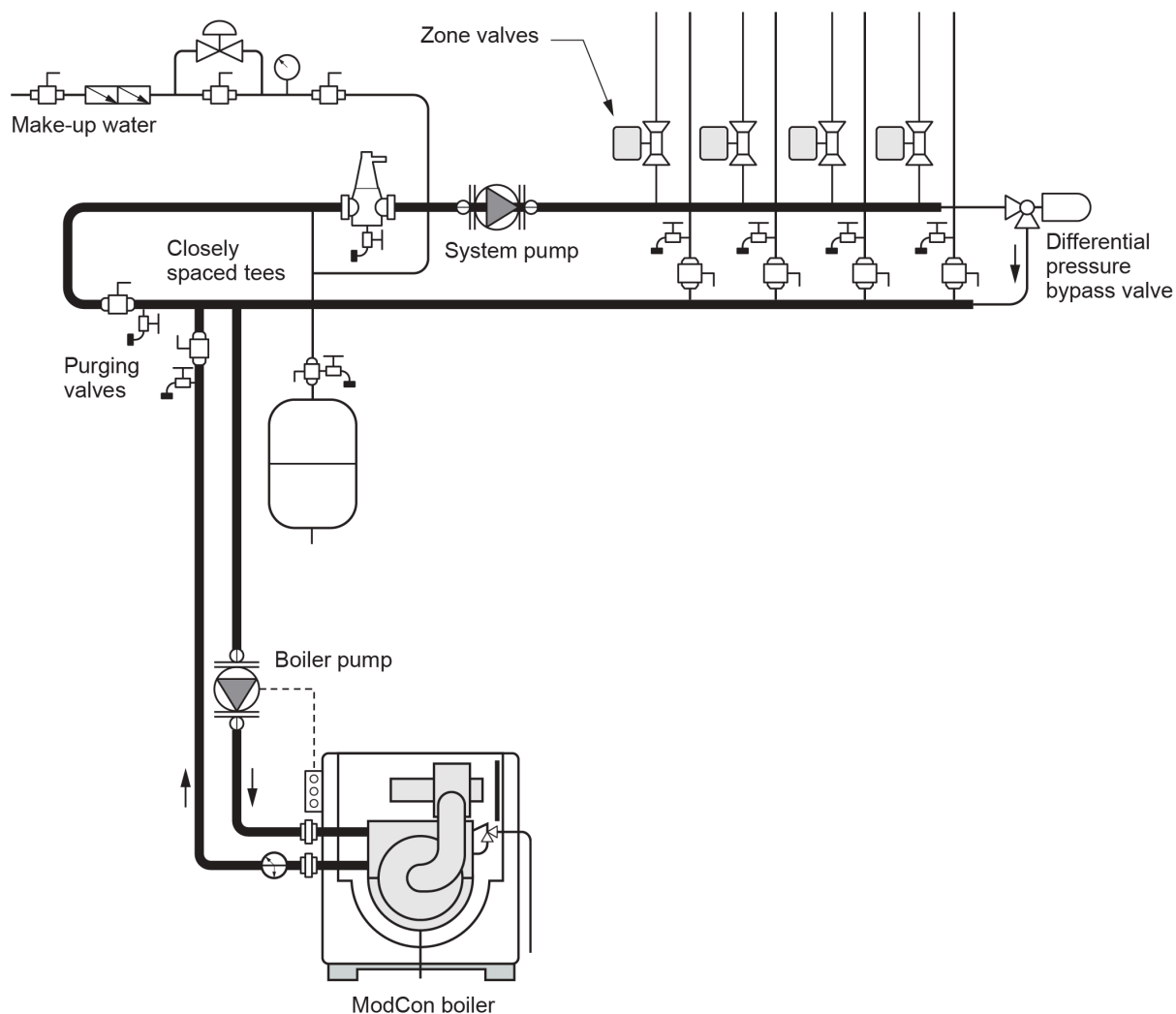


Figure 7 Condensing boiler pump arrangement. (Skilled Trades BC, 2021) Used with permission.

Pump Installation

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

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

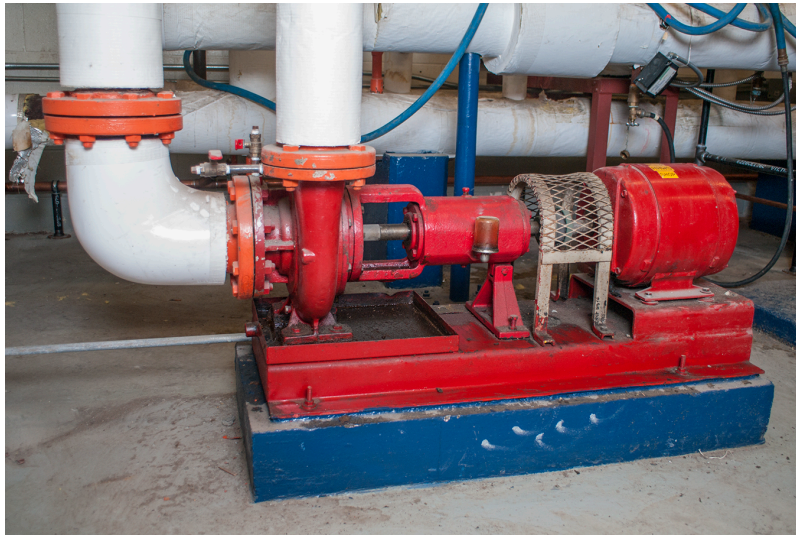


Figure 8 Base-mounted pump. (Skilled Trades BC, 2021) Used with permission.

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

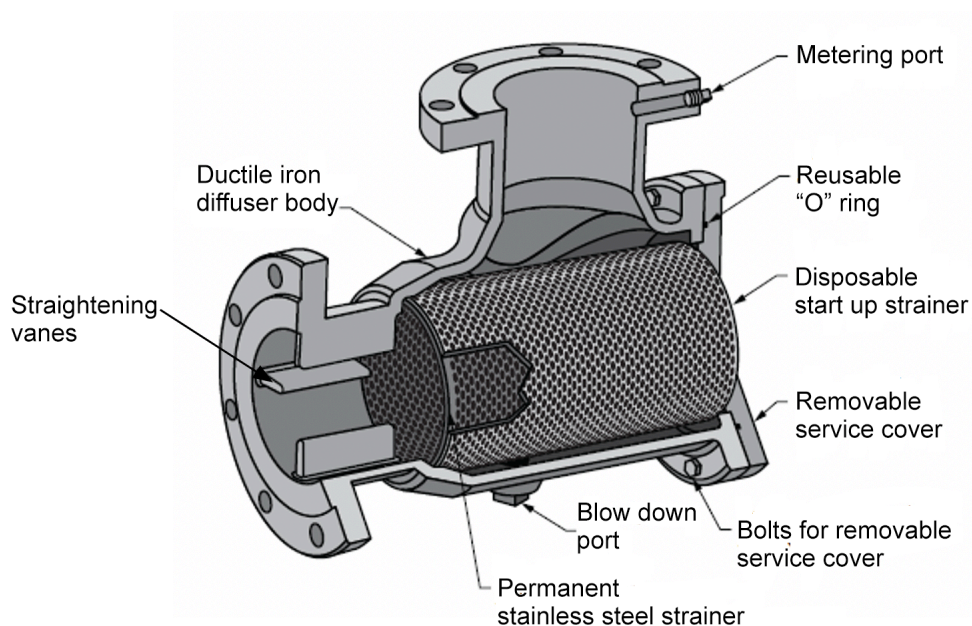


Figure 9 Suction guide for base-mounted pump. (Skilled Trades BC, 2021) Used with permission.

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



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

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

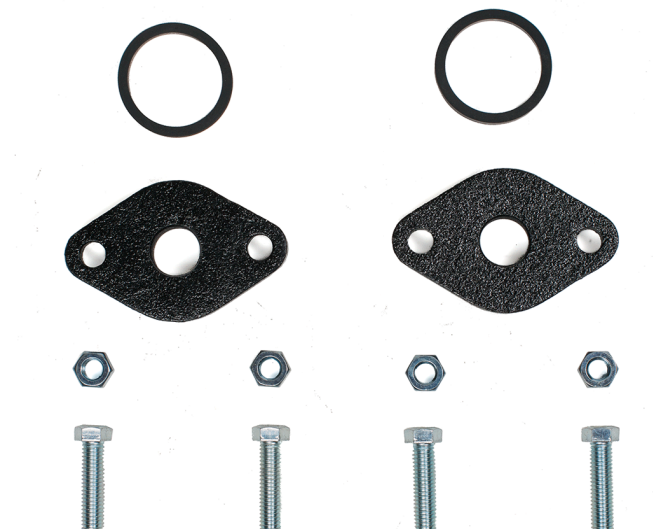


Figure 11 Flange kit. (Skilled Trades BC, 2021) Used with permission.

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



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

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

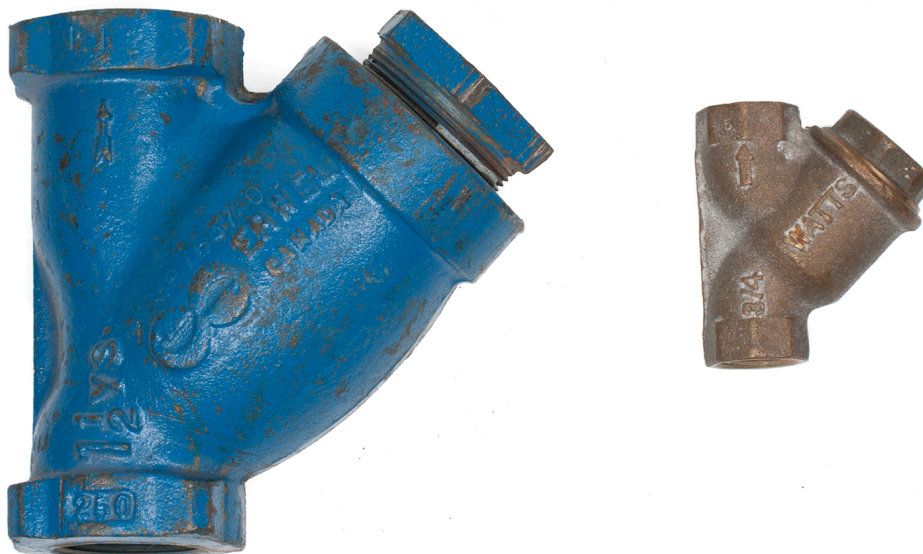


Figure 13 Strainers. (Skilled Trades BC, 2021) Used with permission.

System Pumps in Parallel and Series

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

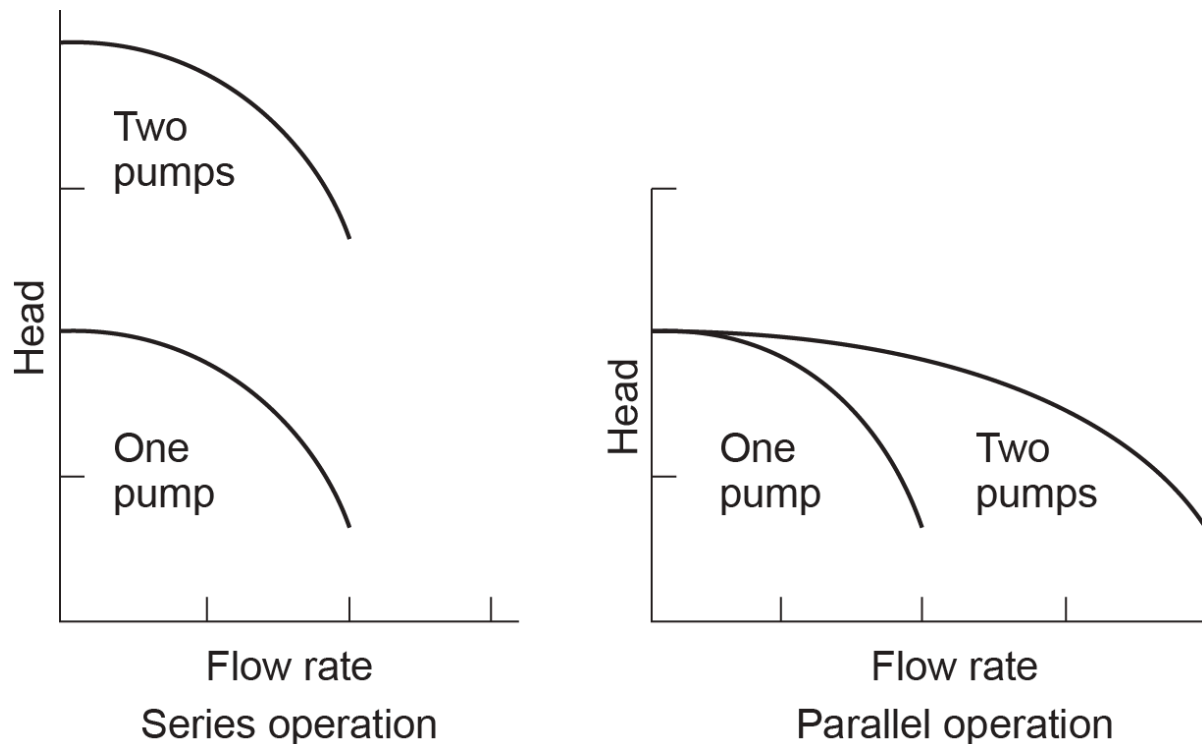


Figure 14 Two pumps in series and in parallel. (Skilled Trades BC, 2021) Used with permission.

Selecting the Pump

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

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

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

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

Determine Temperature Drop and Flow Requirements

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

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

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

Calculate USGPM Flow Rate

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

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

Where:

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

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

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

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

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

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

Determine Head Pressure

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

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

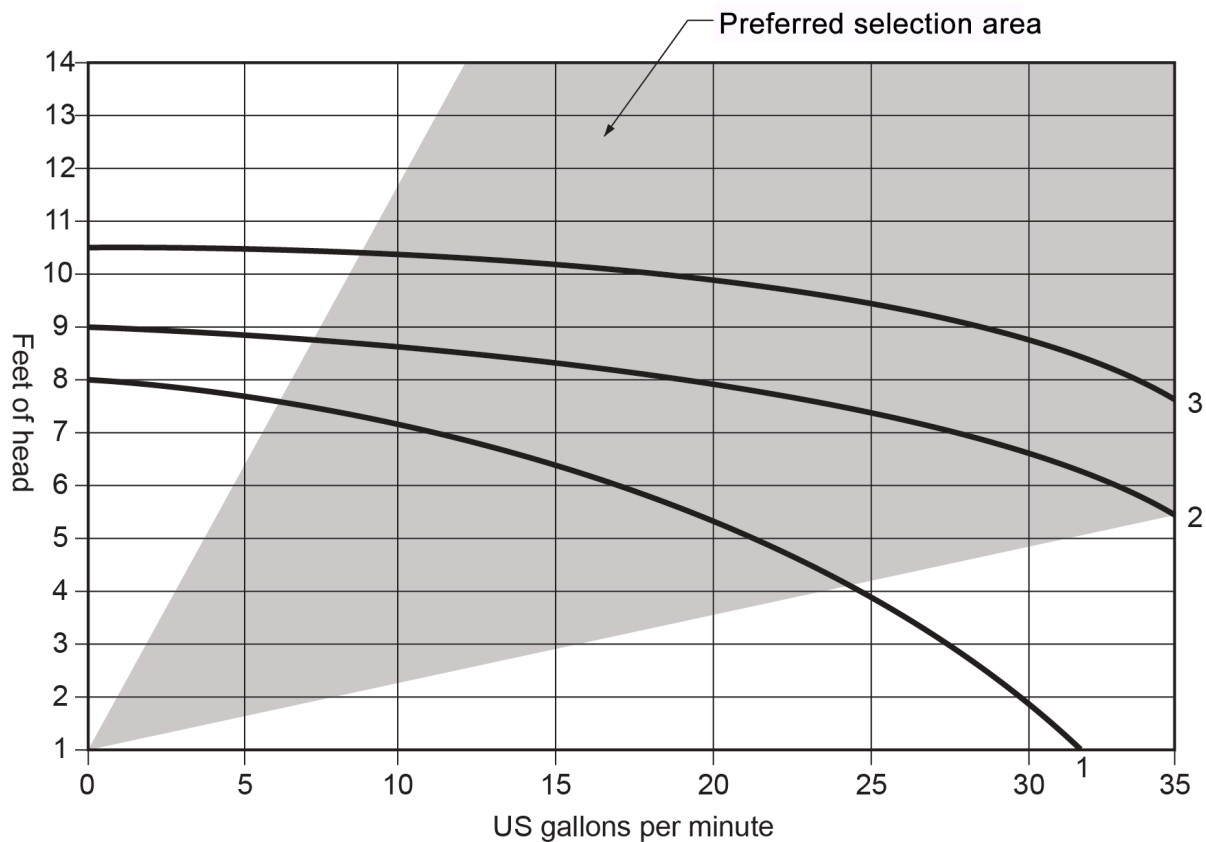


Figure 15 Pump sizing chart. (Skilled Trades BC, 2021) Used with permission.

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

High-Head and Low-Head Pumps

Some circulators are designed to produce relatively high heads at lower flow rates while others produce lower stable heads over a wide range of flow rates. These differences are fixed by the circulator design, particularly the diameter and width of the impeller. The larger the diameter or length of the blades, the higher the pressure; the wider the impeller,

the greater the volume. Impeller speed, measured in revolutions per minute (rpm), is the third factor in determining the capacity and pressure of a circulator.

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

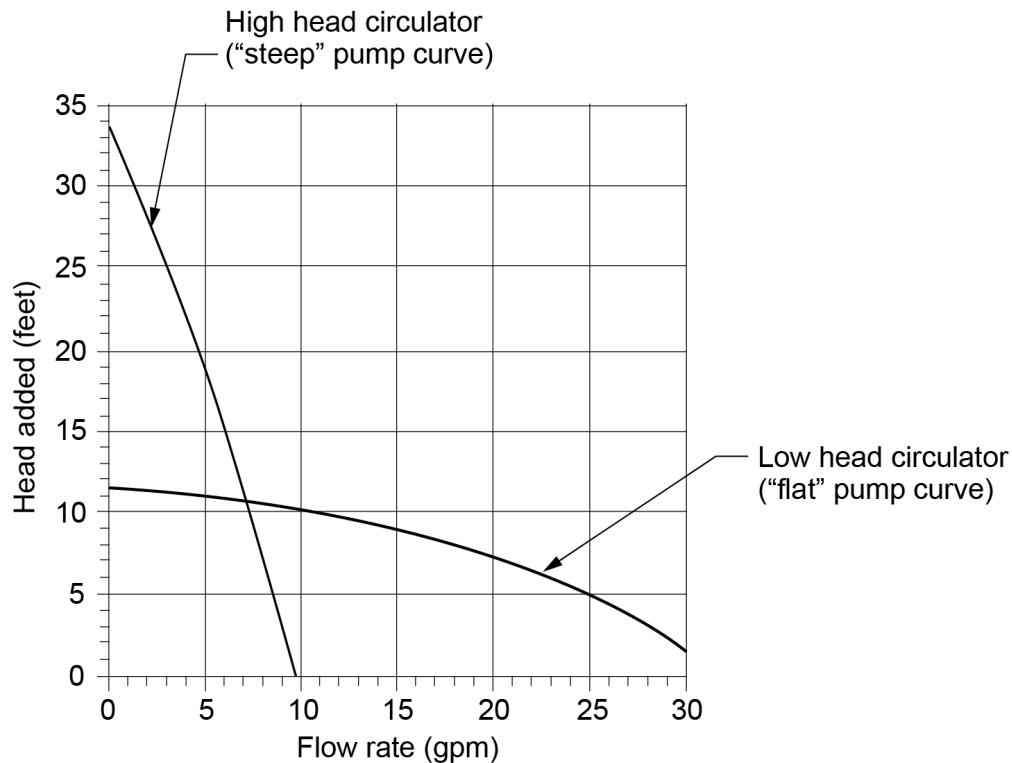


Figure 16 Pump chart. (Skilled Trades BC, 2021) Used with permission.

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

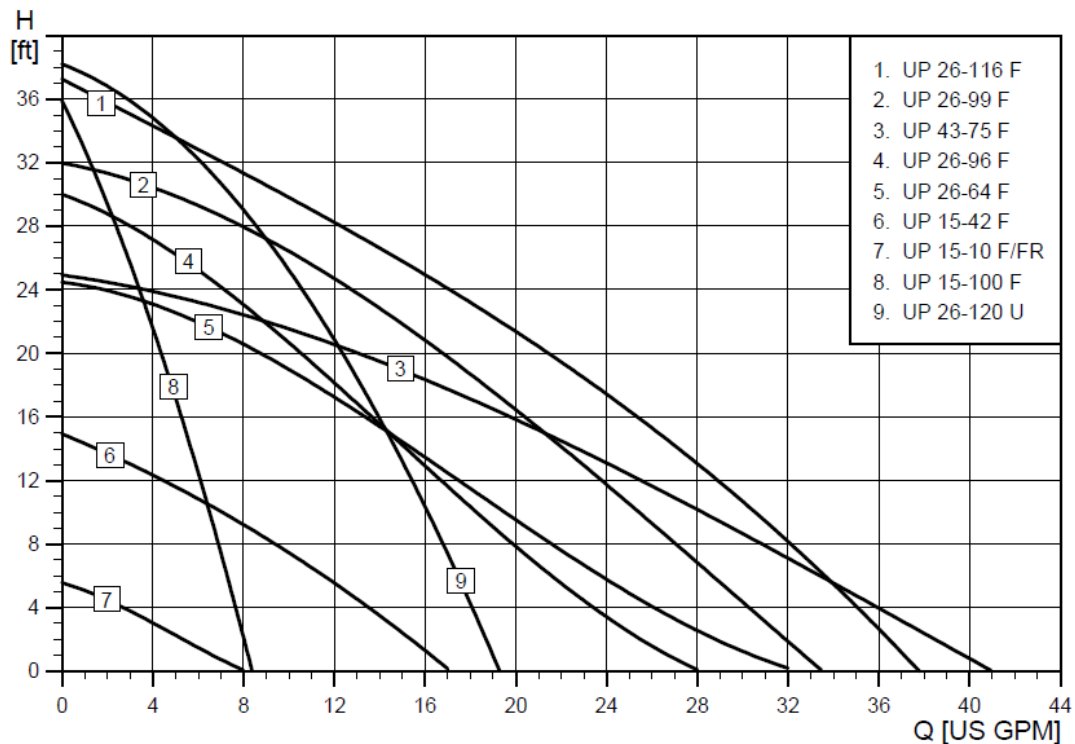


Figure 17 Grundfos UP series cross-reference performance curves. (Grundfos, n.d.) Fair Dealing
<https://laws-lois.justice.gc.ca/eng/acts/c-42/page-6.html#docCont:~:text=Exceptions-,Fair%20Dealing,-Marginal%20note%3A>

Multi Speed Pumps

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

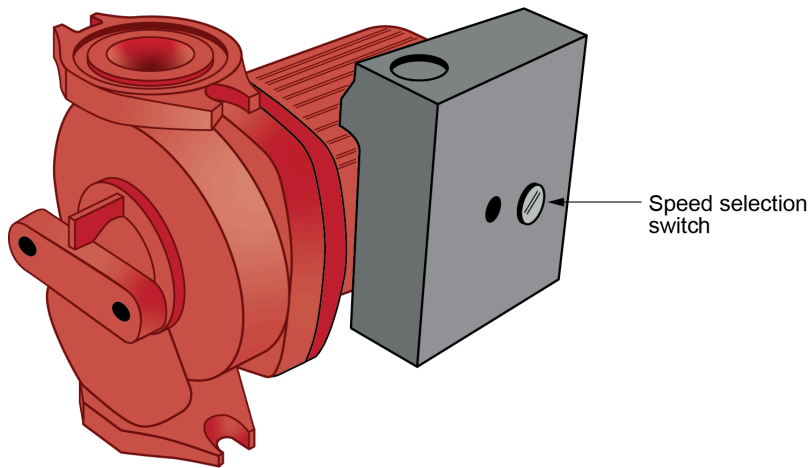


Figure 18 3-Speed circulator. (Skilled Trades BC, 2021) Used with permission.

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

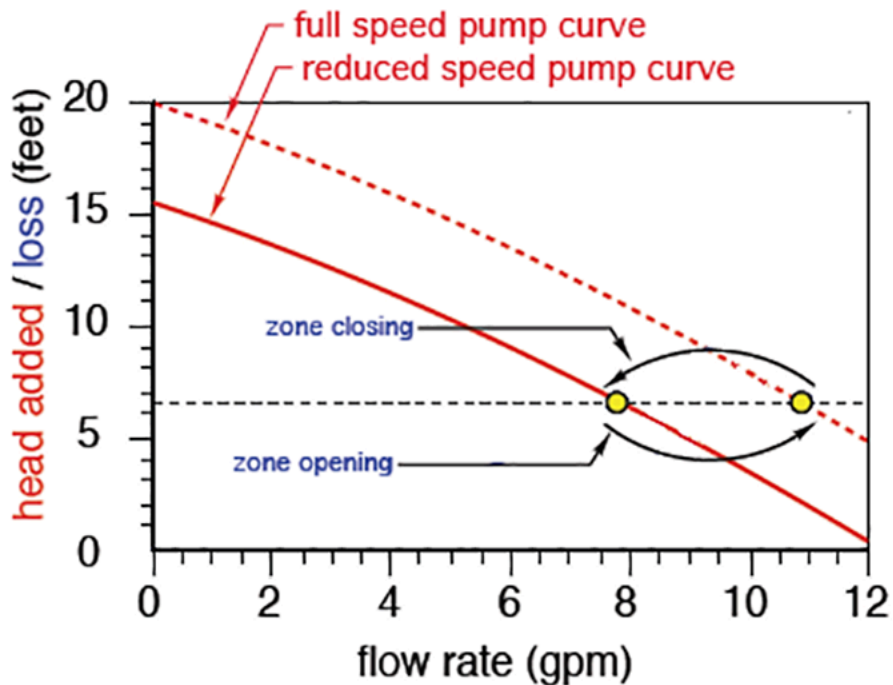


Figure 19 Variable speed circulator maintaining constant pressure. (Image [modified] from Caleffi, idronicsTM, 2015). Caleffi S.p.A. All rights reserved. Used with permission.

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

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

Expansion Tanks

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



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

Calculating Volumetric Thermal Expansion

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

All forms of matter are affected by heat. Expansion of matter occurs in all directions, but, due to the shape of some objects (e.g., pipe), expansion is more profound in its length rather than in its area or volume. The area of a material,

when heated, can increase. The increase in the area of a sheet of aluminum, before being welded, can be calculated and adjustments can be made to minimize warping.

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

On the other hand, if the temperature of that same amount of water is lowered, the molecules' vibrations slow down and they occupy less space, so the water's volume decreases, while its density increases over what it was at the higher temperature. This trend continues down to 4°C (39°F), where the density begins to decrease again. The volume starts to increase because the water molecule (H₂O) is starting to crystallize into ice.

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

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

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

What this means is that, for every 1°C (1°F) increase in temperature of a volume of water, measured in whatever units of volume preferred (m³, ft³, in³, cm³, USG, Imp gal, etc.), the volume will increase by a factor of that unit.

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

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

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

For Celsius or Kelvin:

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

For Fahrenheit or Rankine:

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

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

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

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

If the starting volume of the water was 20 m³, it would occupy 20.3 m³ of space, and so on.

Why the Need for Expansion Tanks?

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

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

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

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

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

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

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

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

Conventional Expansion Tanks

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

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

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

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

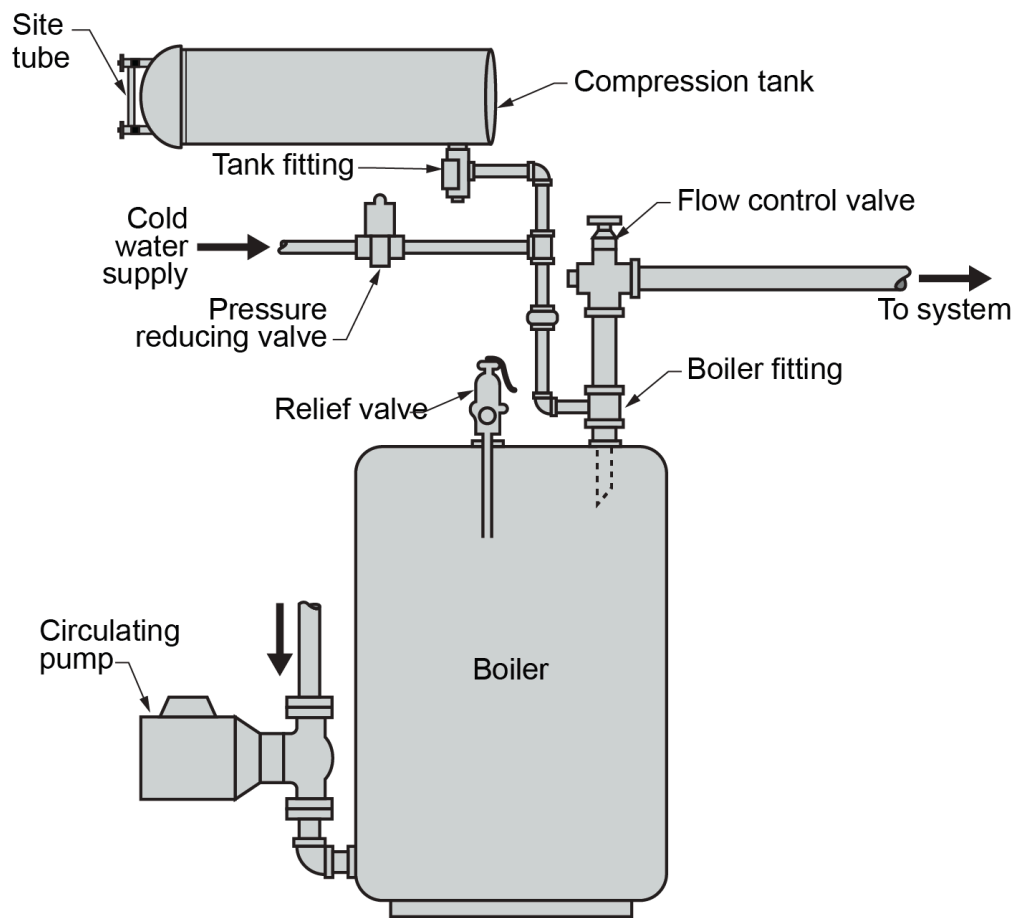


Figure 21 Old-style steel boiler expansion tank. (Skilled Trades BC, 2021) Used with permission.

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

Water also pushed into the expansion tank, a high point on its own, and filled it to approximately $\frac{2}{3}$ to $\frac{3}{4}$ its volume.

The air trapped above the water was compressed to the same pressure. This air was not bled off; it became the “cushion” that accommodated the expanded water volume from the system.

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

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

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

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

Bladder or Diaphragm Tanks

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

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



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

Point of No Pressure Change

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

Selecting Expansion Tanks

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

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

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

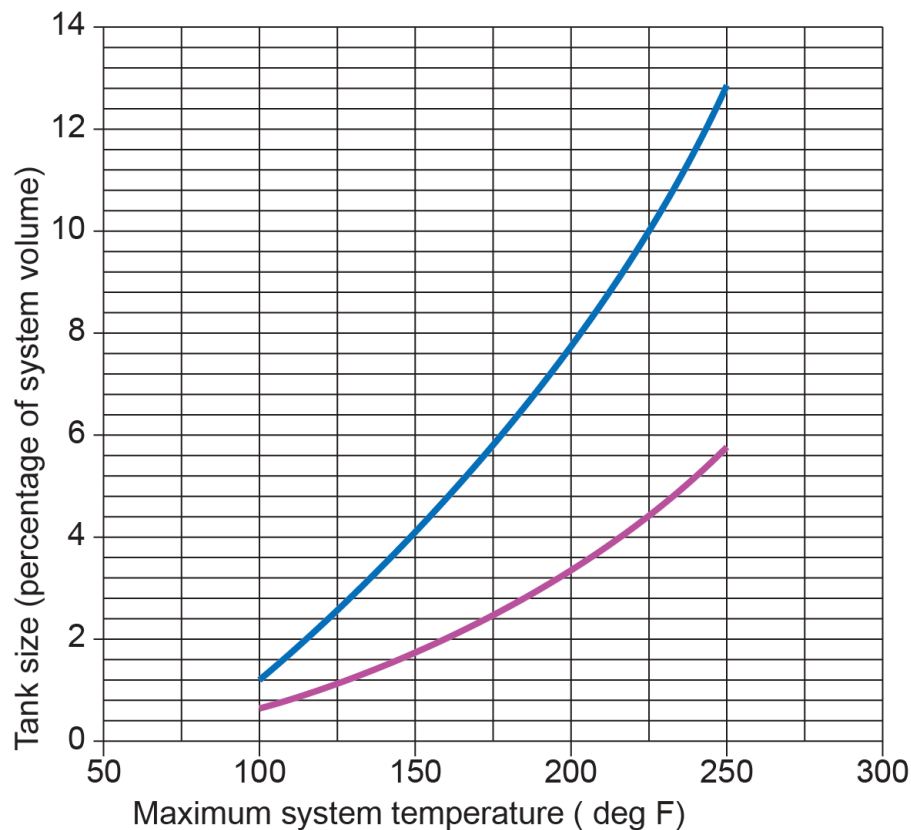


Figure 23 Expansion tank sizing graph. (Skilled Trades BC, 2021) Used with permission.

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

Air Removal

Every hydronics installer will eventually come across the issue of no or very little flow through the system. Although there can be many reasons for this, one of the most common is air trapped within the system. All water contains air in solution, and when that water is heated up, the air slowly separates and collects at high points. These air bubbles move around the system, creating all types of problems. The job of designers and installers is to create a system that is able to remove the air before it becomes a problem.

Problems Created by Entrapped Air

There are several problems that can be traced to excessive air within hydronic heating systems:

- Noisy flow
- Increased corrosion
- Poor or possibly no flow
- Poor heat transfer

- Cavitation leading to circulator damage

For these reasons, air removal must be a priority in system design.

Air Removal Devices

Air removal devices can be categorized by where they are placed in a system.

Because heated air tends to rise, it makes sense to place some type of air vent at the high points in a system. For this reason, these vents are referred to as “high-point vents” or simply “air vents.” Typical locations for such vents are at the top of each heat emitter, at the top of distribution **risers**, or wherever piping turns downward following an upward or horizontal run. High-point vents are particularly useful for removing air immediately after the system has been filled with liquid.

The second type of air removal device is the central air separator. When water passes through a boiler, it is heated, which releases air as bubbles. These air bubbles will then work their way around the piping system until they find somewhere to collect and create issues. A central air separator is located on the supply piping leaving the boiler because air is most easily removed from water wherever it is hottest and slowest.

Manual Air Vents

The simplest type of high-point vent is a manual air vent (Figure 25). As the name implies, the manual air vent requires an operator to both open and close the vent. These vents can sometimes be referred to as coin vents or bleeders. Manual air vents are installed at locations where small amounts of air will have to be eliminated during startup and maintenance, but not where large amounts of air are likely to accumulate during normal operation. The most common location for manual air vents is at the downstream (return) end of heat transfer units. Manual air vents have a needle-type stem with either an insulated hand wheel or simply a slot in the end for a screwdriver or a coin.

Great care must be taken to ensure that these types of vents do not leak after being used because they have been known to leak small, unnoticed amounts of water over long periods; this can cause widespread water damage in wooden buildings.



Figure 24 Manual air vent.(Skilled Trades BC, 2021) Used with permission.

Automatic Air Vents

Automatic air vents open automatically in the presence of air and close automatically in the presence of water. There are automatic disk and automatic float air vents. Automatic air vents should be installed together with isolating valves so that repairs or replacement can occur as required.

An automatic disk air vent (vent valve) contains one or more water-sensitive disks (Figure 26). These disks swell up in the presence of water and shrink in the presence of air. This effect is used to open and close a small valve that automatically releases any enclosed air. Automatic disk air vents are very slow devices, but they do not drip when operating. They can be manually opened to let more air out when you fill the system, and they can readily cope with the small amount of air that is released when water is heated. They can come equipped with a ball check to enable removal and replacement of the air vent while maintaining the liquid within the system.

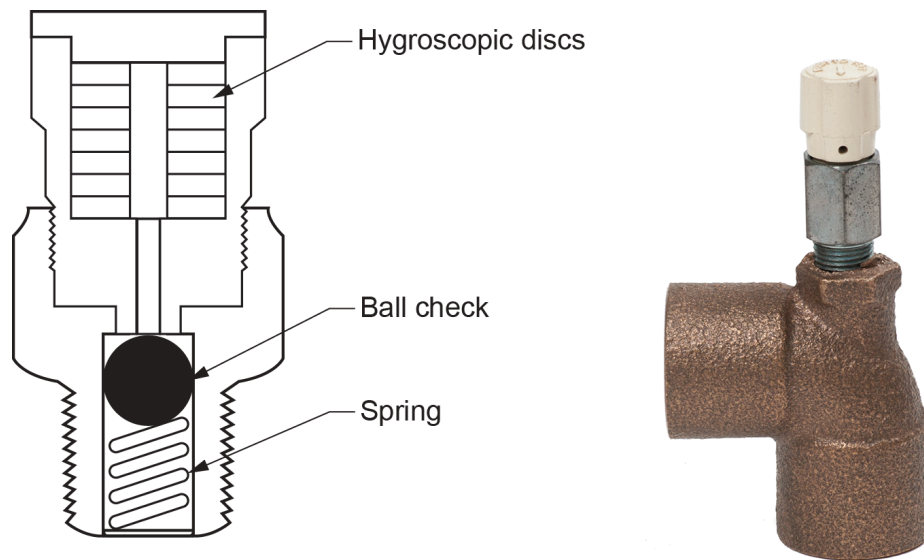


Figure 25 Automatic disk vent. (Skilled Trades BC, 2021) Used with permission.

An automatic float vent (Figure 27) works on the principle of buoyancy. The device contains an air chamber, float, and air valve. The float moves up and down based on the presence of water in the chamber. If there is no water in the chamber, the float will drop down, opening the air valve. This allows the air in the chamber to escape. As the air escapes, water from the hydronic system begins to fill the chamber and lift the float up. This causes the air valve to close. There are times during this process when a small amount of water also escapes, but generally, this is not an issue.

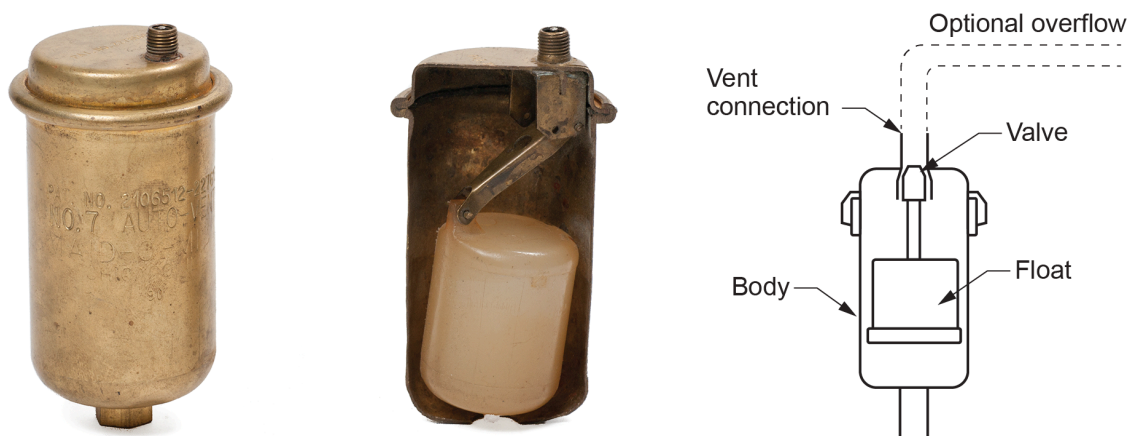


Figure 26 Automatic float vent. (Skilled Trades BC, 2021) Used with permission.

Automatic air vents have a $\frac{1}{8}$ in. threaded connection on the Schrader valve, similar to that found on a car's tire. An adapter and overflow tubing can be connected to the air vent, and any discharge of water during its operation will be directed to a safe location. This is especially helpful in situations where the automatic vent is located high overhead or where it may not be readily visible. The threaded vent connection comes equipped with a threaded cap. It is important to leave the cap partially unscrewed or the air outlet will be sealed. Install these vents in the vertical position, with the vent connection pointing up.

Air Purgers or Air Scoops

Air purgers (also called air separators or air scoops) remove the air in water by separating it from the water and venting it outside the system. An air scoop consists of a one-piece, cast-iron chamber with two passages containing contours and baffles (Figure 28).

As a mixture of water and air flows through these passages, the air is separated and then vented to the atmosphere through an automatic float air vent. Air scoops are installed horizontally on the main as close to the boiler as possible. However, to optimize effectiveness, 18 in. of straight horizontal piping is required on the inlet side to achieve the desired laminar flow. The enlarged cross-sectional area causes a velocity drop through the air scoop that allows more time for entrained air bubbles to float up to the air vent. If a diaphragm compression tank is installed, it may be connected to the bottom of the air scoop.

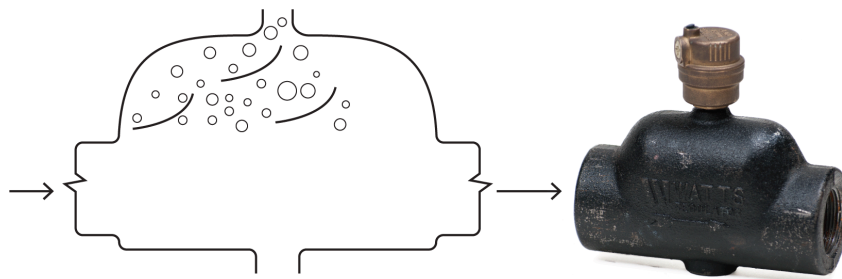


Figure 27 Air scoop and cutaway showing baffles for directing air. (Skilled Trades BC, 2021) Used with permission.

Microbubble Resorbers

Another device similar to an air scoop and serving the same purpose is a **microbubble resorber** (Figure 29). Microbubble resorbers are very effective in removing all types of air from the system. They have many small vertical wires or screens inside that create areas of reduced pressure on their downstream side. The low pressures encourage dissolved air to come out of the solution as microbubbles coalescing and rising along the wires. The microbubbles accumulate in the upper auto air vent and are released from the system. Microbubble resorbers are the preferred choice for air removal devices, especially in situations where there is not enough room to install 18 in. of straight horizontal piping on the inlet side.

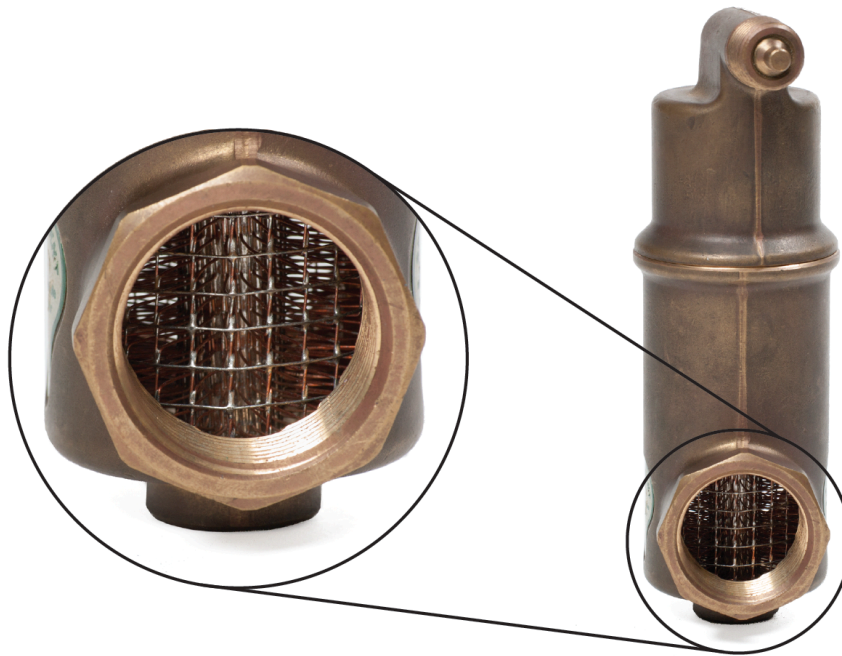


Figure 28 Microbubble resorber. (Trades Training BC, 2021) Used with permission.

Either an air purger or microbubble resorber will be located on the supply piping as it leaves the boiler, where the water is hottest and most easily released from the solution. Figure 30 shows a typical location of an air separator within a system.

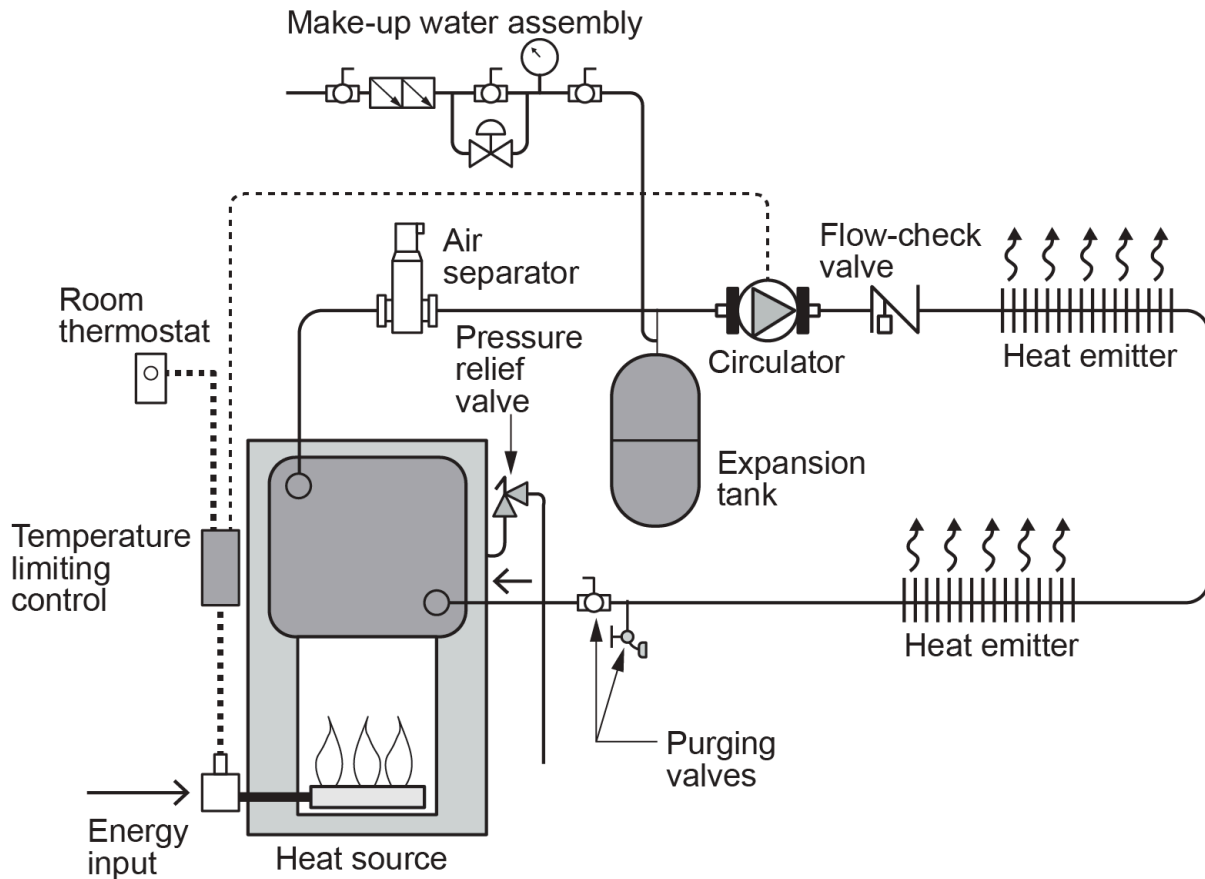


Figure 29 Components of a hydronic heating system. (Skilled Trades BC, 2021) Used with permission.

Water Quality

The ideal water for use in hydronics systems would contain very little physical or chemical contaminants. Treatment for water quality can be divided into two categories:

- Physical water quality
- Chemical water quality

Physical water quality treatment captures and eliminates air and dirt from the system. Chemical water quality modifies or eliminates harmful chemical substances in the system water.

Dirt Removal

The ideal heating or cooling system would be dirt-free. But, in reality, there are many ways that dirt and sediment can get into a hydronic system. The presence of dirt can cause serious problems including:

- Circulator damage

- Reduced heat transfer due to fouled surfaces in heat exchangers
- Increased internal flow erosion
- Blocked sight glasses on flow meters
- Clogging and malfunction of flow meters, zone valves, balancing valves, check valves, vents, and thermostatic radiator valves

There are three common methods of removing dirt and debris from hydronic systems:

- Initial flushing and cleaning
- Basket strainers
- Dirt separators

System Flushing and Chemical Cleaning

An assembled system must be flushed to remove debris, such as solder balls, metal chips and shavings, casting sand, sawdust, drywall dust, insects, paper labels, and dirt, that entered the piping during transportation, storage, or handling on the installation site. Chemical cleaning removes oils and greases from thread cutting oil, soldering flux, or small amounts of machining oil remaining inside system components.

The preferred method for the initial chemical cleaning of the inside of a hydronic system is by circulating a hydronic detergent mixed with hot water through the system. When the cleaning solution has been sufficiently circulated, it is drained from the system, carrying the dissolved oil and grease residue with it.

To perform either initial flushing or chemical cleaning procedures, the system must be equipped with the appropriate valves (Figure 31) to add fluid and remove both air and dirty fluid.

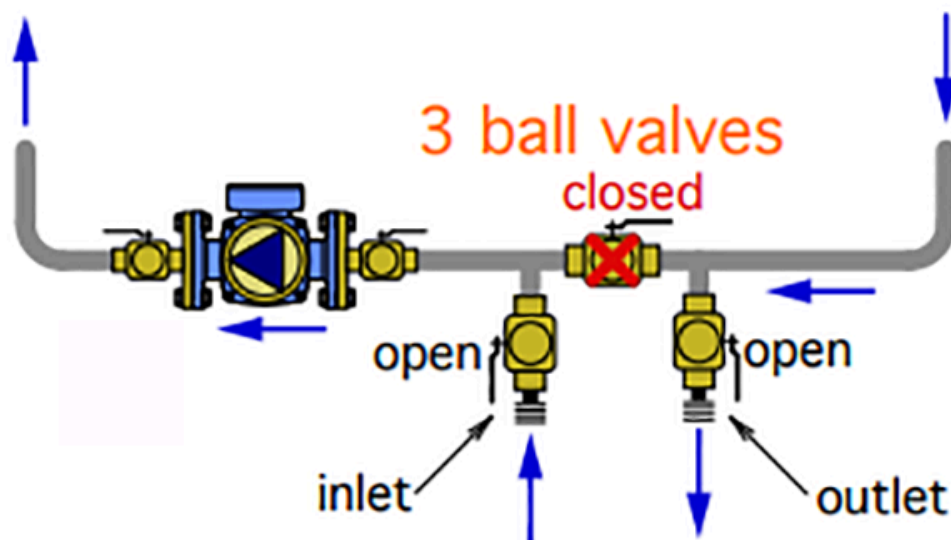


Figure 30 System flushing valve arrangement. (Caleffi, idronics™, 2016). Caleffi S.p.A. All rights reserved. Used with permission.

When possible, purging valves should be located upstream of components such as circulators and heat exchangers.

This minimizes the chance of flushing debris in the piping through these components. After the initial debris flushing, a chemical cleaning solution can be added to systems by use of a flush pump cart connected to the purge valves (Figure 32).

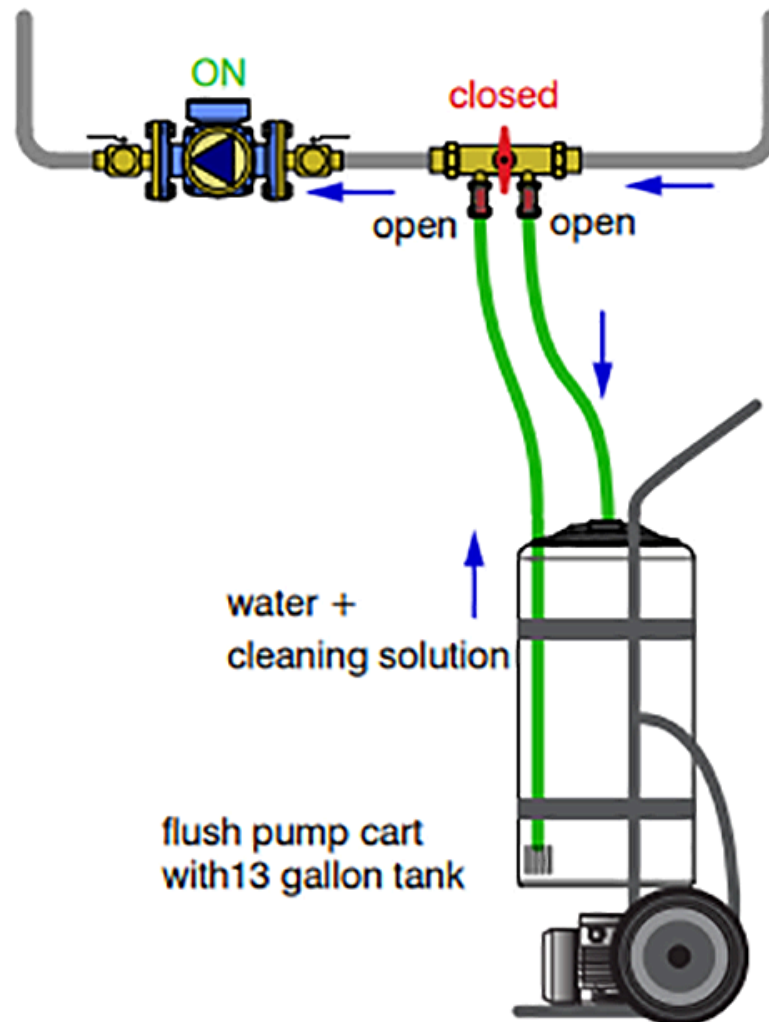


Figure 31 Flush pump cart. (Caleffi, idronicsTM, 2016). Caleffi S.p.A. All rights reserved. Used with permission.

Other methods for performing the initial system purging using the makeup water connection will also be discussed in B-4.2 Hydronic System Valves (#chapter-b-4-2-valves).

Strainers

Basket strainers, also known as Y-strainers (Figure 33), trap dirt within a mesh basket made of stainless steel or brass. A strainer should be installed just upstream of the pump in order to protect the pump. It is important to maintain the strainer so there is not an excessive accumulation of debris on the inside the strainers basket, which will restrict flow. The strainer normally has a tapping with a plug, or a blow-down valve can be installed to allow for easier cleaning. A blowdown is a drain point used to flush out sediment captured in the strainer.

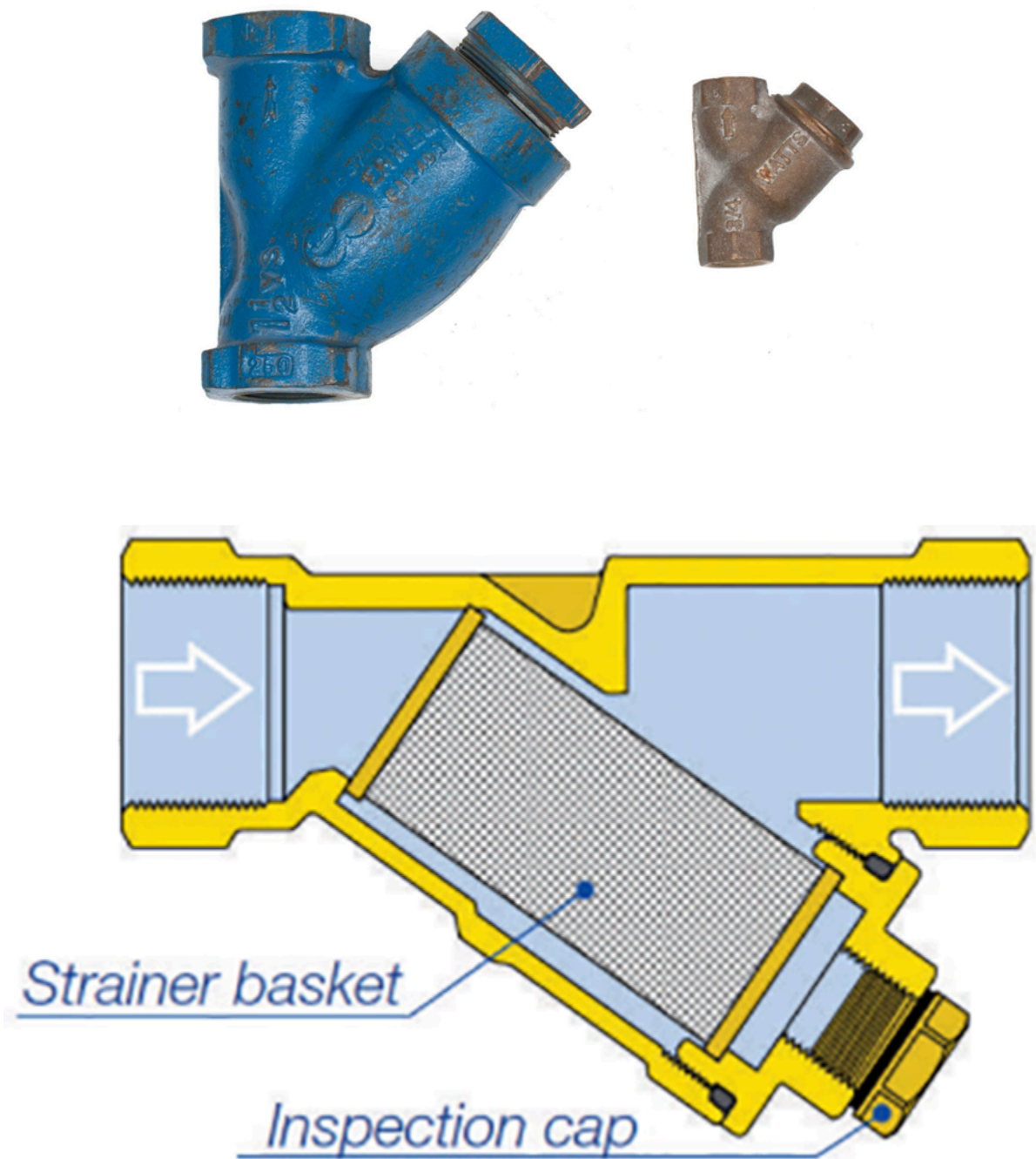


Figure 32 Y-strainer (top: Skilled Trades BC, 2021; bottom: Caleffi, idronicsTM, 2014). Caleffi S.p.A. All rights reserved. Used with permission.

On commercial systems, pressure gauges may be installed to monitor the pressure drop across a basket strainer (Figure 34) and determine when cleaning is needed.

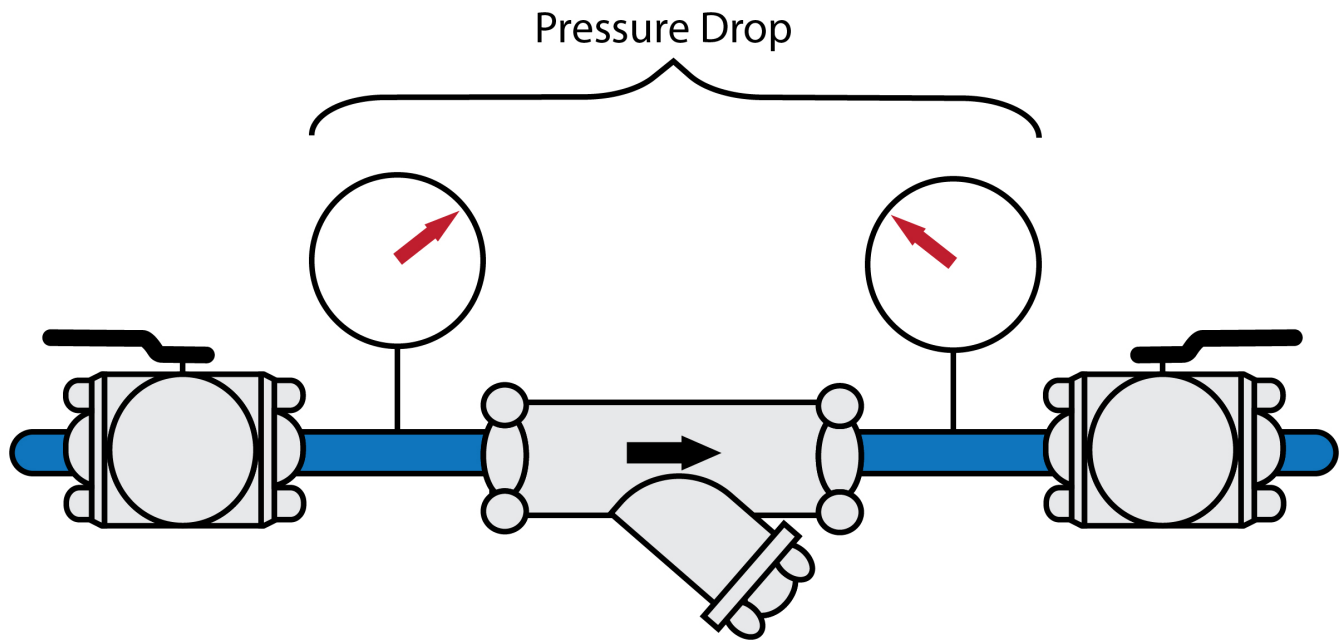


Figure 33 Monitored strainer pressure drop. (Caleffi, idronics™, 2014 [modified]). Caleffi S.p.A. All rights reserved. Used with permission.

Dirt Separators

Many dirt separators are also air vents, as they use the same principle as microbubble resorbers. As the water passes through the low velocity chamber, dirt particles collide with the coalescing media and settle to the bottom chamber. A valve at the bottom of the chamber is used to periodically flush out accumulated particles. Notice that the unit shown in Figure 35 has four pipe connections as it is also a hydraulic separator. The concept of hydraulic separation will be discussed in B-4.3.

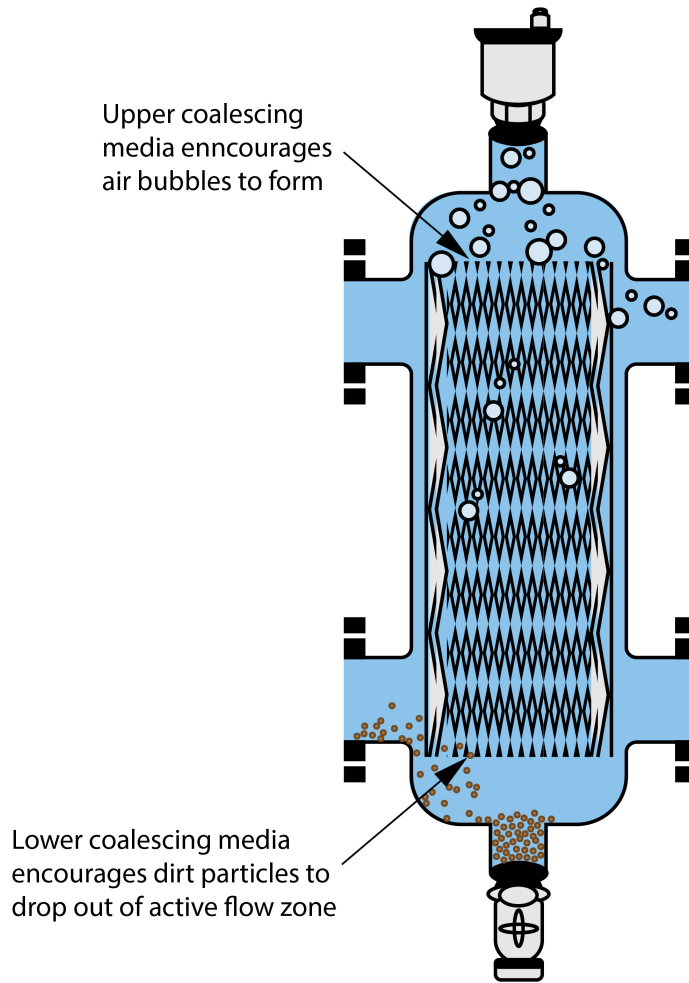


Figure 34 Combined air and dirt separator. (modified from Caleffi, idronics™, 2014).

Because the screens and wires do not accumulate sediment, like a Y-strainer, they do not create an increased resistance within the piping system. Many hydronic systems contain cast iron or steel components, which form iron oxides. As iron oxide particles are attracted to magnetic fields, they tend to accumulate in the circulator due to the motor's magnetic fields. The ability of a dirt separator to capture iron oxide particles is enhanced by adding a powerful magnet on or within the separator. When the magnetic portion of the separator is removed, the iron oxide particles along with other debris can be flushed out from the lower bowl of the separator.

Chemical Treatment

Residential hot-water heating systems do not normally require the periodic addition of chemicals, but commercial and industrial hot-water heating systems may require chemicals to:

- Degrease the system
- Inhibit corrosion
- Lubricate components

- Prevent freezing

Degreasing agents are used to clean the system. Corrosion inhibitors prevent rust from forming on interior surfaces. Lubricants help valves and other components function smoothly. Glycol prevents freezing.

Degreasing agents, corrosion inhibitors, and lubricants are added to the system through a pot feeder (Figure 37). The pot feeder is made of cast iron or steel and can hold several litres or gallons of chemical solution. The pot feeder is installed at a convenient location on one of the mains, typically in the boiler room. The pot feeder is installed on a short bypass to the main with an isolating valve at either end.

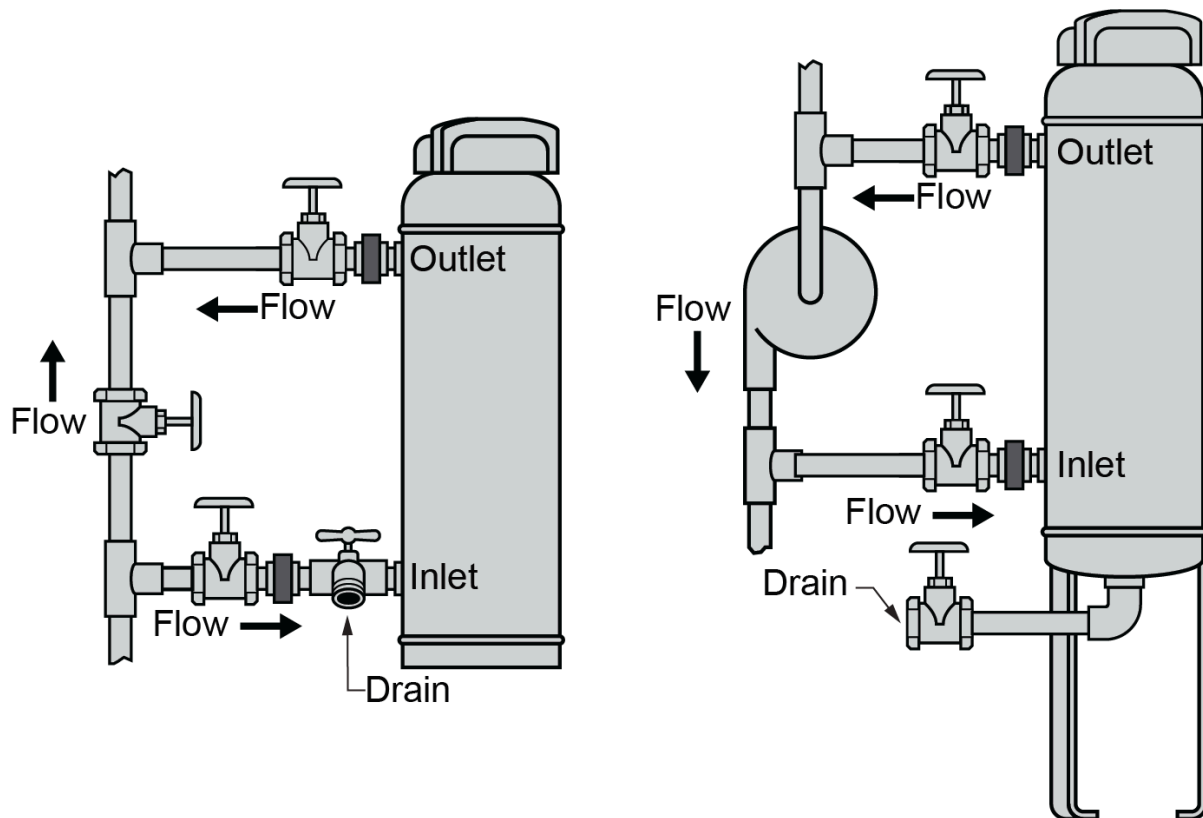


Figure 35 Pot feeder. (Skilled Trades BC, 2021) Used with permission.

When a chemical solution needs to be added to the system, do the following:

1. Isolate the pot feeder by shutting off the inlet and outlet valves.
2. Drain the pot feeder of residual fluid.
3. Open the pot feeder lid.
4. Clean the pot feeder tank.
5. Close the drain valve.
6. Add the required solution.
7. Vent excess air from the pot feeder.
8. Open the isolation valves.

Give the added chemicals a few minutes to circulate and mix with the system water, then repeat the process until the

required amount of chemical has been introduced into the system. Test kits are available for any water characteristics being adjusted.

Degreasing agents must be flushed from the system after they have served their function, whereas corrosion inhibitors and lubricants are allowed to remain in the system.

Glycol solutions are added to an empty system, although not through the pot feeder. A premixed glycol solution can be added to a system with the use of a pump cart, as previously shown. Systems that use glycol solutions rather than water will require a larger compression tank suitable for glycol, a stronger circulating pump, and a higher level of backflow protection.

Low-Water Cutoffs

Another safety device required on some hot-water boilers and all steam boilers is a low-water cutoff (LWCO). A low-water cutoff is installed as a safety guard against a low-water condition in the boiler. If the water in the boiler gets to a dangerously low level, an electrical circuit to the energy source (typically the gas valve) is interrupted and the burner is shut off. LWCOs can either be of a float type (Figure 38) or a probe type. The float type uses a float ball connected to a switch, and the probe type is inserted into the boiler through a tapping at the lowest safe water level. It uses the conductivity of water to complete or break an electrical circuit, which allows the burner to keep firing or shuts it down.



Figure 36 Float type low-water cutoff (left) & probe-type low-water cutoff (right). (Skilled Trades BC, 2021) Used with permission.



Self-Test B-4.1: Hydronic Distribution System Components

Complete the chapter Self-Test B-4.1 and check your answers.

If you are using a printed copy, please find Self-Test B-4.1 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.



An interactive H5P element has been excluded from this version of the text. You can view it online here: <https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=58#h5p-9> (<https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=58#h5p-9>)

References

- Caleffi Hydronic Solutions. (2014, July). Figure 3-10, Y-Strainers, Separation in Hydronic Systems [digital image]. *idronics*TM (15), 2014, 19. <https://idronics.caleffi.com/magazine/15-separation-hydronic-systems>
- Caleffi Hydronic Solutions. (2015, January). Figure 6-8, Constant differential pressure control, Circulation in hydronic systems [digital image]. *idronics*TM (16), 2015, 43. <https://idronics.caleffi.com/magazine/16-circulation-hydronic-systems>
- Caleffi Hydronic Solutions. (2016). Figure 4a, 3 ball valves, Water quality in hydronic systems [digital image]. *idronics*TM (18), 2016, pp. 19 & 22. <https://idronics.caleffi.com/magazine/18-water-quality-hydronic-systems>
- Grundfos. (n.d.). *UP Series Circulator pumps 60 Hz* (p. 33) [Data Booklet – PDF]. Grundfos Holding A/S. Retrieved from <https://api.grundfos.com/literature/Grundfosliterature-5235400.pdf>

Skilled Trades BC. (2021). Book 1: Fuel gas systems, Heating and cooling Systems. Plumber apprenticeship program level 2 book 1 Harmonized. Crown Publications: King's Printer for British Columbia.

Trades Training BC. (2021). B-4: Install hydronic heating piping and components. In: *Plumber Apprenticeship Program: Level 2*. Industry Training Authority, BC.

Media Attributions

All figures are used with permission from Skilled Trades BC (2021) unless otherwise noted.

- **Figure 17** Grundfos UP series cross-reference performance curves (<https://api.grundfos.com/literature/Grundfosliterature-5235400.pdf>) is from Grundfos (<https://www.grundfos.com/ca/>) and is used for educational purposes under Fair Dealing (https://laws-lois.justice.gc.ca/eng/acts/c-42/page-6.html#docCont~:text=Exceptions-,Fair%20Dealing,-Marginal%20note%3A guidelines)) guidelines.
- **Figure 19** Variable speed circulator maintaining constant pressure [Figure 6-8] is by Caleffi Hydronic Solutions (2015, p. 43) in idronics™ and is used with permission.
- **Figure 20** is by TRU Open Press.
- **Figure 30** System flushing valve arrangement [Figure 4-9] is by Caleffi Hydronic Solutions (2016, p. 19) in idronics™ and is used with permission.
- **Figure 31** Flush pump cart [Figure 4-9] is by Caleffi Hydronic Solutions (2016, p. 22) in idronics™ and is used with permission.
- **Figure 32** Y-strainer [Figure 3-10] is by Caleffi Hydronic Solutions (2014, p. 19) in idronics™ and is used with permission.
- **Figure 33** Monitored strainer pressure drop [Figure 3-14, modified] is by Caleffi Hydronic Solutions (2014, p. 20) in idronics™ and is used with permission.
- **Figure 34** Combined air and dirt separator is modified from original [Figure 6-11] by Caleffi Hydronic Solutions (2014, p. 36) in idronics™ with permission.

B-4.2 Hydronic System Valves

There are many types of valves used in hydronic systems. Most of these valves are common to other piping trades and can be found in plumbing, sprinkler fitting, and steam fitting systems. Others are designed for a very specific function in a hydronic heating system. The proper use of valves can make the difference between an efficient, quiet, and easily serviced hydronic system, and one that wastes energy, creates objectionable noise, or even poses a major safety threat.

Common Valves

Most common valves are designed for either component isolation or flow regulation.

Component isolation refers to the use of a valve to stop fluid flow in piping connected to a device that may have to be removed or opened for servicing. Examples include circulators, boilers, heat exchangers, pumps, and strainers. By placing valves on either side of such components, only minimal amounts of system fluid need to be drained or spilled during servicing. In many cases, other portions of the piping system can remain in operation during such servicing.

Flow regulation requires a valve to set and maintain a given flow rate within a piping system or portion thereof. An example is adjusting the flow rates in parallel piping branches to heat emitters.

Valves used for flow regulation are specifically designed to remove mechanical energy from the fluid. This causes the fluid's pressure to drop as it passes through the valve. The greater the pressure drop, the slower the flow rate through the valve.

Valves commonly used in hydronic piping systems (Figure 1) include the following:

- **Gate valves**
- **Globe valves**
- **Ball valves**
- **Check valves**

Gate, globe, and ball valves are all examples of manual valves that can be used for isolation. Air will flow easily through an open gate or ball valve. Because of their restrictive interior design, globe valves are limited to being used to provide throttling or isolation on feedwater lines. The globe valves are also modified into a specialty valve called a balancing valve. These are used for throttling flows in a hydronic system. Check valves can be used wherever reverse flow is unwanted.



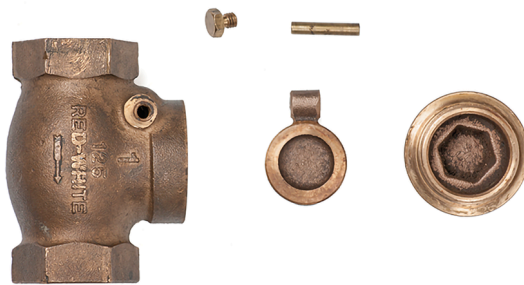
Threaded gate valve



Threaded globe valve



Threaded ball valve



Threaded swing check valve

Figure 1 Commonly used valves. (Skilled Trades BC, 2021) Used with permission.

Specialty Valves

Several valves have very specific functions in hydronic systems. Some provide safety protection, some are required by code, and others automatically regulate the temperature and pressure at various points in the system. All these valves will be incorporated into systems discussed in later phases of training.

Pressure Relief Valves

All closed-loop hydronic systems must be protected by a pressure relief valve. Its function is to provide a relatively controlled and safe release of water in the event of excessive pressure in the system.

Pressure **relief valves** are designed and labelled to open at a specific pressure. In systems with boilers, the relief valve is threaded directly onto the boiler or a nearby supply pipe.

Pressure within a hot-water heating system could reach dangerous levels through the failure of a component to shut off the burner or a failure within the **water makeup** system. Installing the correct pressure relief valve will prevent pressure from building up to an unsafe or dangerous level.

The pressure relief valve for a hot-water heating boiler is spring-loaded and opens at a pressure that is preset at the factory. The valve must not have a discharge pressure setting greater than the maximum rated pressure of the boiler. The pressure relief valve must be capable of discharging as much heat as the boiler can produce. This means that the relieving capacity must match or exceed the output rating of the boiler. An extra margin of safety is given if the boiler's input, rather than its output, is used in selecting the relief valve capacity.

Every pressure relief valve has an information or rating plate (Figure 2) that identifies the following:

- The relief pressure setting; for example, 210 kPa (30 psi)
- The relieving capacity; for example, 44 kW (150,000 BTU)
- The size of the valve; for example, $\frac{3}{4}$ NPS

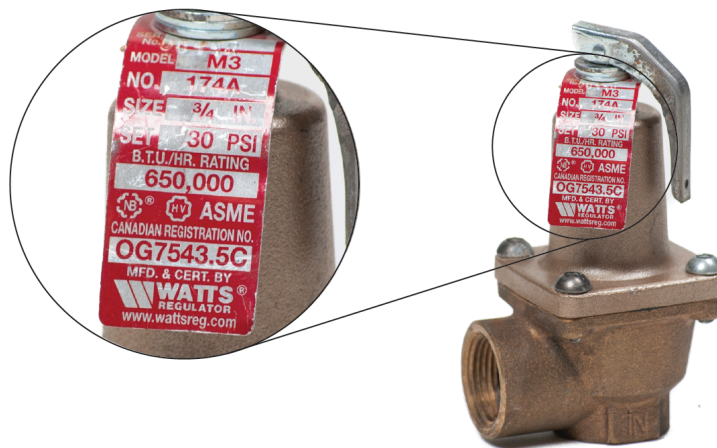


Figure 2 Pressure relief valve and rating tag. (Skilled Trades BC, 2021) Used with permission.

The pressure relief valve must be installed directly on the boiler, and there may not be any other valve between the pressure relief valve and the boiler. The spring-loaded valve of the pressure relief valve opens when the preset pressure is reached. When the pressure within the boiler drops sufficiently, the valve closes.

The pressure is relieved by discharging water through a pipe to a drain or safe location. The piping used for the outlet must be:

- The same size as the pressure relief valve
- As short as possible

- Sloped down and away from the valve to prevent a buildup of back pressure

If the pressure relief valve drips water from its discharge opening, and the pressure indicated is not close to the opening pressure of the valve, there may be some debris in the valve seat. To flush the valve, stand in a position clear of the valve's discharge opening. If the boiler temperature is high, scalding water or steam will be discharged. Open the valve fully for a moment to flush out the valve seat and let a finger slide off the end of the trip lever so that it slams shut to prevent nuisance dripping.



If this does not stop the dripping, the valve has failed and must be replaced. Make sure the replacement valve is of the same type and has the same opening pressure and heat relief capacity. Never plug, cap or install a valve on the discharge side of the pressure relief valve.

If the valve drips because the pressure in the system is at its maximum, the valve is doing its job, and the cause of the excess pressure must be found and fixed.

If the information tag is missing from the pressure relief valve, the valve must be replaced because the correct safe discharge pressure setting cannot be determined.

Boiler Water Makeup

Water makeup refers to the piping and accessories connected to the system that not only fill it, but maintain a constant pressure within it. It's important to carefully select the connection to the system piping. Cold water should never be added directly to a hot boiler, as this can cause thermal shock and crack the metal. Instead, the water makeup is normally introduced into the hot supply main from the boiler through the same fitting used to connect the expansion tank, which is the point where pressure remains stable.

The water makeup to a boiler has four components:

- **Main stop valve**
- **Backflow preventer**
- **Feedwater valve (pressure-reducing valve)**
- **Bypass valve (quick fill)**

Main Stop Valve

The main stop valve is normally a ball or gate valve; in other words, a valve that, in operation, is either open or closed. Although almost any manual valve will perform the intended function, **ball valves** are used most often because they are readily available and easily seen as either open or closed. The position of a valve with a rotary handle, such as a gate or globe valve, cannot be seen at a glance as being open or closed and so they are less commonly used.

Backflow Preventer

As seen above, water is introduced into the hydronic system through the feedwater or pressure-reducing valve. Once in the hydronic system, this water is no longer considered part of the domestic system, and there must be some mechanism that ensures boiler water does not return to the domestic system and contaminate it.

A **backflow preventer** performs this function. A backflow preventer does exactly as the name implies: it prevents the flow of liquid back to where it originated. All boiler systems require a backflow preventer. The type and style of backflow preventer are determined by the presence or absence of additives in the boiler water and whether it is a residential or commercial installation. A typical backflow preventer on a residential hydronic system is a dual check with an atmospheric port (Figure 3).

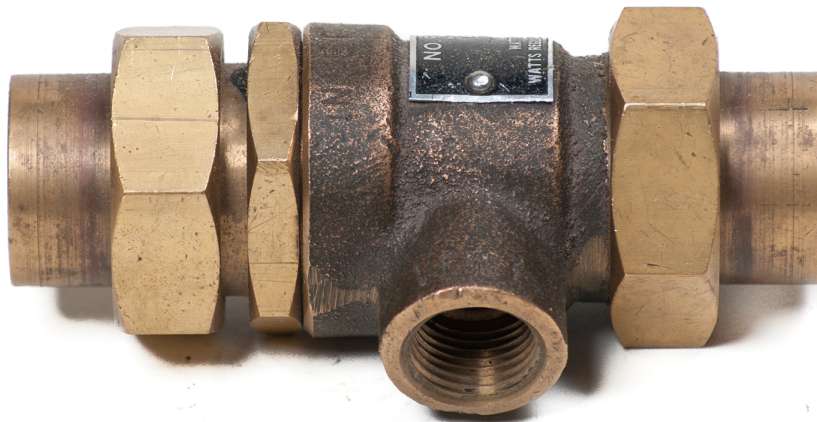


Figure 3 DCAP backflow preventer. (Skilled Trades BC, 2021) Used with permission.

This device has two check valves in series, with a port open to atmosphere located between the two check valves. If water flows in the opposite direction than intended, it will be discharged through the atmospheric port to the atmosphere.

If chemicals have been added to the boiler system, in many jurisdictions, a more reliable backflow preventer must be installed. An example is the reduced pressure backflow assembly (Figure 4), which functions similarly to a dual check with an atmospheric port but with the added advantage of being in-line testable. Testing the assembly regularly ensures its proper operation.

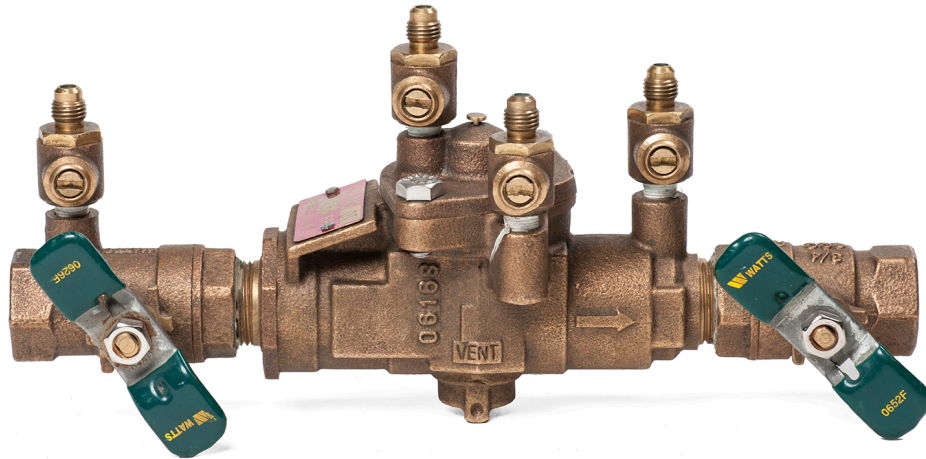


Figure 4 Reduced pressure backflow assembly. (Skilled Trades BC, 2021) Used with permission.

Feedwater Valves

All hydronic systems referred to in this section are known as closed-loop systems. Even though they are closed loop, they still require the ability to fill the system and have water added when necessary. This is done automatically through a **feedwater valve**, also known as a pressure-reducing valve (Figure 5).

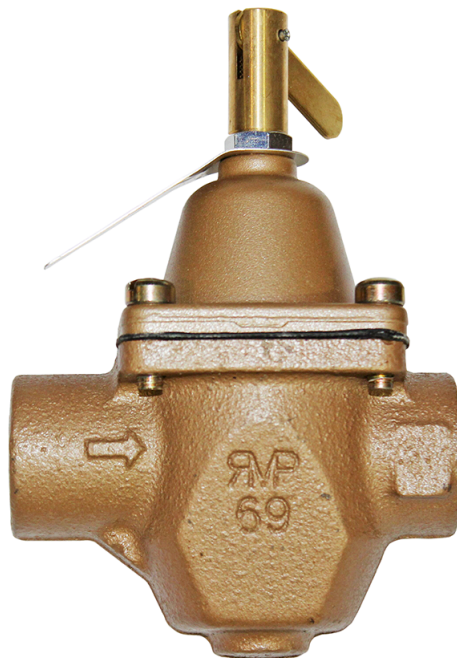


Figure 5 Boiler feedwater valve. (Skilled Trades BC, 2021) Used with permission.

A feedwater valve takes the domestic water from the building and lowers the pressure to the working pressure of a hydronic heating system before it enters the system. For a residential system, this pressure is normally between 12 psig (84 kPa) to 20 psig (140 kPa). A hydronic system will typically lose a little water due to air being eliminated as the system goes through its cycles. Potable water is brought in through the feedwater valve when the valve senses the pressure in the system has dropped below its pre-set level. Once enough water has been introduced into the system to bring it to its operating pressure, the feedwater valve automatically closes and no more water is added.

Bypass (Quick-Fill)

Some feedwater valves, like the one shown in Figure 5, have a lever at the top that allows the valve to be manually opened to quickly fill the system during startup. When lifted, this lever temporarily disables the pressure-regulating function of the valve and is known as a bypass. The lever must be manually returned to its normal position after the system is filled and purged (bled of air).

The bypass feature supplies the system with full building pressure to rapidly fill the system. Furthermore, the velocity of water entering the piping helps push air out of purge valves for better initial air removal (see “purge valve” description below).

The flow speed through the feed water valve when in quick-fill mode is usually sufficient to purge a typical residential system. On larger systems, it is common practice to install a bypass valve (usually a full port ball valve) to provide even faster filling and purging flow (Figure 6). Notice the bypass ball valve is installed on the piping run to minimize the pressure drop for fastest possible purging. This bypass valve should be closed and marked, so it remains closed during normal system operation.

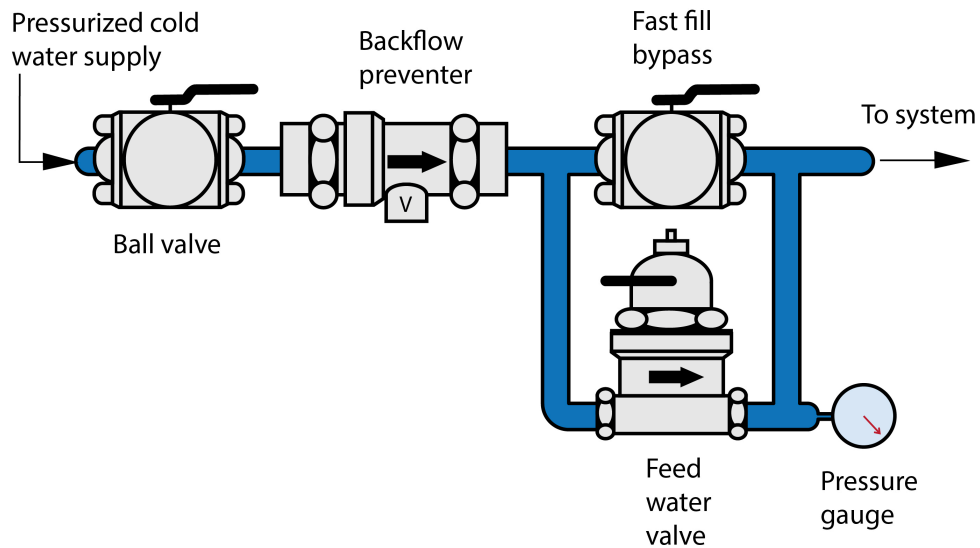


Figure 6 Quick fill bypass arrangement. (TRU Open Press,) CC BY-NC-SA
<https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en>

The backflow preventer is located on the feedwater line in series with the feedwater valve, and in some cases, they are available as a packaged unit (Figure 7). It is important to note that the backflow preventer is always installed upstream of the feedwater valve. This ensures that the pressure drop through the backflow preventer does not affect the final fill pressure setting provided by the feedwater valve. All quick-fill valves must be installed so as to not bypass the backflow preventer.

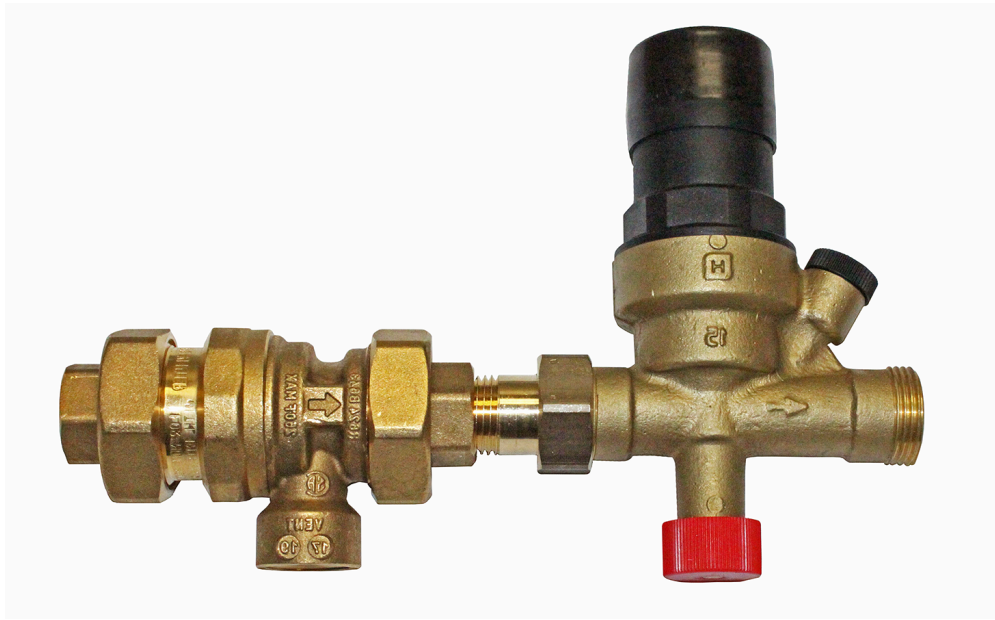


Figure 7 Backflow preventer/feedwater valve as a unit. (Skilled Trades BC, 2021) Used with permission.

Purge Valves

During the initial filling of a hydronic system, most of the air that is in the empty system can be effectively pushed out of the system using the pressure and velocity of the water entering through the makeup line. This is sometimes called power purging or gravity purging, and it reduces the time needed to bleed the air through high-point vents.

The purge valve is located on the return piping near the boiler. Modern purging valves consist of two ball valves in one common body. One ball valve is in line with the system, while the other is a side outlet port with a hose connection. Figure 8 shows two types of manufacture purge valve arrangements. Having different configuration options gives the installer location flexibility. The valve on the left has added installation versatility, as it has a three port ball with a reversible handle, which allows it to be set up for draining from either side of the ball.



Figure 8 Purge valve/drain valve. (TRU Open Press)
CC BY NC SA (<https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en>)

Many wall-hung boilers come supplied with specialty purge valves kits for the supply and return connections (Figure 9).



Figure 9 Wall-hung boiler service valves. (TRU Open Press) CC BY NC SA (<https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en>)

When purging the system (Figure 10), the inline ball valve is closed and the side outlet ball valve is opened, with a hose attached to it directing the water/air to a drain. The feedwater valve bypass or piped bypass can be fully opened to quickly let water into the system. As water enters the system, the air that previously filled the system is pushed out through the purge valve. Continue to fill the system until the fluid stream exiting the outlet port of the purge valve is free of visible bubbles. The bypass valve or quick-fill lever is then closed, the side outlet valve is closed, and the inline ball valve is opened. With the feedwater valve now set to work automatically, the system should require minimal manual bleeding of air. Pressures within the building piping feeding the quick-fill valve are almost always higher than the boiler relief valve; therefore, the boiler should be isolated, or this power purge will typically trip the relief valve. A cast-iron boiler should never be subjected to pressures over 30 psig.

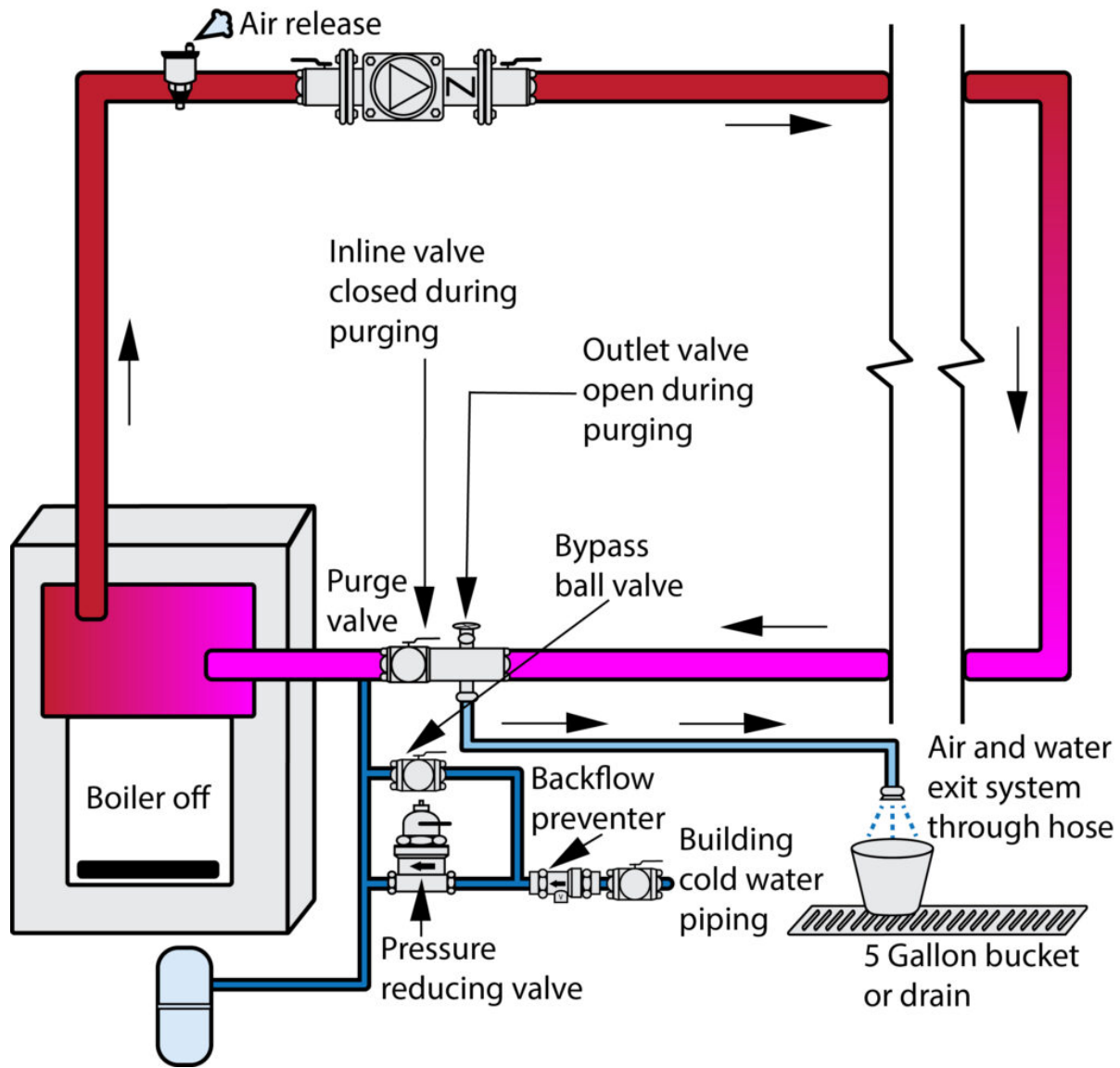


Figure 10 Purging air from system. (TRU Open Press; [modified from] HPAC Magazine, 2017).

For a newly constructed building, it is important that the water supply piping has been thoroughly flushed before using the auto fill as a purge supply. If there is any doubt as to the quality of the water supply, or if the potable supply has not been commissioned yet, it may be necessary to connect to an external source or purge cart. In this case, the previously described flushing procedure that used a three-valve arrangement would be used. For ease of installation, there are specialty manufactured double port flushing valve arrangements available (Figure 11).



Figure 11 Pro-Pal Purge & Fill, Full Port Forged Brass Ball Valve. (Nibco, Inc.) Used with permission.

Flow Check Valve

When water is heated, it becomes less dense than the cooler water on the return side of the boiler. During the off cycle of a boiler, hot water still has the tendency to rise up through the heating system and provide flow and heat, even when none is needed. This is referred to as thermal siphoning or gravity flow. Flow check valves are designed with a weighted internal plug (Figure 12) or a spring that is heavy enough to stop thermal siphoning or gravity flow of hot water while the system's circulator is off, but light enough not to cause unwanted resistance for the pump. They also act like a basic check valve and will prevent reverse flow in a multizone system.

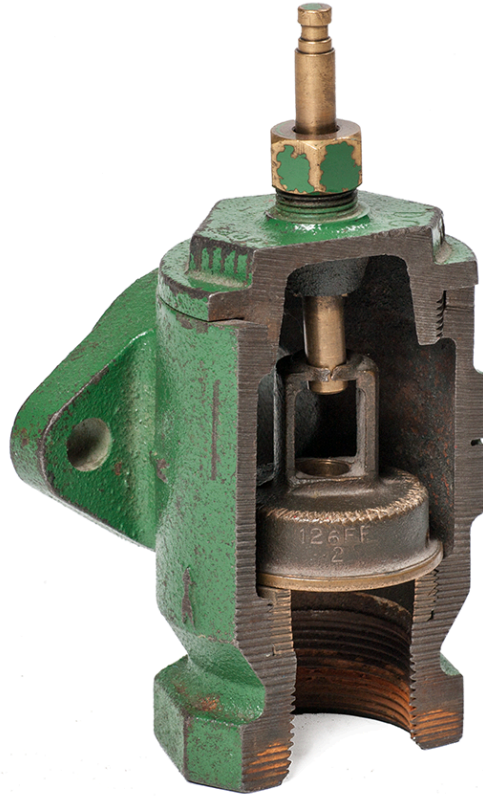


Figure 12 Cutaway of a cast-iron threaded flow check valve.
(Skilled Trades BC, 2021) Used with permission.

The stem at the top allows the valve to be manually opened if gravity circulation is desired or for draining the system.

Thermostatic Radiator Valve

The thermostatic **radiator valve** (TRV) (Figure 13), is a device installed in the inlet or supply side of a heat transfer unit (HTU) and is normally used on a constant flow system. It contains two parts: the valve body and the thermostatic operator. The thermostatic operator senses the temperature of the room air surrounding the valve and forces the valve to either open or close. The TRV can also be fitted with a capillary tube and bulb mounted near the bottom of the HTU that senses the temperature of the air being pulled into the HTU through convection currents.



Figure 13 Thermostatic radiator valve. (Skilled Trades BC, 2021) Used with permission.

Opening the TRV allows more water to flow through the heat transfer unit, causing an increase in the room temperature; closing the TRV does the opposite. The opening and closing of the TRV is done using a spring, a bellows, and a fluid located inside the bellows (Figure 14).

The spring inside the TRV normally holds the valve open, allowing hot water to flow through the heat transfer unit; it will close to stop water flow when the room temperature rises to its set point. This is accomplished through the use of a fluid inside the bellows, which heats up and expands in reaction to the room temperature increasing. The force of the expansion causes the bellows to act upon the valve plug to overcome the opening force of the spring and eventually close the valve. In the reverse, as the room temperature drops, the liquid cools and contracts, releasing the pressure on the bellows and allowing the spring to push the valve open. This allows water to pass through the heat transfer unit, and the whole process starts again.

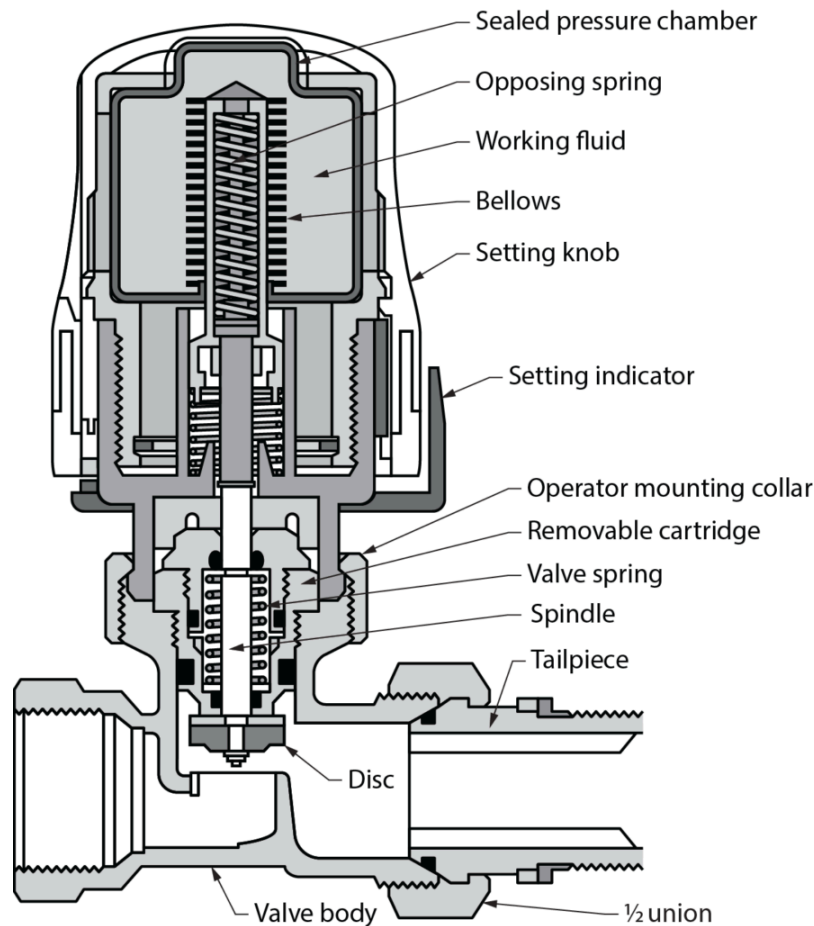


Figure 14 Thermostatic radiator valve (cutaway). (Skilled Trades BC, 2021) Used with permission.

Thermostatic radiator valves can also be controlled via a wall-mounted thermostat. The thermostat senses room temperature and has a capillary tube connecting it to an operator mounted onto the valve on the heat transfer unit. The operation is similar to that of the directly mounted thermostatic valve except that the sensor is now remote to the valve itself. The advantage to this setup is that room temperature is controlled at thermostat height; the drawback is that the exposed capillary tube will be surface-mounted and must be covered to be aesthetically acceptable and also protect it from damage.

Zone Valves

One of the main benefits of a hydronic heating system is the ability to independently control different areas of the building or “zones.” Zone valves play a big part in this control strategy.

Zone valves permit or prevent the flow of water through the zone they control. When a room thermostat senses the need for heat, it signals the control valve for that zone to open.

There are two types of electrically operated zone valves:

- Motor operated actuator
- Wax filled actuator

Their difference is relative to their operation.

Motor Operated Zone Valves

Motorized zone valves are operated by electric motors activated by a 24-volt signal from the thermostat in that zone.

Figure 15 shows a $\frac{3}{4}$ -inch motorized zone valve with sweat connections intended for installation on copper tubing.

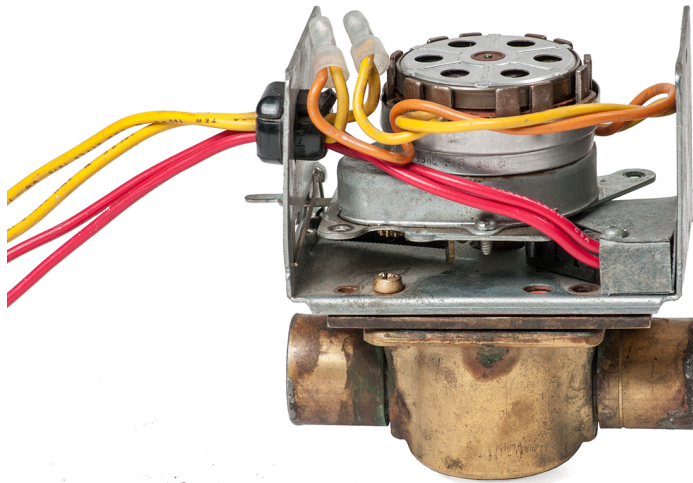


Figure 15 Zone valve. (Skilled Trades BC, 2021) Used with permission.

The electrically controlled motor drives an actuator with a rubber ball mounted on it (Figure 16). When a call for heat occurs, 24 volts AC is sent to the zone valve motor through the yellow wires. The motor spins to move the actuator, and the rubber ball moves away from the opening connected to the piping. Water pushed by a circulator is then able to flow through the piping in that zone. When the call for heat is satisfied, the thermostat contacts open and power to the zone valve is interrupted. A spring then pulls the actuator back to its original position, and the valve closes.

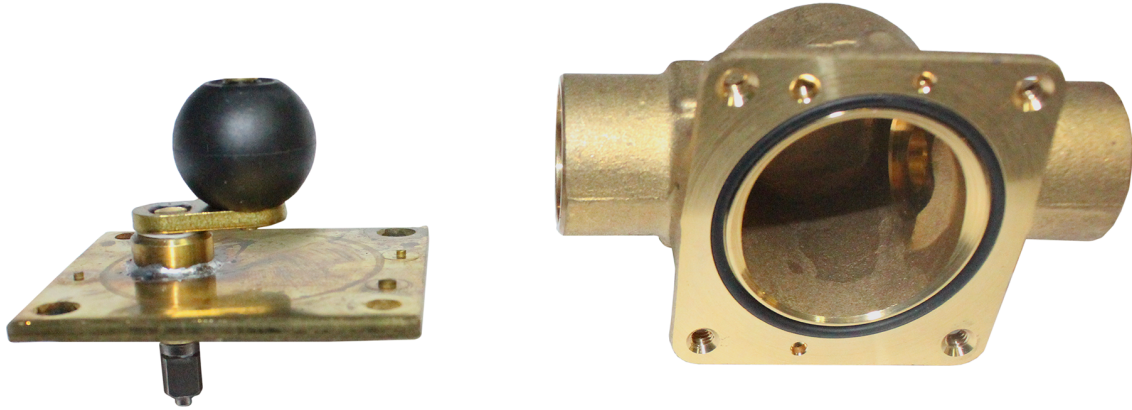


Figure 16 Zone valve ball. (Skilled Trades BC, 2021) Used with permission.

Wax Filled Actuators

Zone valves controlled by a wax filled actuator use a similar valve design as the one shown for thermostatic radiator valves. These valves are opened and closed with a simple linear (versus rotational) movement of their shaft. When the unenergized actuator (Figure 17) is mounted onto the valve body, the cool contracted wax and an internal spring push down onto the valve stem and close the valve. On a call for heat, the valve is energized with 24 VAC and a small heating element warms the wax chamber; the expanding wax lifts up a piston assembly and opens the valve.

The total movement of the actuator shaft is only about $\frac{1}{8}$ of an inch. The movement of the shaft is slow. A typical actuator reaches its fully open position two to three minutes after power is first applied, which is preferred on a radiant system to avoid unnecessary opening for a brief room draft that will be picked up by the high mass of the system.

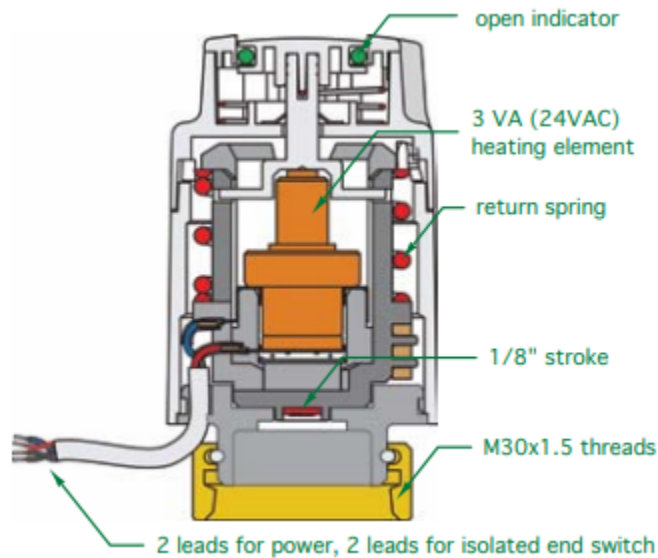


Figure 17 Wax filled zone valve actuator. (Caleffi, idronics™, 2009). Caleffi S.p.A. All rights reserved. Used with permission.

Zone valves are normally installed on the supply side of each zone circuit. This is done so that heat migration will not occur during the off cycle. If the zone valve is installed on the return from a circuit, the supply to that circuit should have a flow check installed.

Zone valves are available in two-wire and four-wire configurations. In a two-wire configuration, power is only sent to the actuator to open and close the valve. A four-wire configuration is used when a circulating pump is required to turn it on but only if a zone valve is open. In this case, there needs to be some way for the system to recognize that there is somewhere for the water to go. The four-wire configuration has two extra wires that incorporate an end switch to prove that the valve is open.

The end switch is simply a proving switch. As the zone valve actuator arm moves, a small metal plate attached to the arm moves with it. Only when the zone valve is fully open does this metal plate press against a microswitch, closing it and allowing the electricity to travel through the switch's red wires to the pump relay. The relay coil energizes, which closes internal contacts and turns the pump on.

If the zone valve fails to open, the end switch will not close, and the pump will not start. This saves the pump from “deadheading” (spinning the impellor without letting water flow), which will eventually cause the pump to fail.

System Operating Pressure Controls

Figure 18 shows a number of zones being supplied by one fixed-speed circulator. As zone valves are closed, the flow resistance of the system is increased and the zones that remain open “feel” this increased differential pressure, and their flow rates immediately increase. In some systems, the increased pressure differential and flow velocity may be of little consequence. In others, it may be sufficient to create flow noise, pipe erosion, and valve stem lift.

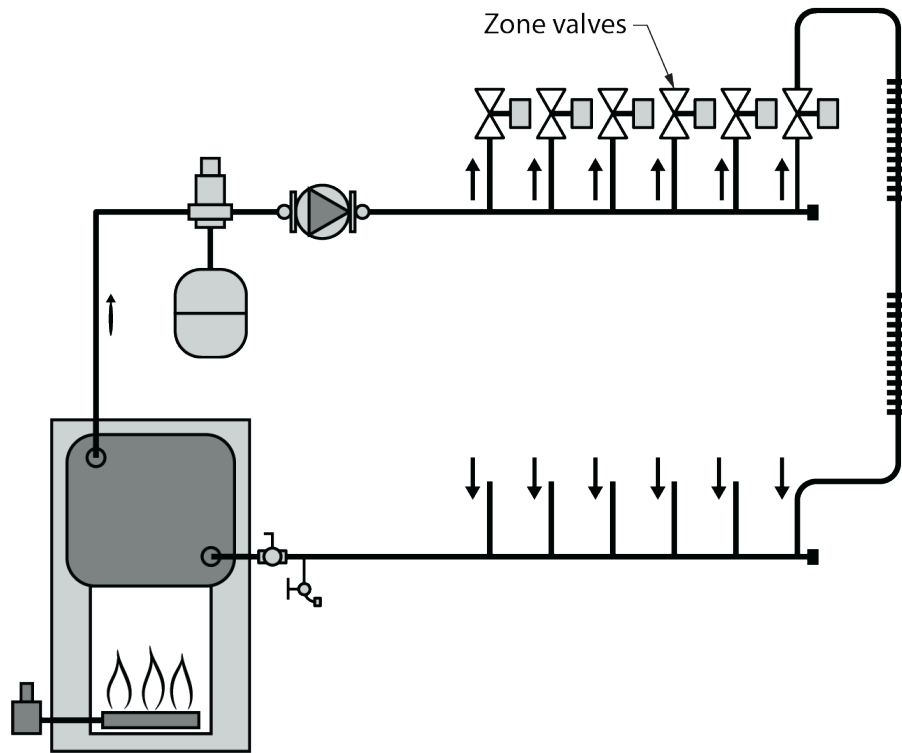


Figure 18 Multiple zones valve system. ([modified] Skilled Trades BC, 2021) Used with permission.

Reducing excess system pressure created by zoning can be achieved by two common methods:

- Differential bypass valve
- Pressure-regulated circulator

A differential bypass valve (Figure 19) is like an adjustable spring-loaded pressure relief valve. The setting knob adjusts the force exerted by the compression spring on the valve.

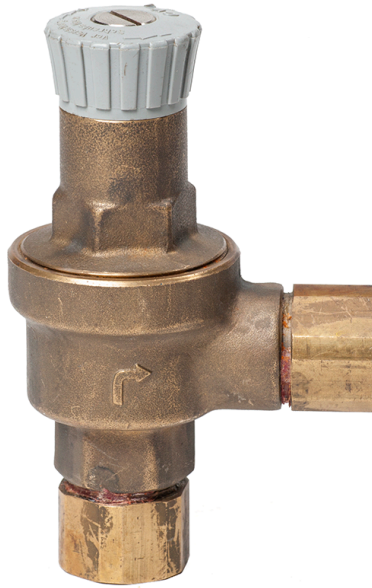


Figure 19 Differential pressure bypass valve.
(Skilled Trades BC, 2021) Used with permission.

Essentially, it gives the pump another route to pump through if most or all zone valves are closed (Figure 20).

The spring pressure should be set so there is just enough tension to keep it in the closed position when the system is balanced with all zones are open. As zone valves close and the differential pressure across the headers increases, the differential bypass valve should begin opening when the differential pressure reaches 0.5 to 1 psi above the differential pressure present when all zone circuits are open. The result is a minimal change in the differential pressure between the supply and return headers.

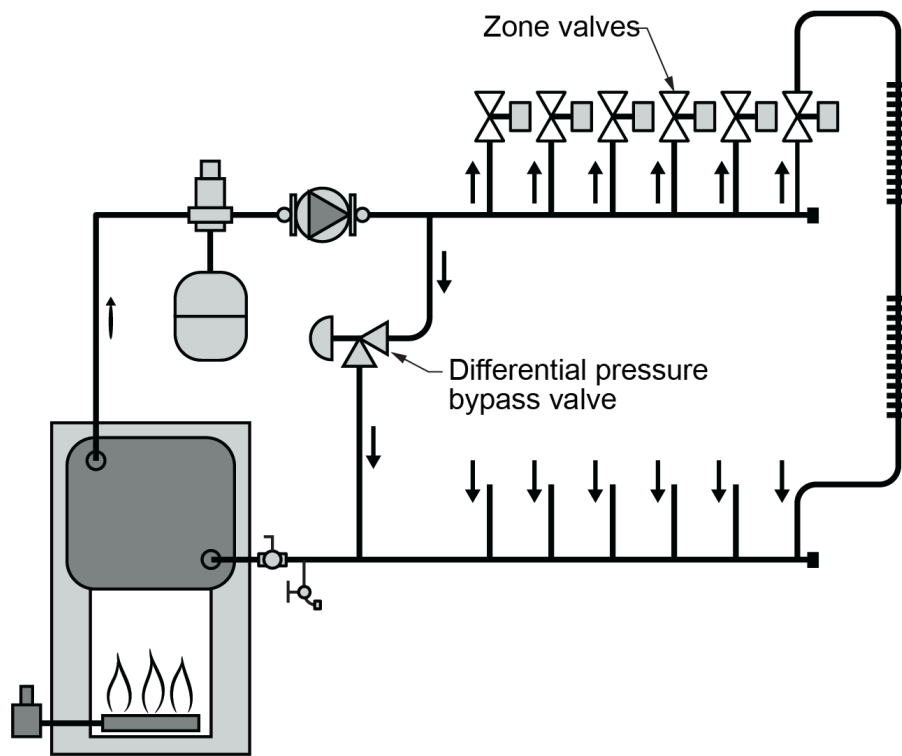


Figure 20 Multiple zones with a differential pressure bypass valve. (Skilled Trades BC, 2021)
Used with permission.

The disadvantage of using a bypass valve is that, at times, when zone valves are closed, the pump is wasting some of its energy. As described in the Section B-4.1 (#chapter-b-4-1-system-components), another way of regulating excess pressure in hydronic systems is through the use of variable speed circulators. These pressure-regulated ECM circulators are ideal for systems using valve-based zoning and eliminate the need for a differential pressure bypass valve.

When a valve in a branch circuit closes or modulates to reduce flow, the circulator detects an increase in differential pressure across it. It quickly responds by lowering its speed to counteract this change in differential pressure. As additional valves in other branch circuits close or modulate to reduce flow, the circulator continues to adjust its speed accordingly to maintain the set differential pressure. This process, known as “constant differential pressure control,” mode, conserves electrical energy that would otherwise be wasted by operating at a fixed speed.

Balancing Valves

Hydronic systems containing two or more parallel piping paths often require adjustments of the flow rates to ensure even heat distribution. This is especially true in two-pipe direct-return systems where, without balancing valves, these systems would produce higher flow rates in the piping paths closest to the circulator compared to those farther out in the distribution system. The proper use of balancing valves can correct for this situation.

Most balancing valves are a type of globe valve that has much less flow restriction through it. A globe valve with a convention disc or plug (Figure 21, left) has a quick opening characteristic which makes them much more difficult to use for the precise flow balancing required on hydronic heating systems. On the linear and equal percentage globe style valves (Figure 21, centre and right), the disc is more cone-shaped, making more of it protrude into the seat. This allows more precise setting of the flow control plug and thus, provides better control of flow rate.

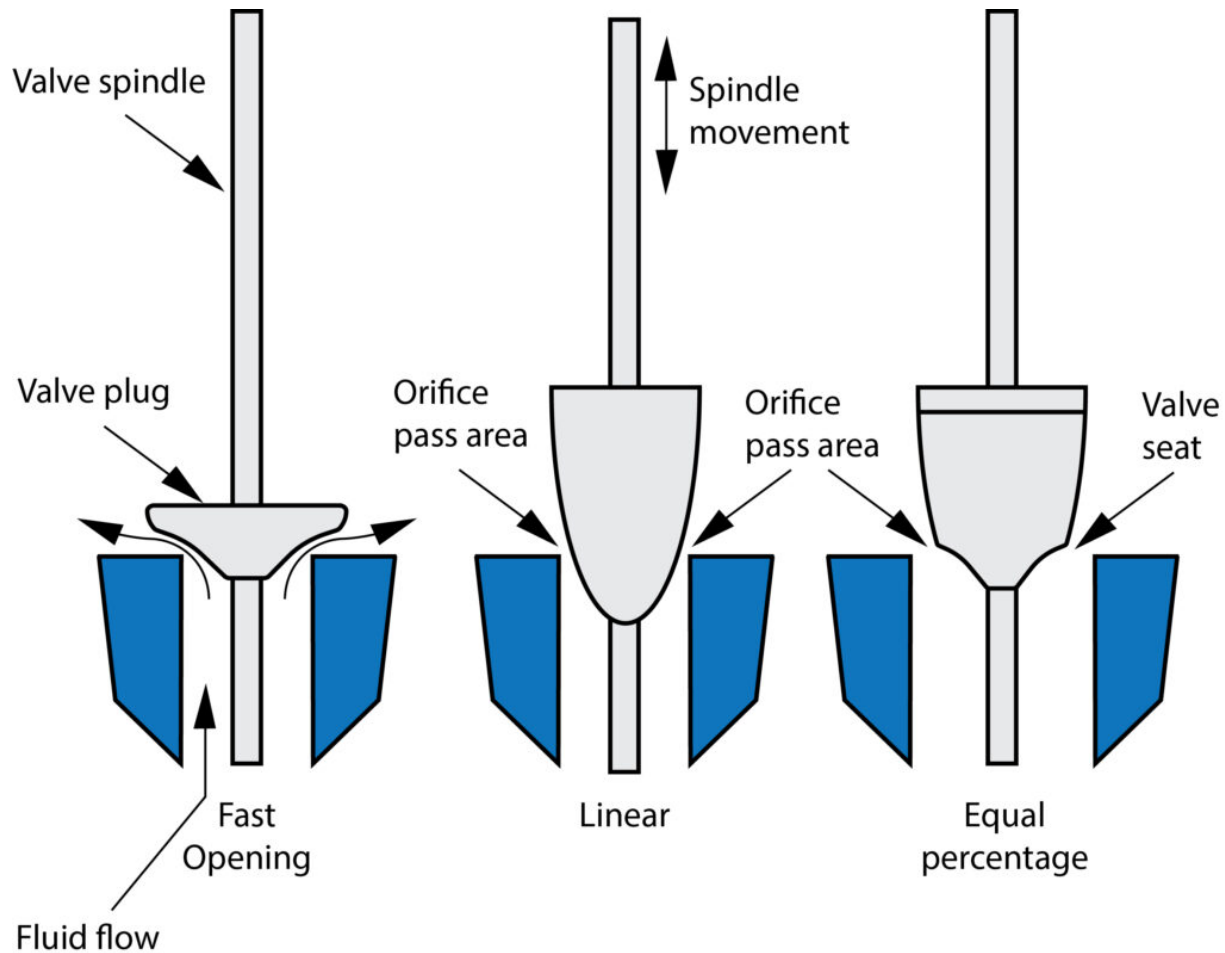


Figure 21 Valve plug shapes. ([modified from] Automationforum.co, 2018) Fair Dealing (<https://laws-lois.justice.gc.ca/eng/acts/c-42/page-6.html#docCont:~:text=Exceptions-,Fair%20Dealing,-Marginal%20note%3A>)

Selecting Balancing Valves

A balancing valve operates best at between 50% and 100% of the maximum opening. Select the balancing valve so that the required pressure drop will be within this range. Do not use a balancing valve that is larger than necessary. Not only does a larger valve cost more, but it will also operate near the closed position, which may give poor flow accuracy. The balancing valve should never be larger than the size of the pipe.

Manufacturers' specifications indicate the flow capacity and pressure drop limits of balancing valves.

There are a variety of balancing valves available to suit the needs of the different systems, some of these include:

- Lockshield valves
- Flow metering balancing valves
- Differential pressure balancing valves
- Automatic flow balancing valves

Lockshield Valves

Lockshield balancing valves are most commonly used to balance the flow on radiators. They are often paired with a thermostatic rad valve (Figure 22). To adjust the flow setting of a lockshield valve, the cap is removed, and the internal plug is rotated with an Allen key. The valves come complete with a half union, which allows the valve to be easily separated in position from the radiator.



Figure 22 Radiator valves. (Xylem Canada, n.d.). Used with permission.

Flow Meter Balancing Valves

Some balancing valves have a self-contained flow meter. On some valves, the flow can be read continuously; on others (Figure 23), the reading is taken by pulling an actuating pin.



Figure 23 Caleffi Quicksetter™ balancing valve. (Caleffi, idronics™, 2010). Caleffi S.p.A. All rights reserved. Used with permission.

Most manifolds for radiant in floor systems will have self-contained flow meter balancing valves for each radiant loop (Figure 24). For some types, the flow adjustments to each circuit are made by rotating the flow indicator column, which is directly connected to the shaft of the internal valve. For others, the flow adjustment may be located underneath the electric zone operator to hinder owners making their own adjustment after the system has been balanced.

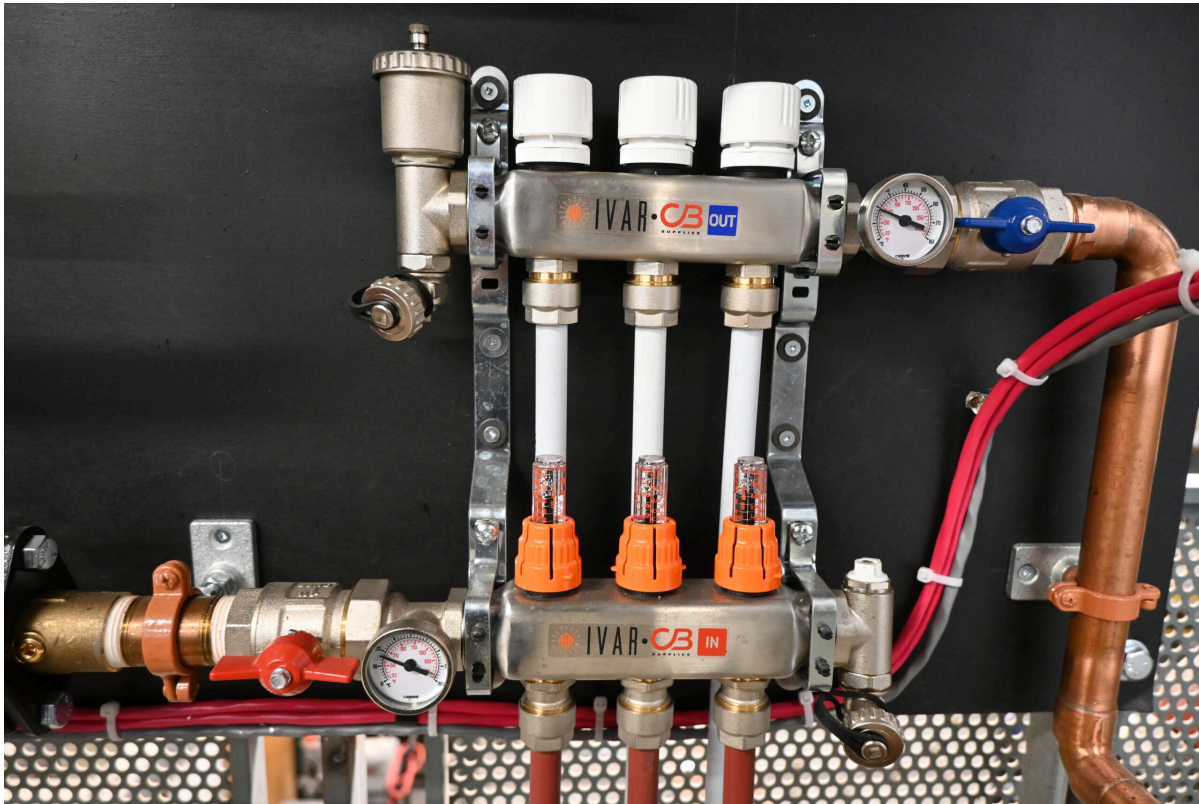


Figure 24 Radiant manifold with flow meters. (TRU Open Press) CC BY-NC-SA (<https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en>)

Differential Pressure Balancing Valves

Differential pressure type balancing valves work on a known relationship between flow rate and the pressure drop across the valve. The valves have two ports, one on each side of the disk/seat (Figure 25), that allow connection of a differential pressure measuring device. The flow rate through the valve can then be found using a chart, slide rule, or electronic device.



Figure 25 Bell & Gossett Circuit Setter. (Xylem, n.d.). Used with permission.

The ports are sometimes called Pete's plugs. This is a twist on the term PT plugs to indicate plugs or ports that can be used to measure pressure and/ or temperature.

Another variation of a differential pressure balancing valve locates the pressure ports on either side of an internal venturi (Figure 26). The venturi passage maintains a more stable relationship between differential pressure and flow rate than that of valves that measure differential pressure across the flow plug.



Figure 26 Venturi balancing valve. (Skilled Trades BC, 2021) Used with permission.

For both types of these types of differential pressure balancing valves, the adjusting knob has setting numbers or increments that must be used to select the proper flow scale on the manufacturer's chart.

Automatic Flow Balancing Valves

Automatic flow balancing valves use an internal cartridge that maintains a specific flow rate over a wide range of system differential pressure ranges. The cartridge consists of a cylinder, a spring-loaded piston, and a combination of fixed- and variable-shaped orifices through which flow passes (Figure 27). The piston automatically adjusts its position based on the amount of thrust created by the differential pressure across the valve. Different cartridges are available for different flow rate requirements.

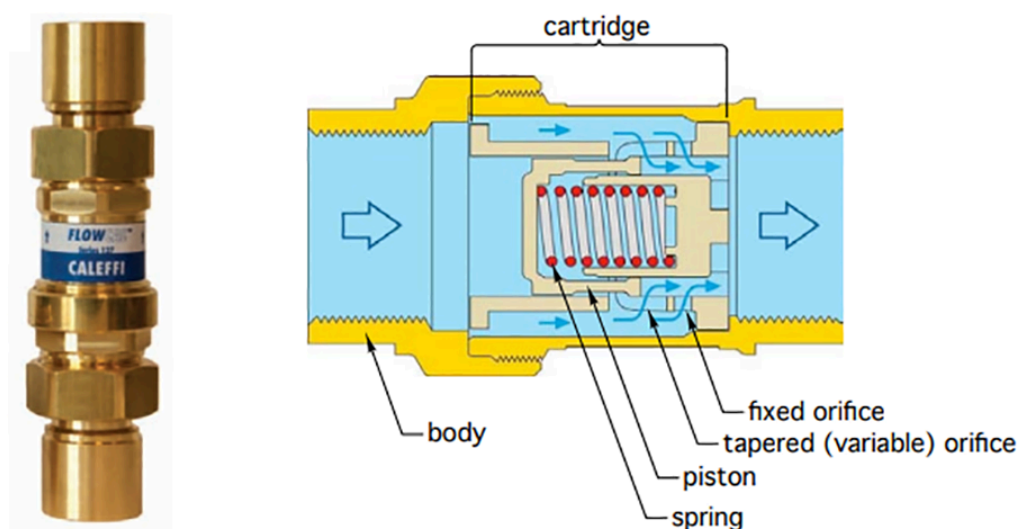


Figure 27 Caleffi FlowCal™ automatic balancing valve. (Caleffi, idronics™, 2010). Caleffi S.p.A. All rights reserved. Used with permission.

Mixing Valves (Tempering Valves)

Some hydronic distribution systems require water temperatures that are substantially lower than the temperatures supplied by the heat source. For example, a radiant floor heating system may require water at 43°C (110°F), while the water temperature from the non-condensing boiler may be over 82°C (180°F). In such cases, the lower water temperature is created by blending water returning from the distribution system with hot water from the heat source. The flow rate of each stream can be regulated by a mixing valve to attain the desired supply temperature.

There are several types of valves used in hydronic heating systems to achieve the water temperatures needed. They include valves operated by electrically motorized actuators, as well as by thermostatic sensors and actuators. The sections that follow describe several types of mixing valves and briefly illustrate how they are used. As well, it is important to note that the term “mixing valve” is used generically in the industry to mean any valve that blends two temperatures of water to achieve a lower temperature. The following section breaks that generic terminology down into more definite terms.

Diverting Valve

A diverting valve (Figure 28) is not actually a mixing valve but is simply a valve designed to divert flow. It has one inlet port and two outlet ports and is not designed to mix any fluids within its body.

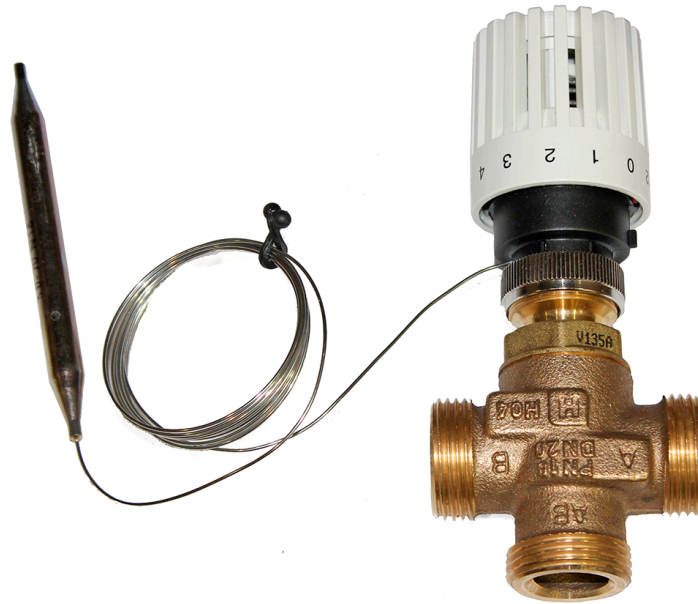
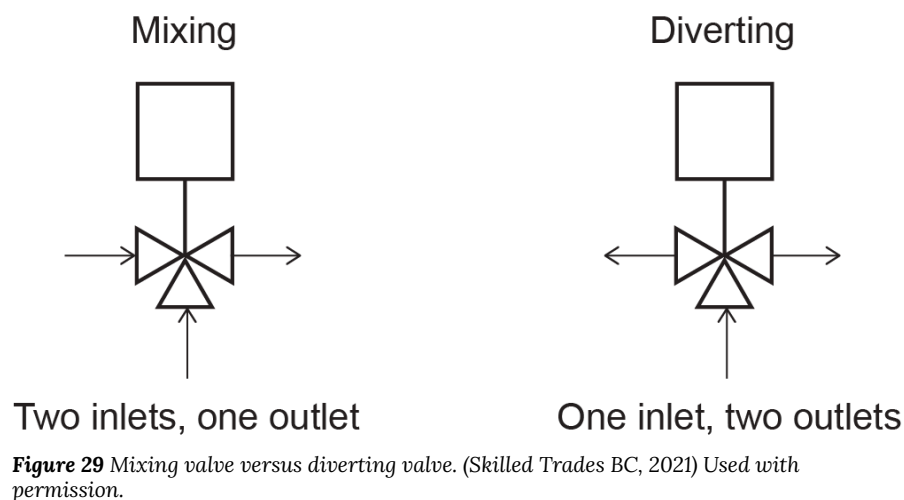


Figure 28 Three-way valve with thermostatic operator. (Skilled Trades BC, 2021) Used with permission.

Figure 29 shows the difference between using a three way valve as a mixing valve or a diverting valve.



A diverting valve is located on the return side of the system, similar to a mixing valve (Figure 30). The flow coming into the valve is the return water from the system. Typically, a three-way diverting valve will divide the cooler system's return water into two flows. A portion of the flow (approximately 25%) goes to the boiler to be reheated. The rest

(approximately 75%) bypasses the boiler to meet and mix with the heated water from the boiler in the system piping. These ratios can vary widely depending on the water temperature required for the heating application.

Diverting valves can be either manually or automatically controlled. If automatic control is desired, the valve must have a remote sensor bulb with a capillary tube mounted downstream of the system mixing point and connected to the valve. A diverting valve achieves finer control and has less head loss through it than a mixing valve.

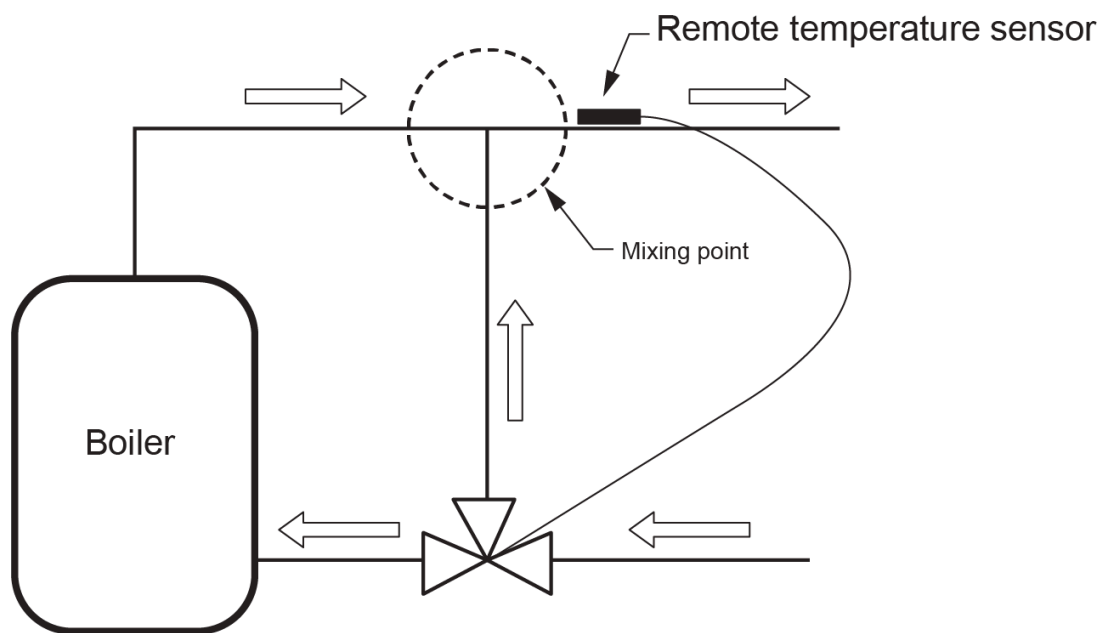


Figure 30 Diverting valve piping arrangement. (Greg Wirachowsky/Skilled Trades BC, 2021) Used with permission.

The mixture of hot boiler water and cool system return water is necessary to maintain the desired temperature needed in a radiant floor system and protect the boiler against lower-than-allowed return water temperatures.

Three-Way Mixing Valve

Like the three-way diverting valve, a three-way mixing valve is also a three-port valve, but it has two inlet ports (one for hot water and the other for cool water) and one outlet port, which is tempered water. Also, unlike the three-way diverting valve, the mixing of the two fluids with the three-way mixing valve occurs inside the valve body itself (Figure 31).

The positioning of the internal valve mechanism determines how much of each fluid will enter the valve body. Adjusting the knob on the valve adjusts the water from each of the hot and cool ports.

A three-way mixing valve can come with or without an actuator. Without an actuator, it cannot adjust itself to compensate for changes in the temperature of incoming water. If automatic water temperature control is required, the addition of an actuator allows the valve to adjust the outgoing water temperature automatically.

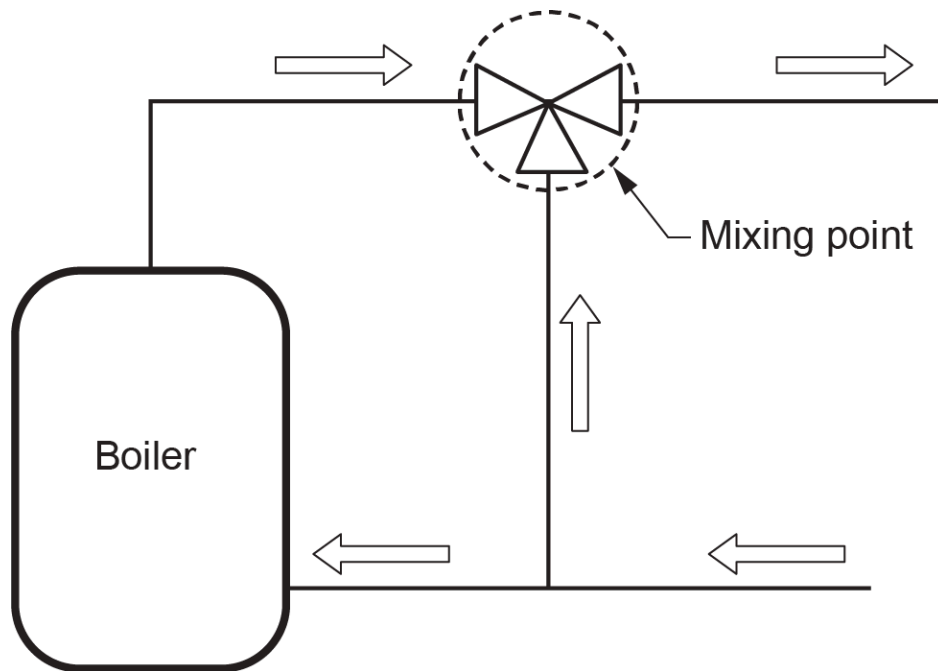


Figure 31 Three-way mixing valve piping arrangement. (Skilled Trades BC, 2021) Used with permission.

If a boiler is unable to handle lower water return temperature, which may result in condensation, then a three-way mixing valve may not be the best option. In that case, a four-way mixing valve might be a better option.

Four-Way Mixing Valve

The basic difference between three-way and four-way mixing valves is that four-way mixing valves (Figure 32) can control the water temperature and flow rates to both the supply piping and return piping to the boiler.

Cool return water is mixed with the hot supply water to achieve the desired temperature to supply the system. The valve also mixes hot supply water and cool return water to maintain boiler return water temperatures above 60° (140°F). This ensures that the water entering the boiler is hot enough to avoid any possible condensation issues.

Like the three-way mixing valve, a four-way mixing valve can be used either with or without an actuator to provide better mixed water temperature control. Motorized actuators for four-way valves often incorporate outdoor sensors to automatically raise or lower the system water temperature in response to changes in outdoor temperature. This control strategy is called outdoor reset.

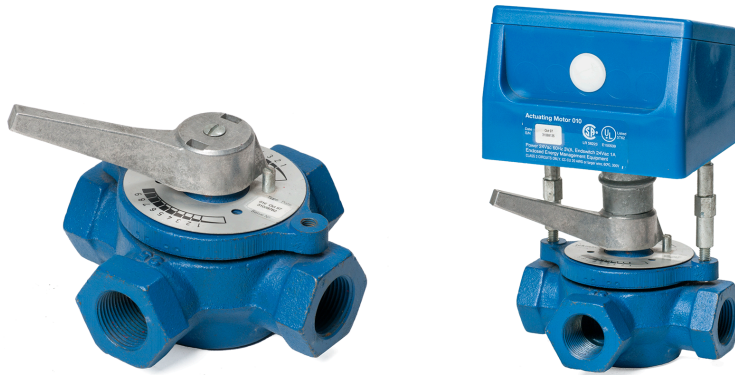


Figure 32 Four-way mixing valve. (Skilled Trades BC, 2021) Used with permission.

Figure 33 shows different internal water pathways and mixing created with different valve positioning.

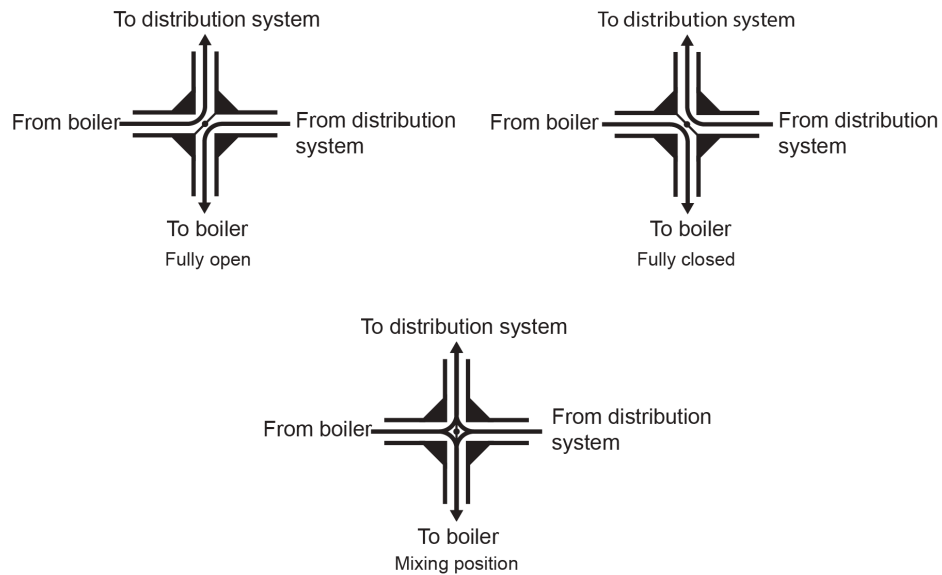


Figure 33 Inside a four-way mixing valve. (Skilled Trades BC, 2021) Used with permission.

Figure 34 shows the piping required for a four-way mixing valve configuration.

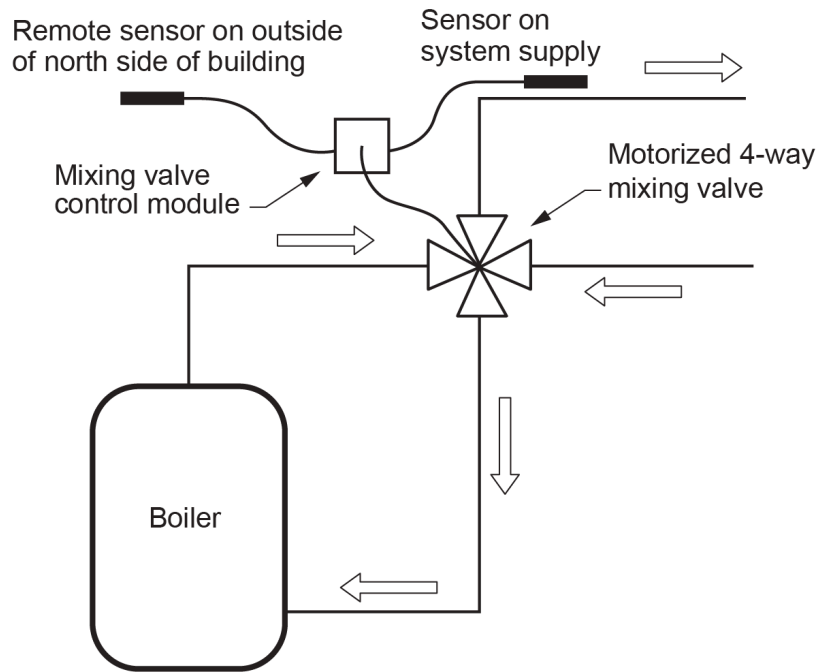


Figure 34—Four-way mixing valve piping arrangement. (Skilled Trades BC, 2021) Used with permission.



Self-Test B-4.2: Hydronic System Valves

Complete the chapter Self-Test B-4.2 and check your answers.

If you are using a printed copy, please find Self-Test B-4.2 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.





An interactive H5P element has been excluded from this version of the text. You can view it online here:
<https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=60#h5p-10> (<https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=60#h5p-10>)

References

- Sivaranjith [username]. (2018, April 4). Control valve characteristics [digital image]. automationforum.co. Retrieved from <https://automationforum.co/control-valve-characteristics/>
- Caleffi Hydronic Solutions. (2009, July). Figure 3-15, a 4-wire valve actuator, Zoning hydronic systems [digital image]. *idronics*TM (5), 2009, 16. <https://idronics.caleffi.com/magazine/15-separation-hydronic-systems>
- Caleffi Hydronic Solutions. (2010, July). Figure 3-15, direct-reading balancing valve, Hydronic balancing [digital image]. *idronics*TM (8), 2010, 21. <https://idronics.caleffi.com/magazine/8-hydronic-balancing>
- Caleffi Hydronic Solutions. (n.d.). Balancing valve with flow meter [product image]. <https://www.caleffi.com/en-int/balancing-valve-with-flow-meter-132-caleffi-132402>
- HPAC Magazine. (2017, December 18). Figure 3: Purging hydronic circuits [digital image]. In Siegenthaler, J. (author), "Hydronic circuit purging: The basics." Retrieved from <https://www.hpacmag.com/features/purging-hydronic-circuits/attachment/hpac-dec-2017-fig-3/>
- Nibco Inc. (n.d.). E-X-P[®] Tankless Water Heater Service Valves. Retrieved from <https://www.nibco.com/brands/webstone/e-x-p-series/e-x-p-TWH/>
- Nibco Inc. (n.d.). Pro-pal purge & fill [digital product image]. Retrieved from <https://www.nibco.com/nibco-products/valves/ball-valves-combination/h-x861/>
- MHS Radiators (n.d.). Sterling TRV [digital product image of radiator]. <https://www.mhsradiators.co.uk/product-item/sterling/>
- Skilled Trades BC. (2021). Book 1: Fuel gas systems, Heating and cooling Systems. Plumber apprenticeship program level 2 book 1 Harmonized. Crown Publications: King's Printer for British Columbia.
- Trades Training BC. (2021). B-4: Install hydronic heating piping and components. In: *Plumber Apprenticeship Program: Level 2*. Industry Training Authority, BC.
- Xylem. (n.d.). Bell & Gossett circuit setter plus calibrated balance valves [digital product image]. Xylem US. <https://www.xylem.com/en-us/brands/bell-gossett/bell-gossett-products/all-bell-gossett-products/circuit-setter-plus-calibrated-balance-valves/drawings/>

Media Attributions

All figures are used with permission from Skilled Trades BC (2021), licensed under a CC BY-NC-SA (<https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en>) license, unless otherwise noted.

- **Figure 6** Quick fill bypass arrangement by TRU Open Press. CC BY-NC-SA (<https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en>)
- **Figure 8** Purge valve/drain valve is by TRU Open Press. CC BY NC SA (<https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en>)
- **Figure 9** Wall hung boiler service valves (<https://www.nibco.com/brands/webstone/e-x-p-series/e-x-p-TWH/>) is by Nibco Inc. (n.d.) and is used with permission.
- **Figure 10** Purging air from system was modified by TRU Open Press, from original image in *HPAC Magazine* (<https://www.hpacmag.com/features/purging-hydronic-circuits/attachment/hpac-dec-2017-fig-3/>) (2017).
- **Figure 11** Double port purge valve (<https://www.nibco.com/nibco-products/valves/ball-valves-combination/h-x861/>) is by Nibco Inc. (n.d.) and is used with permission.
- **Figure 17** Wax filled zone valve actuator (<https://idronics.caleffi.com/magazine/5-zoning-hydronic-systems>) [Fig 3-15] is by Caleffi Hydronic Solutions (2009) and is used with permission.
- **Figure 21** Valve plug shapes modified by TRU Open Press from original image by Sivaranjith [username] in Automationforum.co (<https://automationforum.co/control-valve-characteristics/>) (2018) – used under Fair Dealing (https://laws-lois.justice.gc.ca/eng/acts/c-42/page-6.html#docCont:~:text=Exceptions-,Fair%20Dealing,-Marginal%20note%3A.)).
- **Figure 22** Sterling TRV radiator valves (<https://www.mhsradiators.co.uk/product-item/sterling/>) is from MHS Radiators (n.d.) and is used with permission.
- **Figure 23** Caleffi Quicksetter™ balancing valve is from Caleffi Hydronic Solutions (2010) and is used with permission.
- **Figure 25** Bell & Gossett circuit setter balance valve (<https://www.xylem.com/en-us/brands/bell-gossett/bell--gossett-products/all-bell-gossett-products/circuit-setter-plus-calibrated-balance-valves/drawings/>) is from Xylem (n.d.) and is used with permission.

B-4.3 Distribution Systems

The piping mains connect the boiler to the heat transfer units. In some piping layouts, the piping mains connect directly to the heat transfer units, while in others, the piping mains connect to piping runs or branches that lead to the heat transfer units.

Types of Piping Configurations

There are a number of piping configurations available that deliver heated water from the source to the emitter, and the name of each configuration usually describes how the piping arrangement is installed.

The piping layouts in hot-water heating are named as follows:

- One-pipe series loop
- One-pipe split-series loop
- One-pipe diversion tee
- Two-pipe direct-return
- Two-pipe reverse-return
- Two-pipe primary/secondary

Radiant panels are essentially heat emitters and, therefore, are not categorized as piping layouts. The specifics of radiant heat systems will be covered in Level 3 of Plumber and Steamfitter/ Pipefitter Apprenticeship training.

One-Pipe Systems

In one-pipe systems, hot water is circulated through a single pipe to a number of heat transfer units and back to the boiler. In some cases, the return pipe from one heat transfer unit is the supply pipe for the next unit. In all one-pipe systems, the heat transfer unit nearest to the heat source will receive much hotter water than units farther down the line. One-pipe systems are most common in residential buildings because of their lower installation cost.

As in all hydronic systems, air vents are required at every high point so that air does not form a blockage and prevent water from circulating. As well, drains are required at all low points to allow servicing of piping and equipment.

Series Loop Systems

In a series loop system (Figure 1), the supply main joins directly to the first heat transfer unit, the return pipe from this unit supplies the next unit, and so on. Finally, the return pipe from the last heat transfer unit returns the water to the boiler. It can be said that the heat transfer units are part of the piping main. Series loop systems and one-pipe systems are very similar.

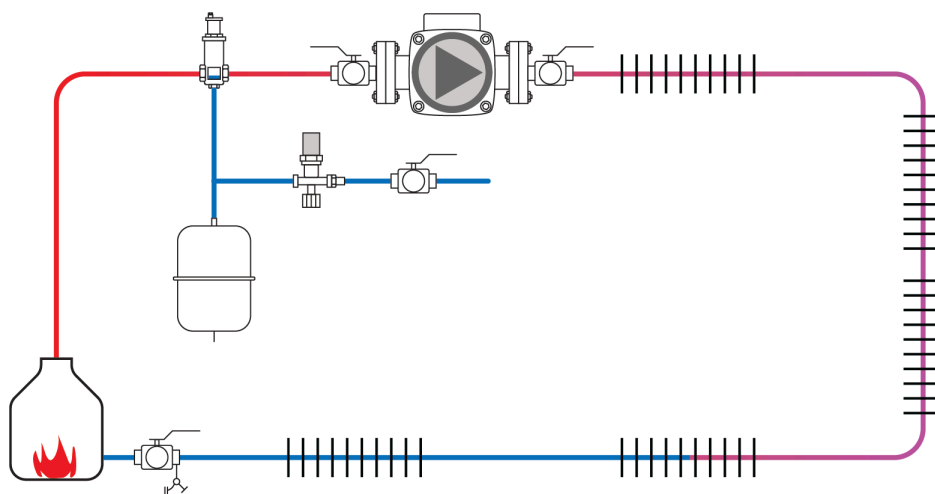


Figure 1 Series loop system. (Skilled Trades BC, 2021) Used with permission.

The series loop system is simple and is the least expensive system to install, but its heat transfer units cannot be individually shut off and should be progressively longer/larger in size, to give them equal heat output, the farther they are from the boiler. This is due to the lower water temperature available in the farther reaches of the system. A single pump responding to a lone thermostat controls the heat in the entire zone. This system is normally used in apartments or small single-family dwellings where the temperature will not vary much between rooms and the heat emitters are finned-tube baseboards. The temperature in any room is adjusted by allowing more or less airflow through each finned-tube baseboard cabinet by opening or closing the damper on the cabinet (see B-3 Hydronic Transfer Units (#part-b-3-hydronic-transfer-units)).

To avoid flow problems, one pipe size (normally $\frac{3}{4}$ in. NPS) should be maintained throughout a loop. The length of each loop and number of heat emitters on it becomes very important because the water releases heat and becomes cooler as it travels through each heat transfer unit. If return water to the boiler has had too much heat removed from it, condensation problems could occur, causing premature heat exchanger failure due to corrosion inside the combustion chamber. Therefore, a rule of thumb in the industry is that no more than 60,000 to 70,000 BTU/h (18–20 kW) should be allocated to each circuit in the system.

Split-Series Loop Systems

The split-series loop system (Figure 2) is a version of the series loop system, with the main difference being that the piping is split into a number of loops. Each loop is controlled by a thermostat connected to a zone valve that controls the heat flow to the heat transfer units within that loop.

In the split-series loop system shown in Figure 2, the supply main is piped from the boiler to the farthest outside wall. The main then splits and water is directed to each of the two loops. The return mains individually return the water to a point near the boiler, where they join together to become the boiler return. There can be more than just two loops in a split-series loop system, and the heat source would be sized to supply all the loops, but each loop is still limited to no more than 60,000 to 70,000 BTU/h output.

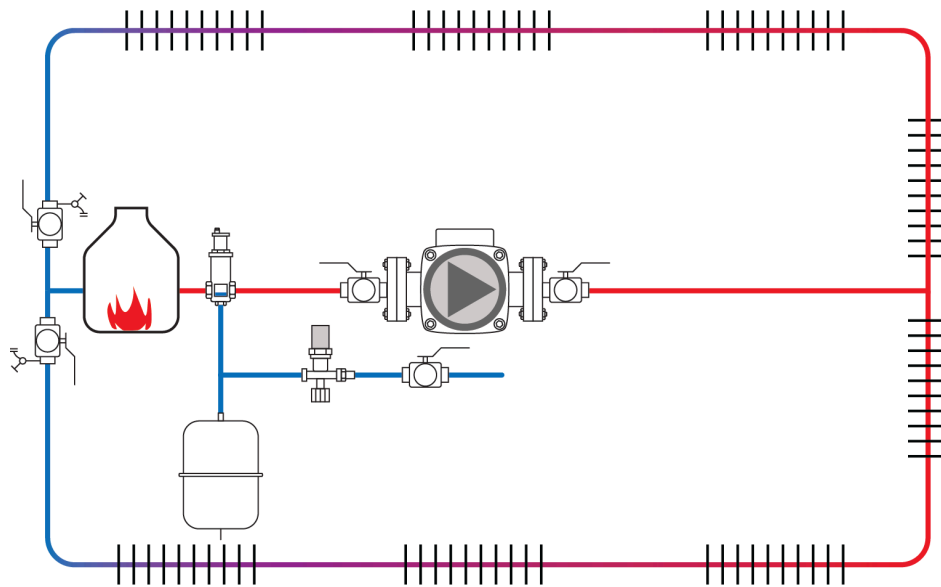


Figure 2 Split-series loop. (Skilled Trades BC, 2021) Used with permission.

The split-series loop system is suitable for larger buildings where there is a larger heat load, such as in small apartment blocks or similar structures.

One-Pipe Diversion Tee System

A diversion tee or Monoflo system is a one-pipe system, but the heat transfer units are placed on branch circuits, parallel to the main supply pipe. Any of the units may be shut off individually without disturbing the flow of hot water in the rest of the system. The layout of a one-pipe diversion tee system is shown in Figure 3.

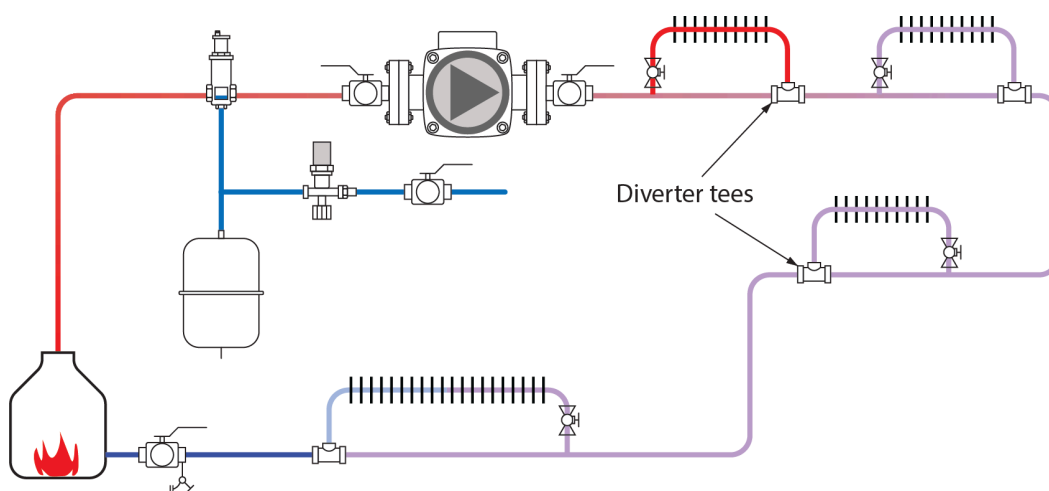


Figure 3 Diversion tee system. (Skilled Trades BC, 2021) Used with permission.

Diversion tees (Figure 4) are installed on the piping main to create flow through the branch piping. Monoflo is the trademarked name for a diversion tee that has been specifically engineered for use in hot-water heating systems. It operates through the use of a venturi and applies Bernoulli's principle, which states that "where velocity is greatest,

pressure is least.” For water to flow through the narrow opening within the tee, it must increase in velocity. This drops the pressure in an area behind the nozzle, which is where the branch outlet is connected, and water is drawn through the branch.

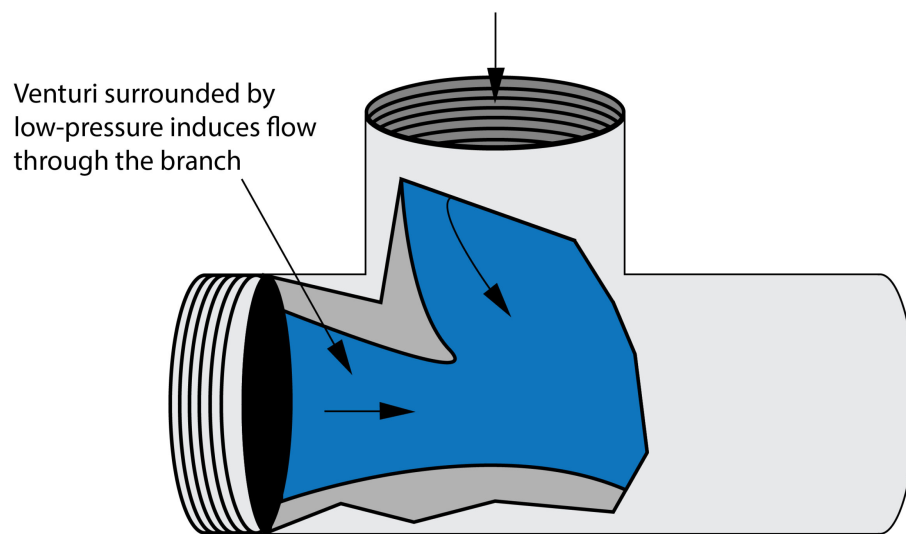


Figure 4 Diversion tee water flow pattern through main and return connection. ([adapted] Skilled Trades, BC, 2021). Used with permission.

To correctly install a Bell & Gossett (originator of the fitting) diversion tee on an **upfed system**, place the Monoflo tee on the heat emitter’s return connection, with the red ring groove closest to the standard tee on the supply connection. Only one tee is normally needed due to the tendency of hot water to rise easily through the standard tee on the supply (Figure 5). If the heat transfer unit has a lot of flow resistance through it, then install two Monoflo tees, similar to the downfed configuration described below. For upfed heat transfer units, the tees should be installed at least the length of the heat transfer unit apart.

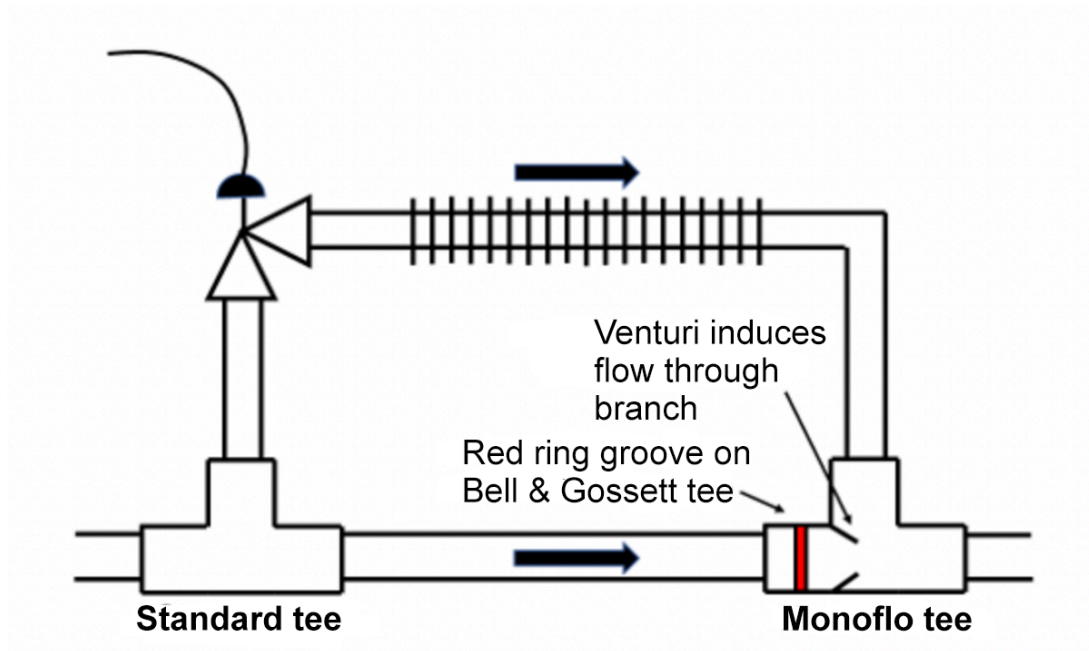


Figure 5 Upfed heat transfer unit. (Greg Wirachowsky/ Skilled Trades BC, 2021) Used with permission.

Downfed heat transfer units are located below the supply mains and require more definite flow diversion to make heated water fall below the main (Figure 6). Monoflo tees are installed on both the supply and return connections, with the red groove rings on the tees facing each other. The Monoflo tee on the supply acts to divert water flow through the branch outlet.

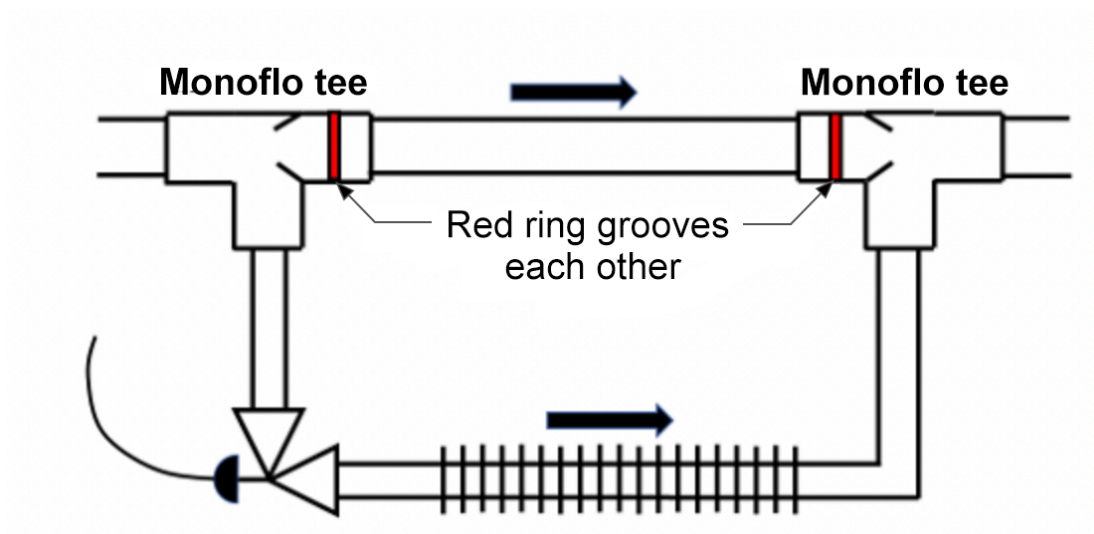


Figure 6 Down fed heat transfer unit. (Greg Wirachowsky/ Skilled Trades BC, 2021) Used with permission.

The diversion tee system is adaptable to almost any type or size of building, from a small single-family residence to a multi-storey office to an apartment complex. For more specific installation requirements, always consult the manufacturer's literature.

Two-Pipe Systems

Two-pipe systems have distinct supply and return mains. Water from the supply main is fed to each heat transfer unit and ends at the last HTU. The return water from each HTU is collected in a return main and delivered back to the boiler.

The supply main is gradually reduced in size as it feeds the circuits and, similarly, the return main is gradually increased in size as it receives the return water from each circuit. In this way, each heat transfer unit can and should receive water at the same temperature as when it left the boiler.

Two-pipe systems are generally found in large commercial or industrial buildings, or in smaller systems where better control of heat and flow is desired. Two-pipe systems are categorized as either direct-return or reverse-return.

Two-Pipe Direct-Return System

In a two-pipe direct-return system (Figure 7), each heat transfer unit has a supply line of hot water from the boiler and a return line to the boiler. This is also known as a “first fed, first return” system.

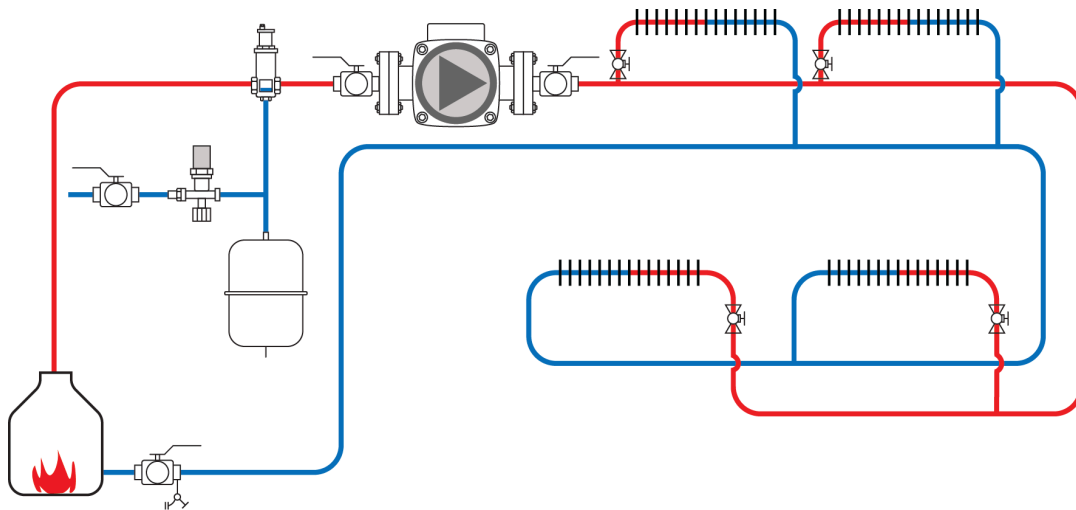


Figure 7 Direct-return system. (Skilled Trades BC, 2021) Used with permission.

A difficulty with direct-return systems is that the circuits from the boiler to different heat transfer units and back to the boiler are usually of different lengths. This difference in length influences the flow of water to certain units, which cause an imbalance of heat transfer. To counteract this imbalance, larger diameter pipes can be used for the longer circuits or the size of the heat transfer units on those units can be increased. The most common method of balancing the heat transfer is to install balancing valves at each heat transfer unit to restrict the flow. The heat transfer unit nearest the boiler would have its flow restricted more than those farther out along the supply line, with the farthest heat transfer unit not likely needing any flow restriction at all. When balanced, the resistance to flow through all the heat transfer units should be roughly equal to that of the furthest circuit.

A direct-return system can supply different amounts of heat simultaneously to a variety of equipment. The equipment may include heat exchangers and heat transfer units.

The direct-return system is unpopular for residential systems because it is:

- Difficult to balance
- More expensive to install because of the balancing components
- More expensive to maintain because of the balancing components

Two-Pipe Reverse-Return System

The two-pipe reverse-return system (Figure 8) was developed to provide a better balance of heat transfer between circuits of different lengths without the need for balancing valves. In the reverse-return piping layout, each circuit is of nearly equal length. The heat transfer unit that has the shortest supply pipe route has the longest return pipe route. Pipe size must still be matched to flow requirements in each section.

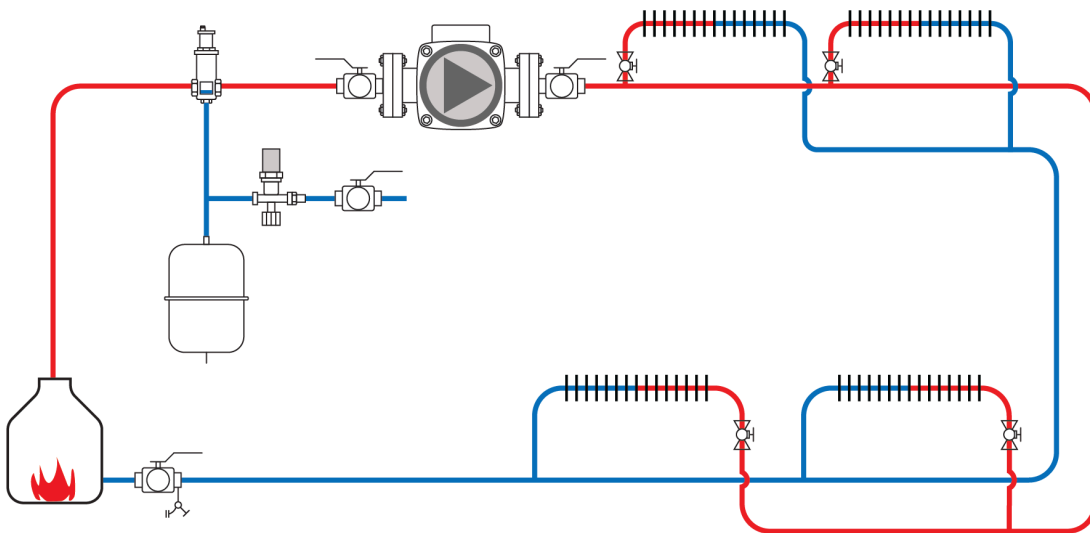


Figure 8 Reverse-return system. (Skilled Trades BC, 2021) Used with permission.

This system is also known as the “first fed, last return” system and is the most common system installed in commercial buildings.

Home-Run Distribution System

In the previously mentioned systems, it is assumed that rigid piping is used. The introduction of PEX (cross-linked polyethylene) in the piping industry has led to a piping system known as the home-run distribution system (Figure 9).

A home-run system consists of a supply and return manifold station placed in an easily accessible location within each dwelling, such as one for each storey. Supply and return mains to the manifolds are piped in a reverse-return configuration. In this way, the manifolds are treated much like heat transfer units and should have relatively equal temperatures of supply water available. From the supply manifold, a separate small-diameter PEX tube, such as $\frac{3}{8}$ in.

or $\frac{1}{2}$ in., is run to each heat emitter and then returns back to the return manifold. In this way, with throttling valves on the tubing at the return manifold connections, the flow of water to each heat emitter can be controlled. It is similar to

a radiant floor system in that each run leaves the supply manifold and returns to the return manifold, but a home-run system will have different heat emitters, such as a finned-tube baseboard (wallfin).

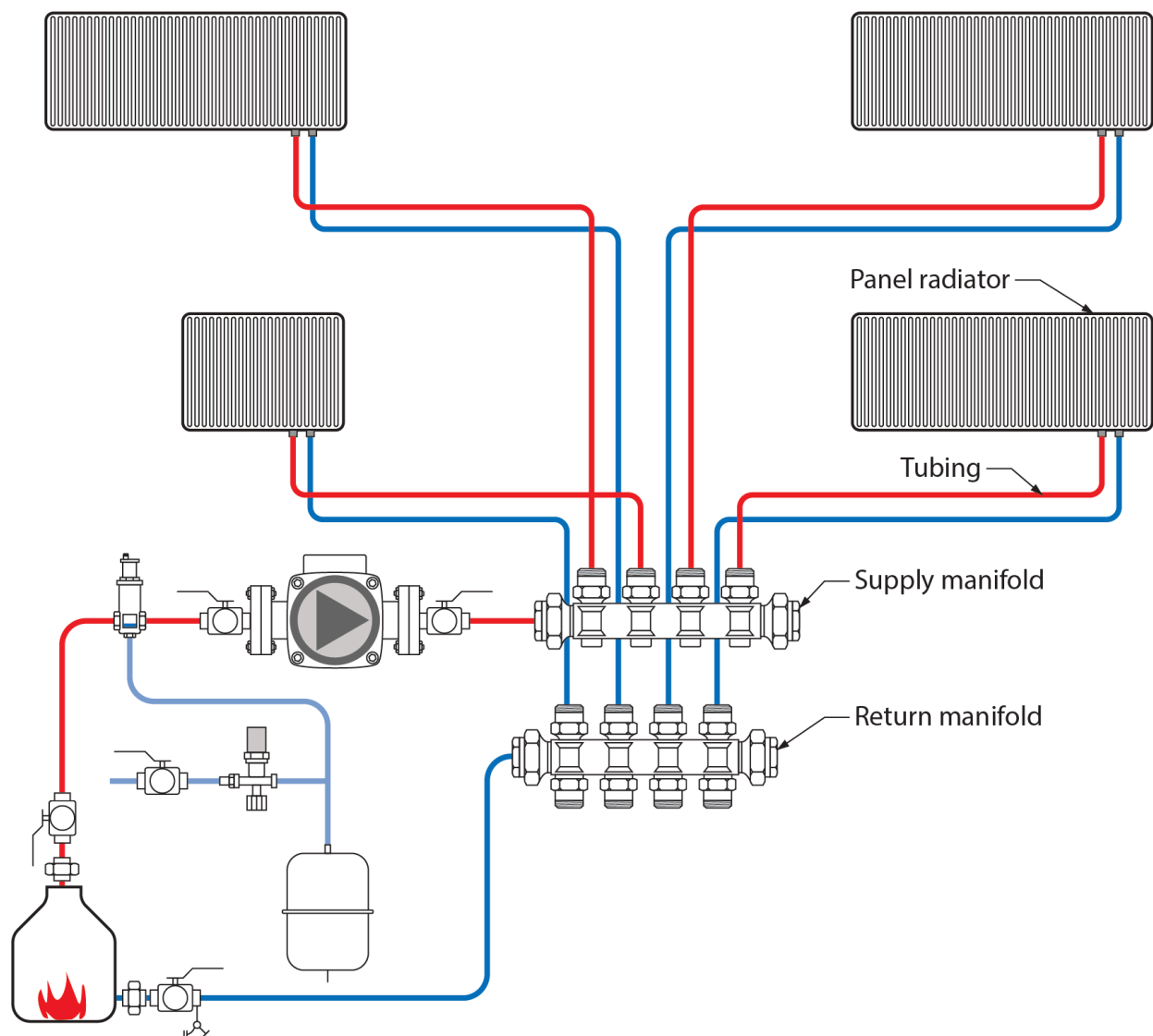


Figure 9 Home-run distribution system. (Skilled Trades BC, 2021) Used with permission.

The small diameter and flexibility of the PEX tubing allows for quick and easy installation. Some of the other benefits of the home-run system include the following:

- The heat output of each room can be individually controlled by flow rates.
- Water is delivered to each heat emitter at approximately the same temperature.
- Manifolds can be used in conjunction with a variety of heat emitters.
- Balancing valves can still be used to regulate flow through each separate home run.

Hydraulic Separation

In a hydronic system, it is often necessary to have two or more circulators operating simultaneously within the same system. Circulators work on the principle of creating a pressure differential between the inlet and outlet to move water. Ideally, each circulator works independently of the other, and the pressure differential created by one does not affect the other. When this occurs within a system, it is referred to as hydraulic separation. If the circulators create a situation where they interfere with each other, undesirable flow conditions can occur.

Primary/Secondary Systems

The degree to which two operating circulators interact with each other depends on the head loss of the piping path they have in common. Head loss is “pump-speak” for pressure loss. All systems need a pressure differential to create flow. If this common piping has low flow resistance through it, then very little head or pressure loss occurs.

The system shown in Figure 10 contains multiple pumps, each of which circulates water through a circuit. Hydraulic separation is achieved when the working of one pump does not affect the working of another. Once again, hydraulic separation is created when the head or pressure loss through common piping is limited. In Figure 10, the designer used what is known as closely spaced tees to achieve this effect. Spacing the tees closely together on common piping minimizes head loss between tees, thus ensuring hydraulic separation. If the tees were even only a few feet apart, there would be enough friction loss between the tees for flow through the primary circuit to cause small flows in the secondary circuit, which must be avoided.

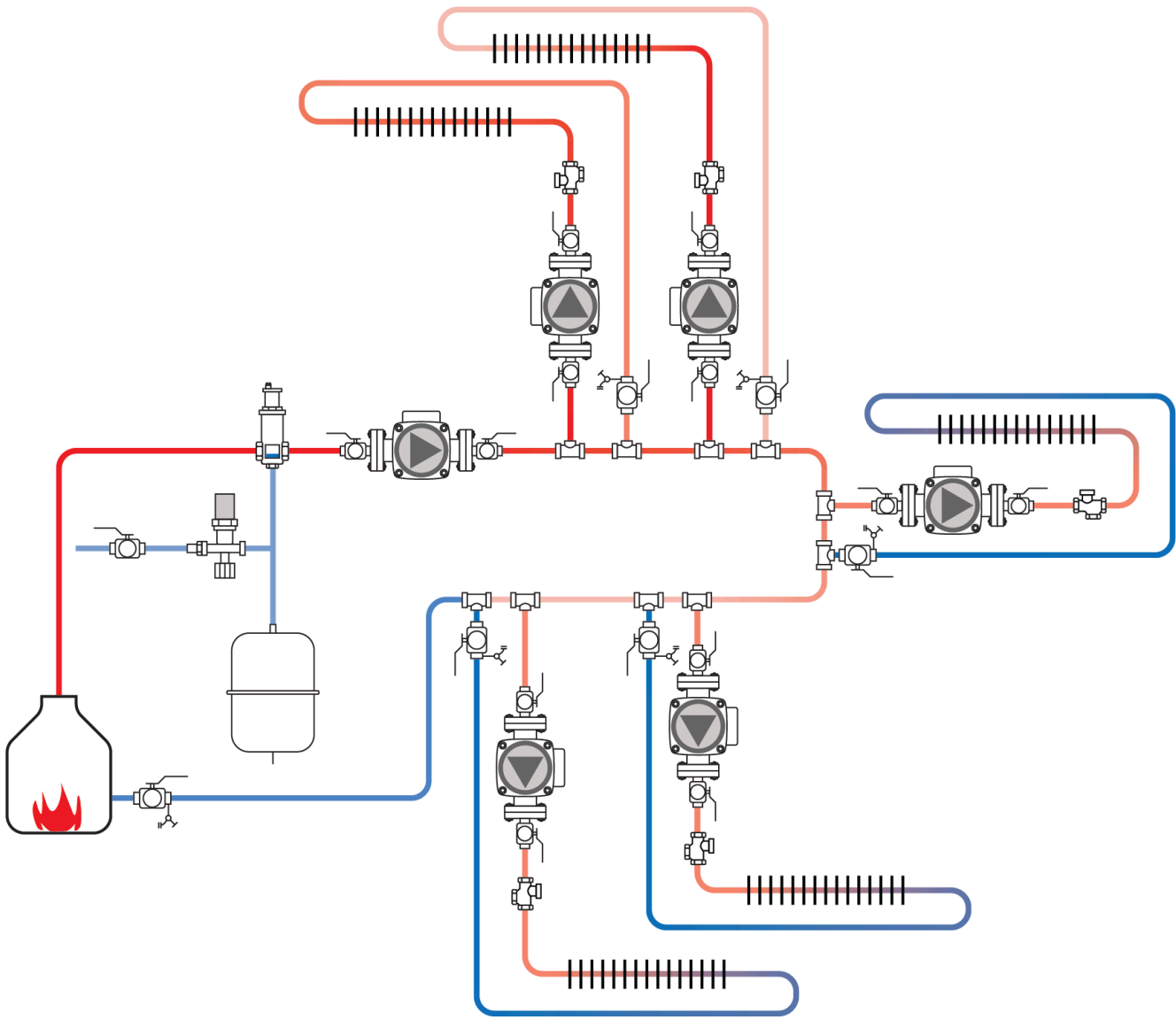


Figure 10 Primary/secondary system using closely spaced tees. (Skilled Trades BC, 2021) Used with permission.

The system illustrated in Figure 10 uses a piping system referred to as a primary/secondary system. Primary/secondary piping, originating in the 1950s, is one way to achieve hydraulic separation. Back then it was mainly used in large commercial heating and chilled water-cooling systems. Advances in technology and the complexity of residential and small commercial systems have led to an increase in the use of primary/secondary systems in those areas.

These systems consist of a primary circuit with secondary circuits connected to it. The primary circuit consists of a pump and piping large enough to carry the expected heating water for the entire system and long enough to have space for the closely spaced tees for the secondary circuits. This circuit has no other function than to keep a hot supply of water flowing through it.

The secondary circuits involve the heat source(s) and different types of heating loads. These loads could be for space heating, domestic water heating, pool heating, or any other heating load desired. Primary/secondary piping is ideal for systems with multiple smaller boilers, rather than one large boiler, feeding into the primary circuit as needed or when different heating circuits are connected to the same boiler.

All primary/secondary systems require protection against the tendency for hot water to migrate into and through

inactive secondary circuits. This occurs because the less-dense hot water tends to rise. Although the closely spaced tees offer hydraulic separation when the pump is operating, they do not protect against thermal migration (**thermosiphoning**).

Thermal migration can be limited using circulators with integral spring-loaded check valves or installing an external spring-loaded check valve, known as a flow check. Thermal migration can also be limited with the use of a thermal trap (Figure 11). The thermal trap discourages convection currents from moving through it and into the system.

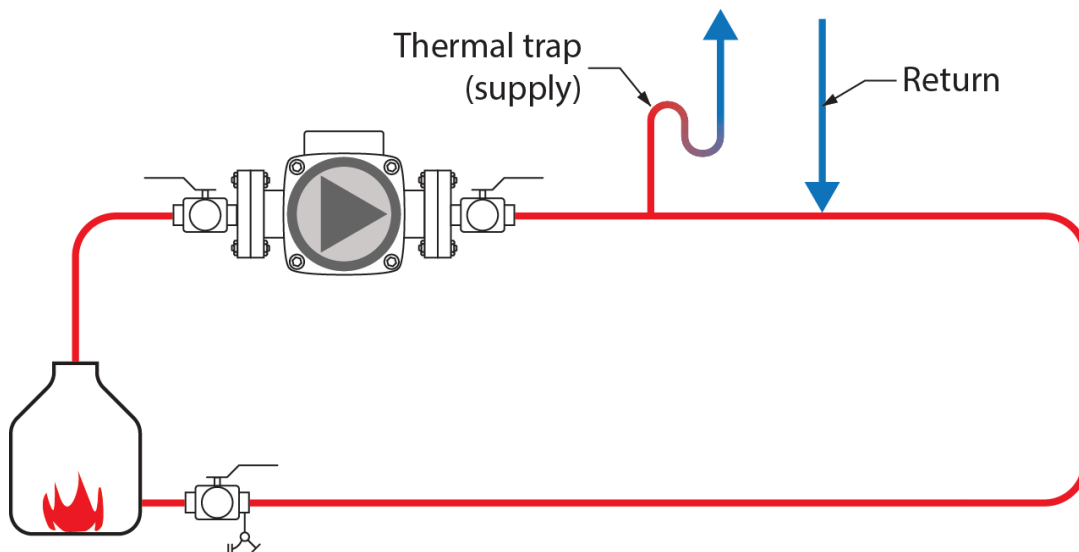


Figure 11 Thermal trap used to lessen the effects of thermal migration. (Skilled Trades BC, 2021) Used with permission.

Besides using closely spaced tees, hydraulic separation can also be accomplished using a hydraulic separator or low-loss header. Both use a large-diameter vertical chamber to slow down the water flow rate. This vertical chamber is generally three times larger in diameter than the diameter of the system piping. Slowing the water down creates very little head loss through the chamber and ultimately creates the hydraulic separation needed between systems to be effective (Figure 12).

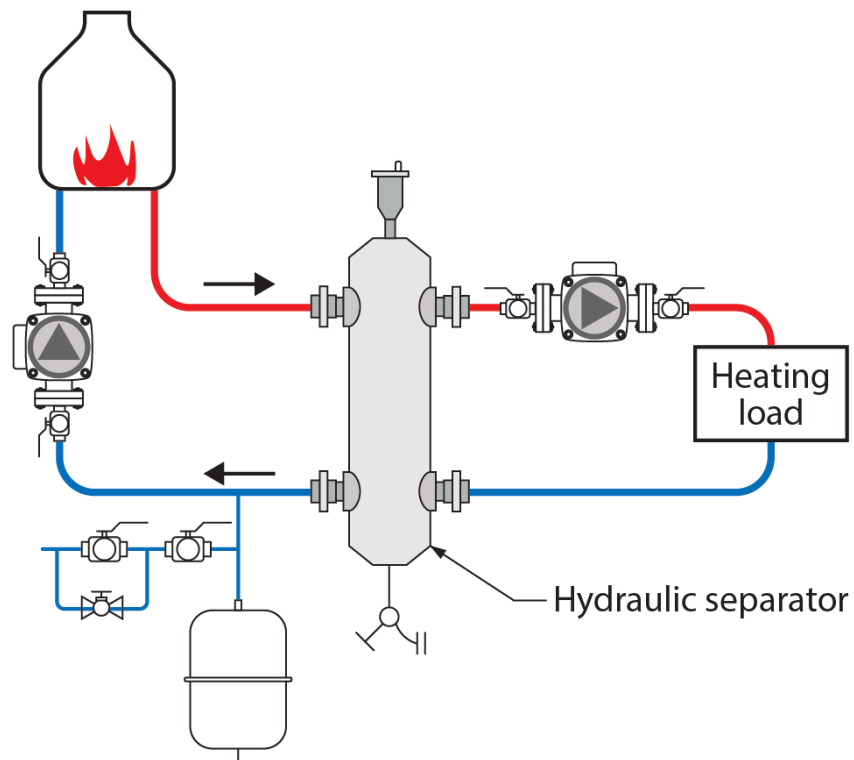


Figure 12 Hydraulic separator piping arrangement. (Skilled Trades BC, 2021) Used with permission.

The unit shown in Figure 13 also provides high-efficiency air and dirt separation for the system.



Figure 13 Hydraulic separator. (TRU Open Press) CC BY NC SA
(<https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en>)



Self-Test B-4.3: Distribution Systems

Complete the chapter Self-Test B-4.3 and check your answers.

If you are using a printed copy, please find Self-Test B-4.3 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.



An interactive H5P element has been excluded from this version of the text. You can view it online here:
<https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=62#h5p-11> (<https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=62#h5p-11>)

References

Skilled Trades BC. (2021). Book 1: Fuel gas systems, Heating and cooling Systems. Plumber apprenticeship program level 2 book 1 Harmonized. Crown Publications: King's Printer for British Columbia.

Trades Training BC. (2021). B-4: Install hydronic heating piping and components. In: *Plumber Apprenticeship Program: Level 2*. Industry Training Authority, BC.

Media Attributions

All figures are used with permission from Skilled Trades BC (2021) unless otherwise noted.

- **Figure 13** Hydraulic separator is by TRU Open Press and can be used under a CC BY NC SA (<https://creativecommons.org/licenses/by-nc-sa/4.0/deed.en>) license.

B-4.4 Distribution System Installation

As mentioned earlier, piping layouts are categorized by the configuration of the supply and return mains. Piping branches, also called runouts, connect the mains to the heat transfer units through drops, stubs, and spring pieces. All of these terms lack clear-cut definitions that relate to their sizing, in contrast to the definitions of piping in drainage, waste, and venting systems. Mains, **risers**, and branches are all sized according to the amount of heat they need to transport.

Regardless of the names describing the parts of a hydronic system, piping must be designed to prevent air blockages within the system. The correct installation of piping must also prevent the buildup of stress that would cause damage and leaks.

Parts of the Distribution System

The following terms identify pipes in hydronic systems:

- Supply main
- Return main
- Branch or spring piece
- Riser
- Runout
- Stub
- Drop

Supply and Return Mains

The supply and return mains are typically attached to the boiler in all systems except primary/ secondary and carry all of the system water to the other pipes. In larger buildings, the supply and return mains are usually run down a hallway, while the heat transfer units are positioned along the outside walls. This pattern is repeated on every storey.

Figure 1 shows piping connected to supply and return mains. Note that the spring pieces are installed to minimize the effects of expansion and contraction of the piping and are classified as branches.

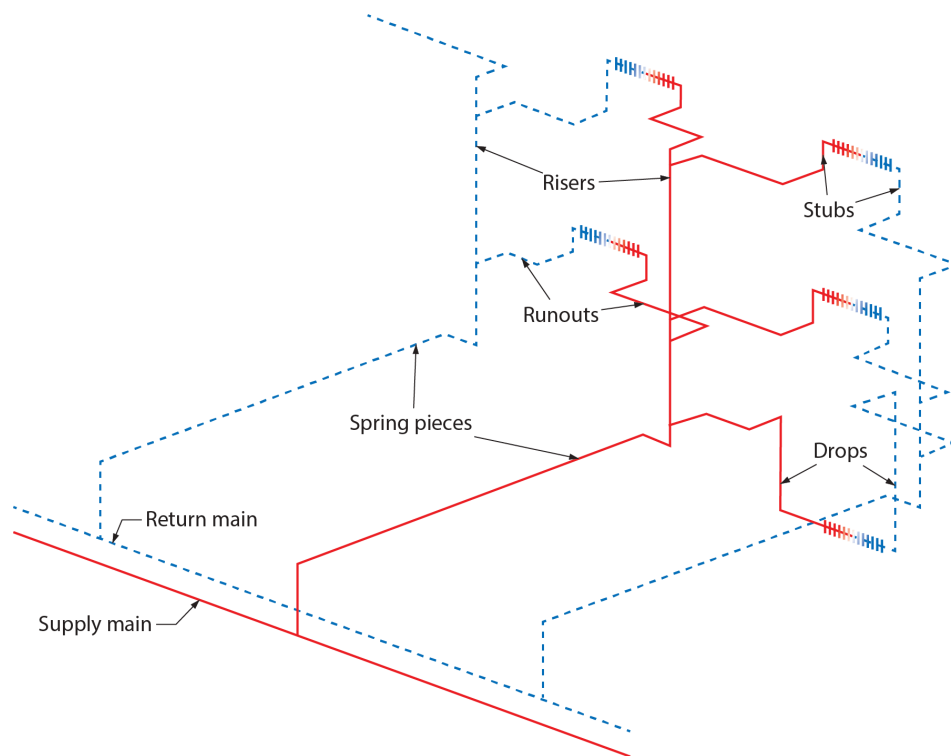


Figure 1 Heating runs.

Branches, Spring Pieces, and Risers

A branch in piping is simply a pipe connected to a main, much the same as a branch of a tree is connected to the trunk of the tree. Branches connect the heat transfer units to the mains via drops and stubs. A spring piece is a branch that connects a main to a riser. A riser runs vertically to the highest floor in the building and is usually located within an interior wall near the outside wall. This keeps the riser within the heating portion of the building, preventing freezing. The distance from this location to the heat transfer units is normally kept fairly short. Figure 2 shows the location of the riser.

Piping branches must be designed to prevent the buildup of stress through thermal expansion and contraction as well as to prevent air blockages within the pipes. Risers must be protected from stresses caused by thermal expansion, building shrinkage, and settlement.

Runouts

A runout is a horizontal pipe that connects the heat transfer unit to a riser or main. Runouts may connect directly to the heat transfer unit or by way of a stub or drop. Runouts may also form a series loop along the outside wall. Runouts on outside walls are usually installed below the floor, between the floor joists, which prevents them from freezing. Figure 2 shows how runouts are installed with respect to an outside wall.

Stubs and Drops

A stub is a short vertical pipe connected to a runout that passes up through a floor to a heat transfer unit. A drop runs down from a runout to a heat transfer unit.

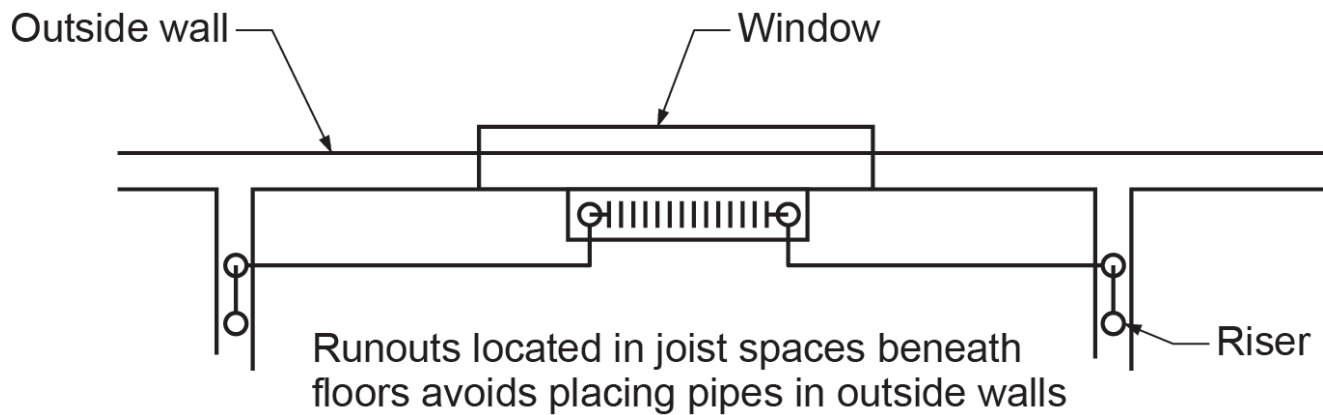


Figure 2 Standard piping practices for runouts near an outside wall.

Thermal Expansion and Other Forces

Pipes and connections can crack and leak if subjected to severe stresses. These stresses are created by thermal expansion and other forces that make a component move with respect to others. Allowance must be made for these movements to minimize these stresses.

All materials expand when heated. This is called thermal expansion. As a pipe becomes warmer, it becomes longer. When water in a 30 m (100') steel pipe is heated from its fill temperature of approximately 10°C (50°F) to operating temperature of 82°C (180°F), the pipe will become 25 mm (1 in.) longer. Copper tubes expand at a similar rate, and plastic tubes expand even more. Boilers, heat transfer units, and other components are also affected by thermal expansion, but these components are stationary, so they cannot be modified.

Other forces that cause stress in a hot-water piping system are fluid surges, pipe misalignments, impacts, and movements during an earthquake. The buildup of stress through thermal expansion and other forces is prevented using:

- Swing joints
- Expansion loops
- Expansion bellows
- Oversized holes through building structures

Swing Joints

Swing joints, such as spring pieces (Figure 3), are used to conveniently install piping that allows for stresses and for

grade. Making a swing joint involves adding three or more elbows and connecting pipes to a piping run. The changes in direction created by the swing joint provide offsets that can move without breaking as pipes expand and contract.

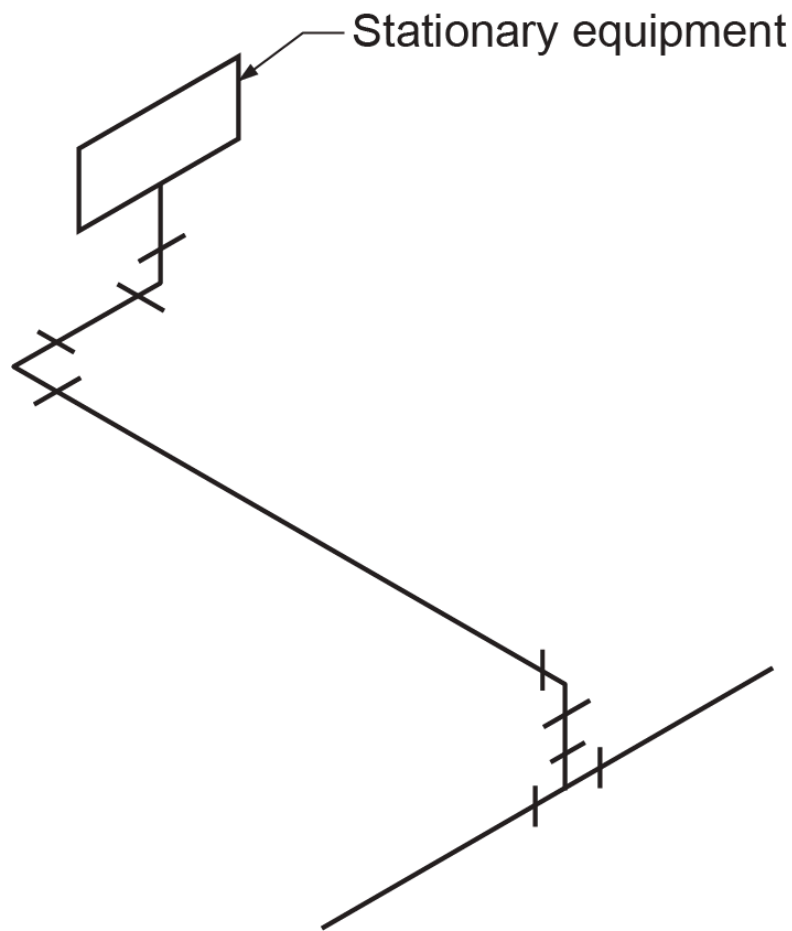


Figure 3 A swing joint (spring piece).

Figure 4 shows how a swing joint reacts to thermal expansion. The stub is rigidly fixed to the supply main. As the water in the supply main becomes warmer, the supply main expands so the stub moves in the direction of flow. The offset to the stationary component allows enough motion to prevent significant stress. The movement of swing joints responds to other forces as well.

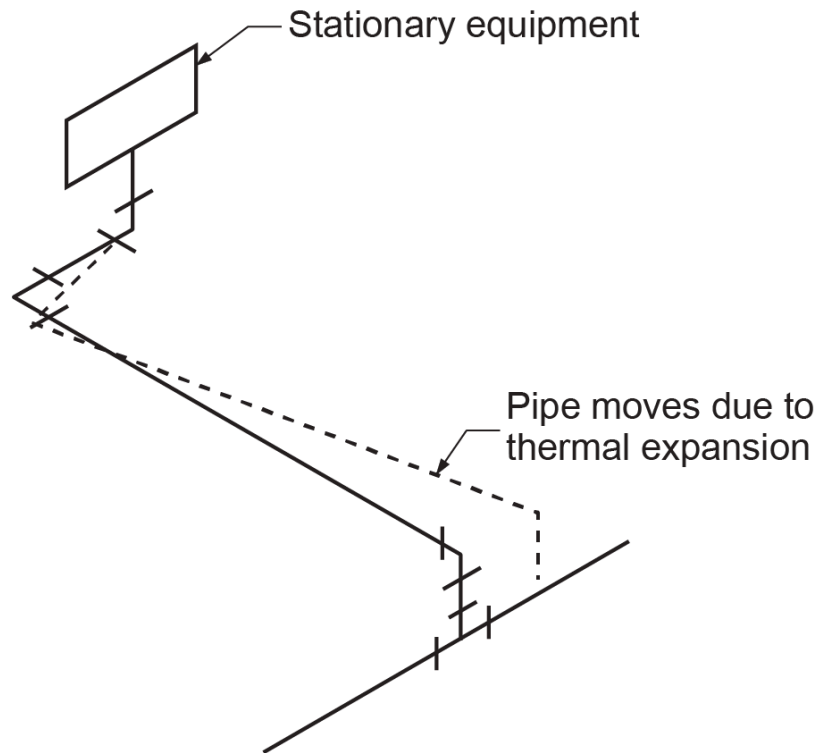


Figure 4 Movement of swing joint caused by thermal expansion.

Ease of Installation

Swing joints make installation and repair easier and leaks less likely. Swing joints make it easier to install a pipe with grade for draining and air elimination and easier to align fittings. For threaded pipe installations, alignment of threaded connections is less difficult if the installer is able to use an extra fitting to take up slight misalignments. A tee in a main is often not well positioned for good alignment. Turning the tee on the main would loosen one side and possibly cause a leak, but an extra elbow installed at the main would allow easy alignment and hook-up.

The elbows in swing joints can be 90° elbows or a combination of 45° and 90° elbows. Figure 5 shows the differences between 45° and 90° swing joint configurations.

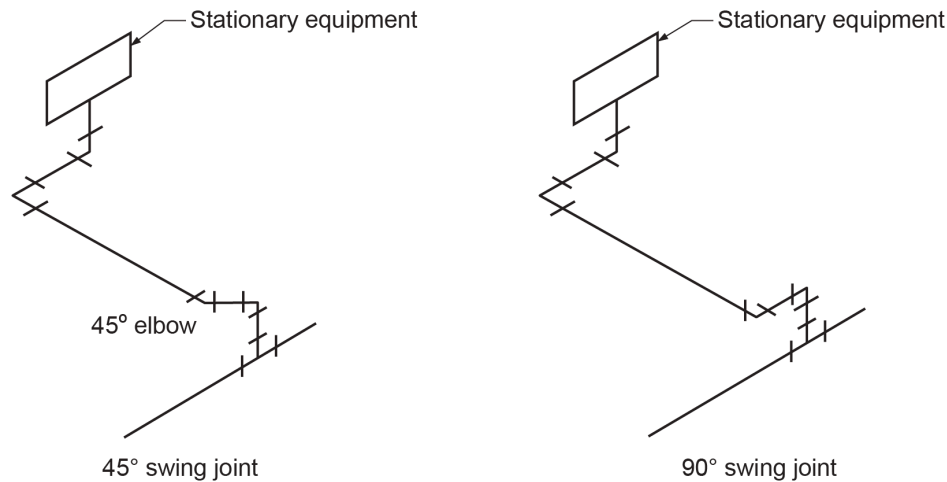


Figure 5 Swing joint configurations.

Expansion Loops

Expansion loops are a variation of a swing joint. Expansion loops allow a pipe to change in length as parts of the loop twist or bend. An expansion loop may be either U-shaped or scissor type (Figure 6). Expansion loops are most commonly used on long mains.

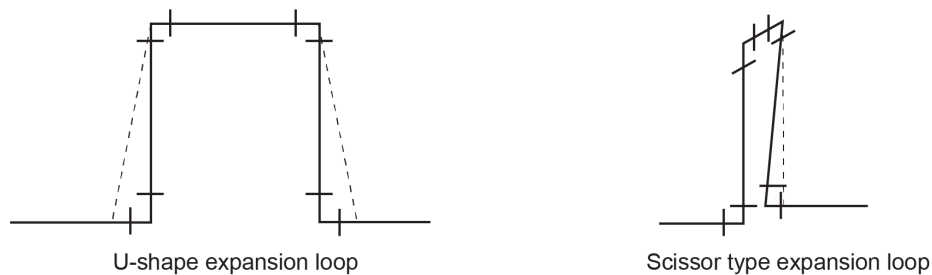


Figure 6 Plan views of U-shaped and scissor-type expansion loops.

Expansion Bellows

An expansion bellows has the same function as an expansion loop. However, the expansion bellows is made of materials, such as reinforced butyl rubber or corrugated metal, that collapses like an accordion when adjoining pipes expand. In other words, the expansion bellows becomes shorter as the pipes become longer and are much more compact than expansion loops.

Oversized Holes Through Building Structures

There must be room for pipe movement in any hole a pipe goes through. In some jurisdictions, the size of the holes is

also specified by local seismic codes. For commercial applications, specific requirements for installation will be detailed by the mechanical engineer in the drawings and specifications. For instance, a 3 m (10 ft) horizontal pipe will expand 2.5 mm ($\frac{1}{8}$ in.) through its operating temperature range. If this pipe is connected to two vertical pipes that pass through a floor, the vertical pipes will move away from one another by 2.5 mm.

Pipes will expand in diameter as well as in length. To allow for both directions of expansion, drill all holes a minimum of 12 mm ($\frac{1}{2}$ in.) larger than the size of the pipe. After installing the pipe, seal the hole to prevent air leaks and create fire stops. Grommets or silicone caulk will seal the hole but still allow the pipe to expand and contract.

Prevention of Air Blockage

The installation of piping requires paying attention to more than just the prevention of stress caused by thermal expansion and contraction. Of equal importance is the control of air within the system. Pockets of air can cause a reduction in the transfer of heat as well as no heat transfer at all. Installing piping correctly will help to minimize or eliminate problems caused by the accumulation of air within the system piping.

Air blockage is prevented using:

- Correct grade on piping
- Vent tees at high points

Grade

Air blockages are prevented by installing some grade (slope) to piping runs. Horizontal runs must grade slightly upward in the direction of flow to allow air to move along with the heated water and reach an air vent. This grade can range from almost perfectly level to a rise of 4 mm/m (four millimetres per metre), which equates to roughly $\frac{1}{2}$ inch per 10 feet. The amount of grade will depend on the amount of space available and the ability to install swing joints to make up any misalignment caused by one pipe having grade and another not.

Although it is acceptable to install pipes in a level manner, it is advisable to install them with some grade so that air will be sure to clear the system. Figure 7 shows horizontal runouts that slope (exaggerated) upward, in the direction of flow, to vented high points.

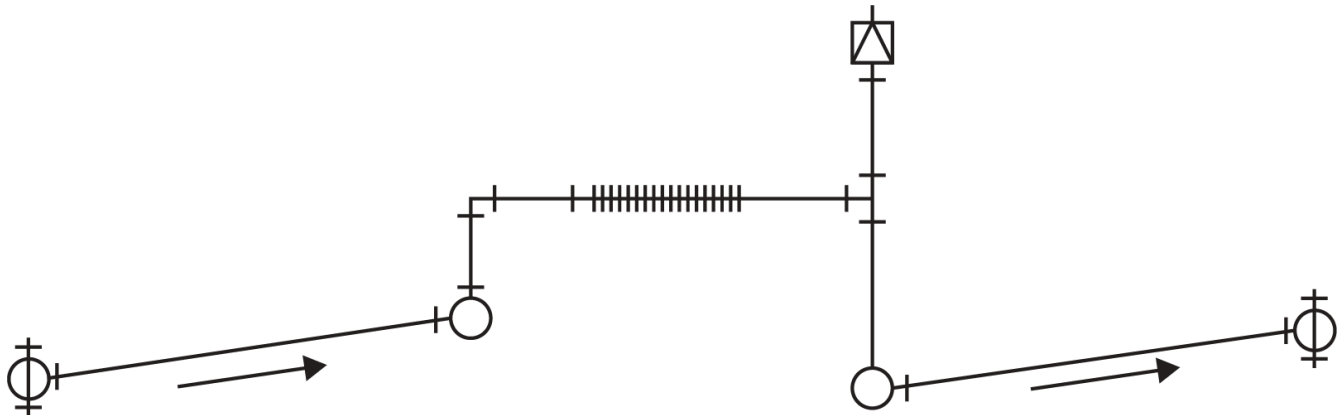


Figure 7 Horizontal runouts sloping upward in the direction of flow.

Air vents should be located at all high spots, where air will naturally accumulate. Occasionally, upward slope in the direction of horizontal flow involves the installation of an extra air vent. The extra air vent should be installed where it will be easily accessible, so that it can be serviced. Figure 8 shows the same runout as in Figure 7, but with an extra vent installed. If it appears that an air vent is going to be situated in an inaccessible area, do not install it there. Instead, run a vent pipe upward to an open area and install the vent there.

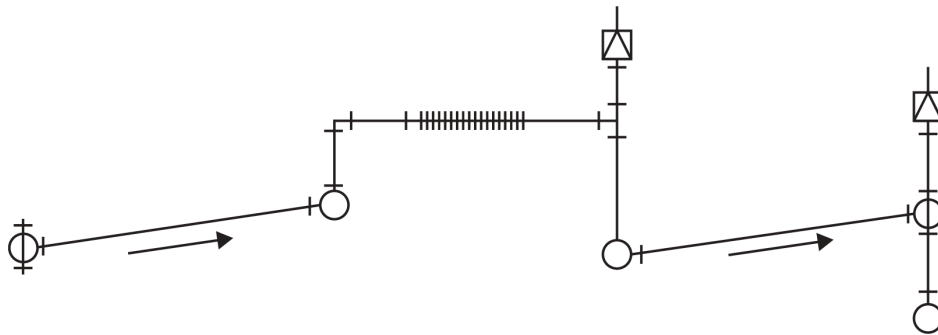


Figure 8 Extra vent installed.

Pumps Cannot Clear Air Blockages

Air blockages cannot be overcome by the pressure or flow developed by a heating system circulator and should be avoided. A pump is designed to overcome the friction of the piping as it pushes the water through the heating system. Velocities in hot-water heating systems are far slower than when the heating system was initially purged, and therefore any air that accumulates at high points cannot be carried downward and to an air eliminator by a pump.

A heating system must be entirely full of water so that the pump is not required to lift the water, only to move it. All circuits of a hot-water heating system must have water flow to deliver heat. When there is an air blockage in a circuit, there is not enough pressure for the air to be forced through the system. Water flow is then redirected to other heating circuits not obstructed by air.

Zoning in a Hydronic System

A zone is a heating area controlled separately from other heating areas. Each zone is typically controlled by its own thermostat.

Installing zones in a hot-water heating system allows for:

- Greater comfort
- Lower operating cost
- Better temperature control in buildings with areas difficult to heat

Zoning makes a building more comfortable because it can provide each area with the amount of heat appropriate to its heat loss. Zoning saves money because not all areas require the same temperature (occupied as opposed to unoccupied) and because people are less likely to open windows if they are comfortable. Temperature control is possible in buildings with comfort challenges because every part of the building can be given a different piping or control strategy.

Selecting Zones

A hydronic system should be divided into zones if rooms or areas within the building have differences or similarities of factors, such as:

- Heat losses
- Orientation
- Occupancy
- Use patterns
- Floor constructions
- Glazing

The larger a building, the greater the need for zones.

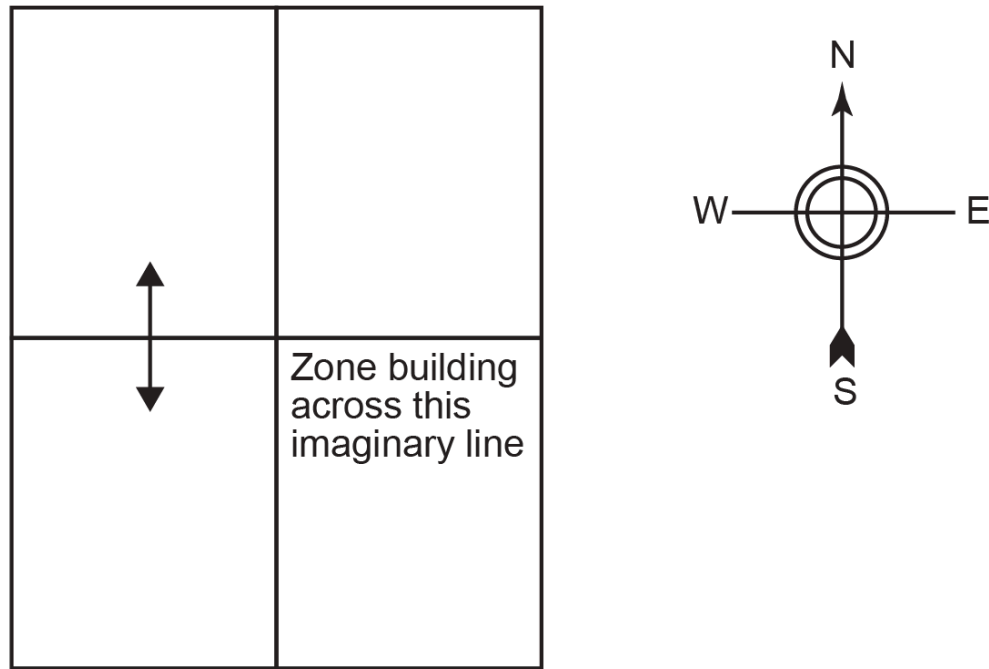
Different Heat Losses

Every room or space will experience heat loss differently. To achieve the same temperature in every room, each room requires a different amount of heat. Installing one zone for every room enables the system to supply a required amount of heat to each room, although this will increase the cost of installation.

Orientation

The orientation of a building will determine on which sides the sun will influence the temperature of the rooms. Consider the square building in Figure 9. The rooms on the southeast receive heat from the sun in the morning. On the southwest side, however, the sun is not contributing heat, so heat is in greater demand. If the thermostat were in an east room, it would reduce the demand for heat in the morning, and the west room would be cold.

In the afternoon, the west room would receive heat from the sun and the east room would not. Since the thermostat is in the east room, it signals for high heat transfer, which makes the west room too hot. If the building were divided into four zones as shown in Figure 9, both these situations would be avoided. However, it is usually only necessary to use two zones because during the heating season, the sun rises in the southeast and sets in the southwest. Thus, more heat is needed in the cooler north side.



Zone 1 - Heating units on north and west walls
Zone 2 - Heating units on south and east walls

Figure 9 Zones in a building lying north and south.

Occupancy

There is also a greater need for zoning in commercial buildings than in residential ones. An office worker, for instance, will not wish to spend much of their workday fussing with dampers on baseboard heaters, while homeowners are more likely to take on those type of issues. These days, large buildings are usually controlled by remote means. Occupants call, text, or email a building operator to relay information on the level of discomfort they are feeling, and the building operator can make adjustments from a computer, sometimes in a different city or province. Most commercial buildings no longer give the occupants control of the room thermostats. Thermostats have been replaced by remote sensors.

Use Patterns

The intended use of each area will influence the desired temperature. Infrequently used rooms should be separately zoned so they may be set at a lower temperature to conserve energy.

In a home, some rooms, such as a playroom or a work area, are used for high-energy activities. These activities will be more comfortable if the temperature is somewhat lower than normal. Other rooms will be used for low-energy activities, such as watching TV or eating. These activities will be more comfortable if the temperature is somewhat higher.

Sleeping is a low-energy activity, but bedrooms should generally be kept at a lower temperature because bedding provides the necessary comfort. The level of clothing worn varies with the room as well. Less clothing is worn in a bathroom than in a living room, and heat loss from a person who is wet after getting out of a shower or bathtub will be much higher than normal, so the temperature is usually kept higher.

Commercial buildings usually have one or two types of activity, such as shopping and office work. The energy level of the activity and the amount of clothing that people will wear should be considered when selecting zones.

Industrial buildings may require different heat zones. Industrial processes, such as agriculture, manufacturing, and warehousing, may require a particular temperature or number of air changes per hour. This makes proper zoning critical. These processes often produce waste heat, which must be calculated before zones can be selected.

Use patterns may change over the life of the building. Zones should be versatile enough to accommodate changes in use patterns. The installation of flow-balancing valves in each zone can help minimize the impact to the rest of the system by altering flow rates when changes in use occur.

Different Floor Constructions

If radiant floor panel heating is used, different floor constructions require different zones. Concrete and wood allow the passage of heat but at very different rates. The type of thermostat used for a concrete floor installation is different from that used for a wood floor installation. As a result, the same zone cannot include these two types of floor construction without proper design and planning.

Additional Heat Gains and Losses

Consider additional heat gains and losses when selecting zones. Additional heat gains result from activities, such as cooking or bathing, or from the operation of the boiler or other equipment. Additional losses result from frequently opened doors or windows. In commercial and industrial buildings, additional gains may result from industrial processes, lighting, operation of equipment, or occupants.

Most large commercial buildings will typically have a higher rate of heat gain than heat loss. Lighting, the people themselves, and especially computers emit much heat, so the cooling systems tend to have more work to do and are, therefore, larger than the heating systems.

Higher storeys of a building require less heat than lower storeys because of the stack effect. The stack effect refers to the movement of heat upward in a multi-storey building. The heat moves up elevator shafts and staircases and, to some extent, through the floors themselves.

The amount of heat gained through exposure to the sun is influenced by the orientation of the building, amount of window area, and amount of shade created by trees or roof eaves.

South-facing windows can contribute a significant amount of heat (solar gain). East- and west-facing windows may

contribute some heat. North-facing windows cannot produce a heat gain regardless of their construction. Wide eaves and other objects, such as trees or other buildings, in close proximity can shade the window and reduce the amount of exposure to the sun.

Windows may have a heat gain when it is sunny, but they will always have a heat loss when there is no sun. The heat loss through windows is reduced if multi-glazed windows or insulating drapes are installed. The presence of a large window area increases the need for precise local zone control. The amount and type of glazing will minimally affect the heat loss in a residential home but will significantly affect the heat loss in a very large building.

Residential and Commercial Zones

In both residential and commercial hot-water heating systems, a zone is a primary division of the piping system. In a residential system, a zone is normally the smallest division, whereas in a commercial system, the zones are further divided into sub-zones.

In a residential system, using finned-tube baseboards, each zone is typically a one-pipe circuit that starts and ends near the boiler or manifold off of the supply and return mains.

Each zone is controlled by a thermostat and zone valve. There is normally one zone for every major room or cluster of small rooms of a house (Figure 10).

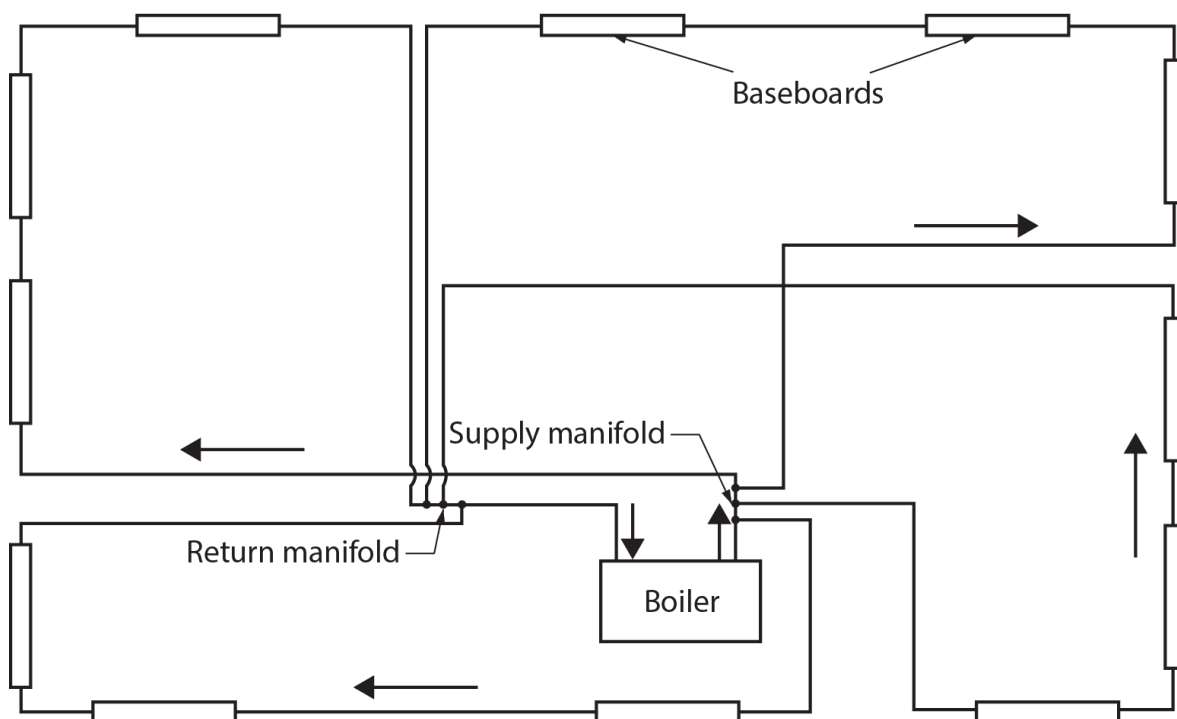


Figure 10 A residential hot-water baseboard system that has four zones.

In a commercial system, each zone is typically a two-pipe system supplying many circuits that start and end near the boiler. There is normally one zone for every wing of a large building. The rooms within the wing are served by circuits that connect to the zone piping. Zone valves are installed on each circuit. Figure 11 shows a commercial system that has four zones, with four circuits in each.

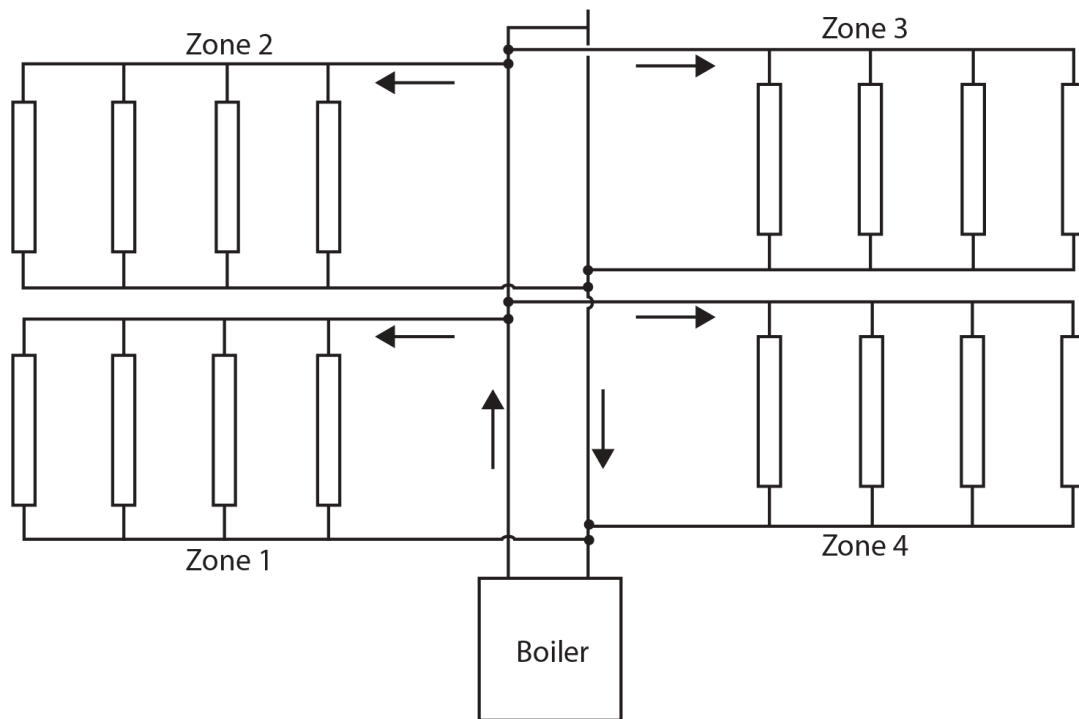


Figure 11 A commercial system that has four zones, with four circuits in each.

Piping a System With Zone Valves

Every zone requires its own piping run, thermostat, and zone valve or pump. In a single-pump system, there is only one pump on the supply main or on the return main (Figure 12). The zone valves are shown installed on the return piping of each zone, near where the return main joins the boiler.

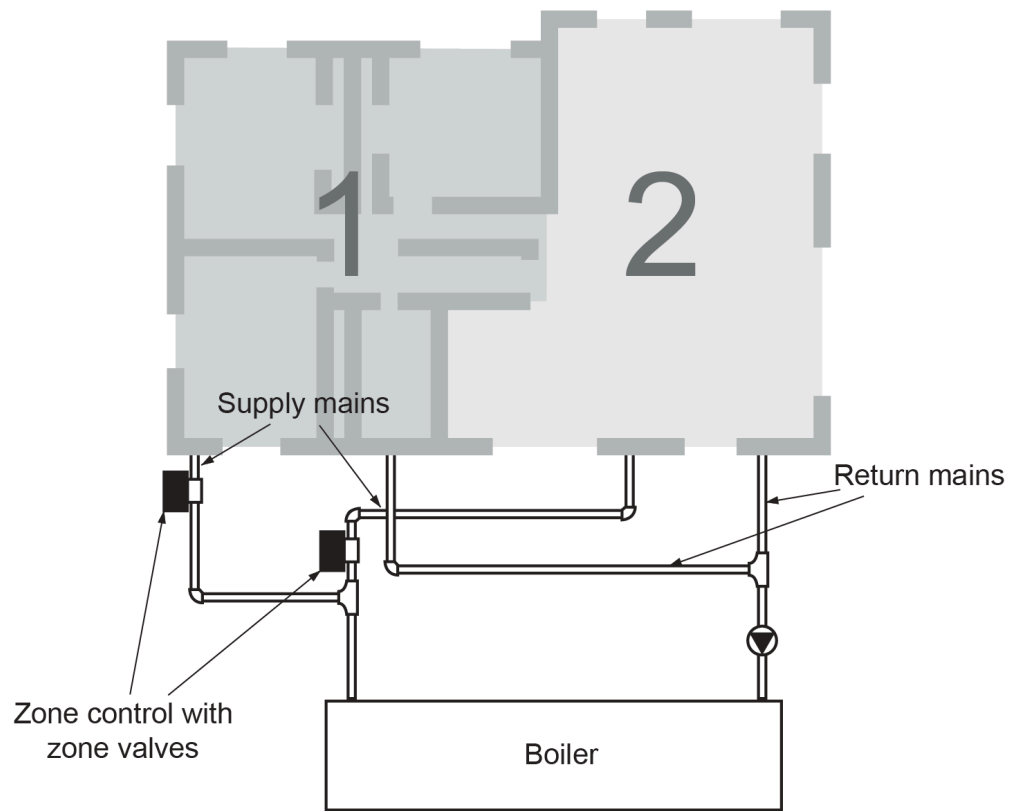


Figure 12 Zone valves and one pump.

In a multiple-pump system (Figure 13), there is a pump on the supply piping to each zone and a zone or flow control valve on the return piping from each zone.

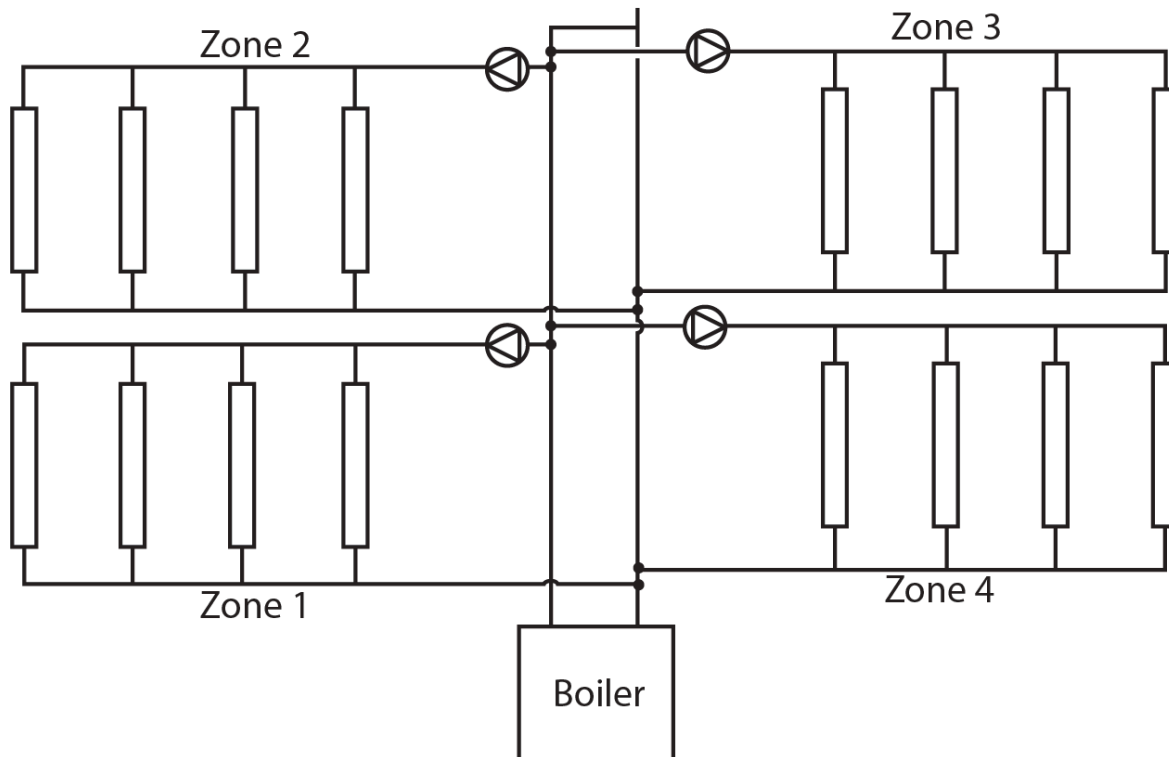


Figure 13 Flow control with multiple pumps.

Balancing a Hot-Water Heating System

Balancing is the measurement and control process used to obtain the required flow in hot-water circuits. Balancing valves adjust the flow through circuits by restricting the flow. The system is balanced for flow before the operating controls are adjusted.

Here are some of the reasons why balancing is necessary:

- The circuits must be balanced to obtain design flow in the boiler.
- Fluctuations in flow reduce the efficiency of the heat transfer units and make control difficult.
- The distribution system must be balanced to make sure that all heat transfer units get design flow.
- The control loops must be balanced to bring about the proper working conditions for the control valves and to make primary and secondary flows compatible.

Balancing a Series Loop System

The series loop system has all of its heat transfer units connected end to end, so there is only one circuit and no balancing valves, but a number of series loops can be combined in a multi-zoned system. In that case, the zones are supplied by mains that are either direct-return or reverse-return, so the zones must be balanced accordingly.

The split-series loop system has two circuits that come off a common supply main. In a split-series loop system, a balancing valve is installed at the beginning of each circuit to be able to control the flow to that circuit.

Balancing a Diversion Tee System

The diversion tee system does not use balancing valves. Diversion tees are used to induce flow through the heat transfer units, so any throttling done on any of the runouts or mains would defeat the purpose of the diversion tees. Each heat transfer unit is equipped with a valve for allowing or stopping flow.

A number of diversion tee circuits can be combined in a multi-zoned system. The zones are supplied by mains that are either direct-return or reverse-return. The zones must be balanced according to the heating requirements for each zone.

Balancing a Reverse-Return System

The layout of a reverse-return system results in a well-balanced system. Balancing valves may be required in some complex systems, but the majority of the simple systems do not require balancing valves.

Balancing a Direct-Return System

Direct-return systems are normally installed for commercial or industrial applications and have many zones and sub-zones. Due to the complexity of balancing direct-return systems for large buildings, this work is often performed by contract firms that specialize in this process.

Every circuit of a direct-return system should have a balancing valve installed in the return pipe. If the balancing valve contains a drain, the location on the return pipe will also allow the circuit to be drained without having to drain other piping. Balancing valves are usually installed where they are easy to access and where there is minimal turbulence within the piping. Also, by placing all balancing valves in the same location relative to the other circuits, such as where they all connect to the system return main, it will be easier to balance the system flows.

To ensure accurate flow measurements at a balancing valve, install a straight pipe line a minimum of five pipe diameters upstream of the valve and two pipe diameters downstream. Do not install any fittings within these distances. If the balancing valve is installed downstream of a pump or other component that creates strong disturbances in flow, increase the minimum length of straight pipe upstream of the valve to 10 pipe diameters.

How Balancing Valves Affect One Another

Flow adjustment at one balancing valve disturbs the flow at the other balancing valves, including those that have already been adjusted. Balancing methods differ in how they compensate for this interaction.

Figure 14 compares the flow through each of five heat units when all the balancing valves are open (left diagram) to when the valve on one unit is closed (unit 3 in right diagram). When that valve is closed, the flow in all the other heat transfer

units will change, but not proportionally. The flow in the farther away heat transfer units will increase the most (from 100 to 109.7 in unit 5), while the flow in the closer heat transfer units will increase less, with the closest one increasing the least (from 100 to 102.8 in unit 1). The flow rate of 100 has been chosen at random to show the change and is not indicative of any system operation.

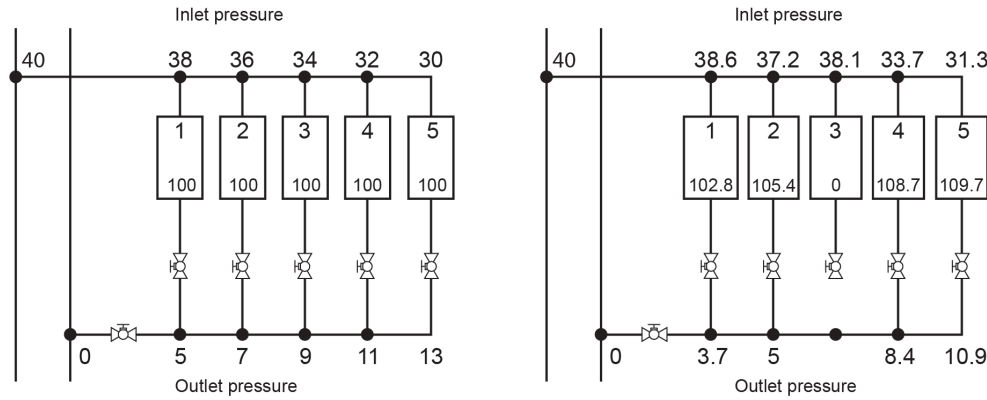


Figure 14 Flow change when one valve is closed.

Optimum balancing is achieved when the heat transfer units all receive their design flow and the balancing valves impose the least restriction on the flow.

After balancing a system, it is important that the valve actuators (handles, etc.) are locked in place or marked to discourage any inadvertent tampering. If system maintenance is necessary, always take note of the balancing valve positions to ensure that they are reset properly after maintenance is completed.



Self-Test B-4.4: Distribution System Installation

Complete the chapter Self-Test B-4.4 and check your answers.

If you are using a printed copy, please find Self-Test B-4.4 and Answer Key at the end of this section. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.



An interactive H5P element has been excluded from this version of the text. You can view it online here:
<https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=64#h5p-12> (<https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/?p=64#h5p-12>)

References

Skilled Trades BC. (2021). Book 1: Fuel gas systems, Heating and cooling Systems. Plumber apprenticeship program level 2 book 1 Harmonized. Crown Publications: King's Printer for British Columbia.

Trades Training BC. (2021). B-4: Install hydronic heating piping and components. In: *Plumber Apprenticeship Program: Level 2*. Industry Training Authority, BC.

Media Attributions

All figures are used with permission from Skilled Trades BC (2021) unless otherwise noted.

Self-Test B-4.1 Hydronic Distribution System Components

Complete Self-Test B-4.1 and check your answers.

1. Where is the ideal location for a pump?
 - a. Immediately downstream of the point of no pressure change
 - b. Immediately upstream of the point of no pressure change
 - c. Anywhere downstream of the boiler
 - d. Anywhere upstream of the boiler
2. The pump in a hot-water heating system is also called a cavitator.
 - a. True
 - b. False
3. What is the location where the compression tank and its piping join the system piping called?
 - a. Point of no return
 - b. Point of no pressure change
 - c. Circulation point
 - d. Static fill point
4. A strainer should be installed upstream of the pump.
 - a. True
 - b. False
5. Some circulators have water-cooled and lubricated motors.
 - a. True
 - b. False
6. What effect will oversizing a circulator cause?
 - a. Lower system heat output
 - b. A marked increase in intake pressure
 - c. Noisy operation
 - d. No noticeable effect
7. What do closed-loop systems with pumps use to accommodate volume expansion?
 - a. Overflow
 - b. Expansion tank
 - c. Solution tank

- d. Standpipe
8. If volume expansion is properly accommodated, the pressure will not increase significantly in a closed system when the water is heated.
- a. True
 - b. False
9. What occurs as water is heated in a hot-water heating system?
- a. Contraction
 - b. Radiation
 - c. Expansion
 - d. Reduction
10. Complete the following statement: "Air contained in fresh water _____."
- a. Immediately separates and rises
 - b. Slowly separates and rises
 - c. Increases the water density
 - d. Remains mixed as long as the water is heated
11. Complete the following statement: "Mixed air separates more quickly when the _____."
- a. Water is heated
 - b. Water is cooled
 - c. Flow is greater
 - d. Turbulence increases
12. Which one of the following is **not** normally added through the use of a chemical pot feeder?
- a. Degreasing agents
 - b. Corrosion inhibitors
 - c. Lubricants
 - d. Glycol
13. What purpose do air vents serve on a heating system?
- a. Allow air to enter as required
 - b. Maintain the correct water-to-air mixture
 - c. Separate air from water
 - d. Remove air from the system
14. Complete the following statement: "Automatic air vents open when the _____."
- a. Pressure within them drops
 - b. Temperature within them drops
 - c. Water level within them drops

- d. System requires more air
15. What component's operation is interrupted if the LWCO (low-water cutoff) operates?
- a. Circulator
 - b. Burner
 - c. Thermostat
 - d. Mixing valve
16. When possible, purging valves should be located downstream of components such as circulators and heat exchangers so that the system debris is drawn through these components.
- a. True
 - b. False
17. When there is a choice of more than one pump that meets the system requirements, it is usually best to choose the pump with the flattest curve.
- a. True
 - b. False
18. What are the effects of an oversized hydronic heating circulator?
- a. Decreases efficiency
 - b. Higher flow velocity and friction head
 - c. Higher than design heat emitter operating temperature
 - d. All of the above

Answer Key: Self-Test B-4.1 (#chapter-answer-key-self-test-b-4-1) is on the next page.

Answer Key: Self-Test B-4.1

1. a. Immediately downstream of the point of no pressure change
2. b. False
3. b. Point of no pressure change
4. a. True
5. a. True
6. c. Noisy operation
7. b. Expansion tank
8. a. True
9. c. Expansion
10. b. Slowly separates and rises
11. a. Water is heated
12. d. Glycol
13. d. Remove air from the system.
14. c. Water level within them drops
15. b. Burner
16. b. False
17. a. True
18. d. All of the above

Self-Test B-4.2 Hydronic System Valves

Complete Self-Test B-4.2 and check your answers.

1. A boiler's relief valve senses and reacts to what characteristic(s) of water?
 - a. Pressure
 - b. Temperature
 - c. Temperature and pressure
 - d. Pressure or vacuum

2. What is the purpose of balancing valves?
 - a. Maintain the correct water-to-air mixture
 - b. Ensure equal flow of water through each circuit
 - c. Achieve the design flow for each heat transfer unit or circuit
 - d. Ensure continuous flow in the system

3. What is the purpose of flow check valves?
 - a. Balance flow
 - b. Protect the potable water supply
 - c. Stop thermal siphoning
 - d. Isolate heat transfer units

4. Why is a differential pressure bypass used?
 - a. Protects the boiler
 - b. Ensures continuous flow
 - c. Flushes the system
 - d. Relieves high pressure from the radiators

5. What is the normal pressure setting on a feedwater or pressure-reducing valve for a residential hydronic system?
 - a. 160–180 psig
 - b. 68–72 psig
 - c. 40–54 psig
 - d. 12–20 psig

6. The feedwater valve should be located where in relation to the backflow preventer?
 - a. Downstream of the backflow preventer
 - b. Upstream of the backflow preventer
 - c. Parallel to the backflow preventer
 - d. On the opposite side of the piping as the backflow preventer

7. What is the purpose of a backflow preventer?
 - a. Prevents thermal siphoning
 - b. Creates continuous flow throughout the heating system
 - c. Prevents contamination of the domestic water supply
 - d. Creates positive pressure within the system

8. The backflow preventer, feedwater valve, isolation valves, and bypass all combine to form what part of the hydronic system?
 - a. Zone of reduced pressure
 - b. Makeup water line
 - c. Thermal bypass loop
 - d. Boiler bypass

9. Where should the pressure relief valve on a residential boiler be located?
 - a. On the high point of the system piping
 - b. Just downstream of the system circulator
 - c. On the boiler
 - d. On the return piping next to the purge valve

10. What does a purge valve purge?
 - a. Water out of the system on initial filling
 - b. Air out of the system on initial filling
 - c. All impurities out of the system during operation
 - d. Air out of the system during operation

11. Complete the following statement: "Balancing valves operate best when _____."
 - a. 25% open
 - b. Between 25% and 50% open
 - c. Between 50% and 100% open
 - d. 100% open

Answer Key: Self-Test B-4.2 (#chapter-answer-key-self-test-b-4-2) is on the next page.

Answer Key: Self-Test B-4.2

1. a. Pressure
2. c. Achieve the design flow for each heat transfer unit or circuit
3. c. Stop thermal siphoning
4. b. Ensures continuous flow
5. d. 12-20 psig
6. a. Downstream of the backflow preventer
7. c. Prevents contamination of the domestic water supply
8. b. Makeup water line
9. c. On the boiler
10. b. Air out of the system on initial filling
11. c. Between 50% and 100% open

Self-Test B-4.3 Distribution Systems

Complete Self-Test B-4.3 and check your answers.

1. In this system, the flow through one heat transfer unit cannot be shut off without stopping the flow in the other heat transfer units.
 - a. Series loop
 - b. Diversion tee
 - c. Direct-return
 - d. Reverse-return

2. Which of the following systems provides the most uniform heat?
 - a. Series loop
 - b. Diversion tee
 - c. Direct-return
 - d. Radiant panel

3. Which system is a one-pipe system in which flow can be diverted to individual heat transfer units?
 - a. Series loop
 - b. Diversion tee
 - c. Direct-return
 - d. Reverse-return

4. In which system is it easiest to balance heat transfer units?
 - a. Series loop
 - b. Diversion tee
 - c. Direct-return
 - d. Radiant panel

5. Which system is also known as a first fed, first return system?
 - a. Series loop
 - b. Diversion tee
 - c. Direct-return
 - d. Radiant panel

6. What does a diversion tee use to induce flow in the branch?
 - a. Balancing valve
 - b. Friction loop
 - c. Venturi
 - d. Zone valve

7. What system is shown in Figure 1?
- Series loop
 - Diversion tee
 - Direct-return
 - Reverse-return

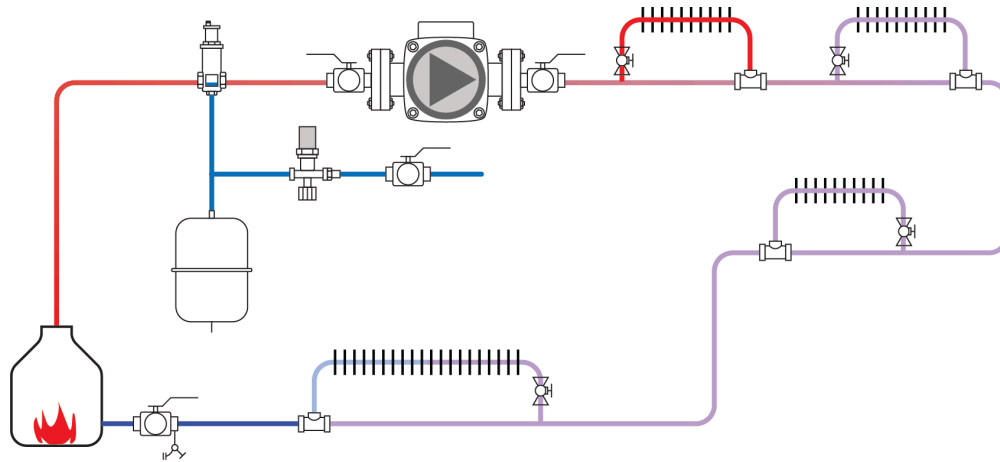


Figure 1

8. What system is shown in Figure 2?
- Series loop
 - Diversion tee
 - Direct-return
 - Reverse-return

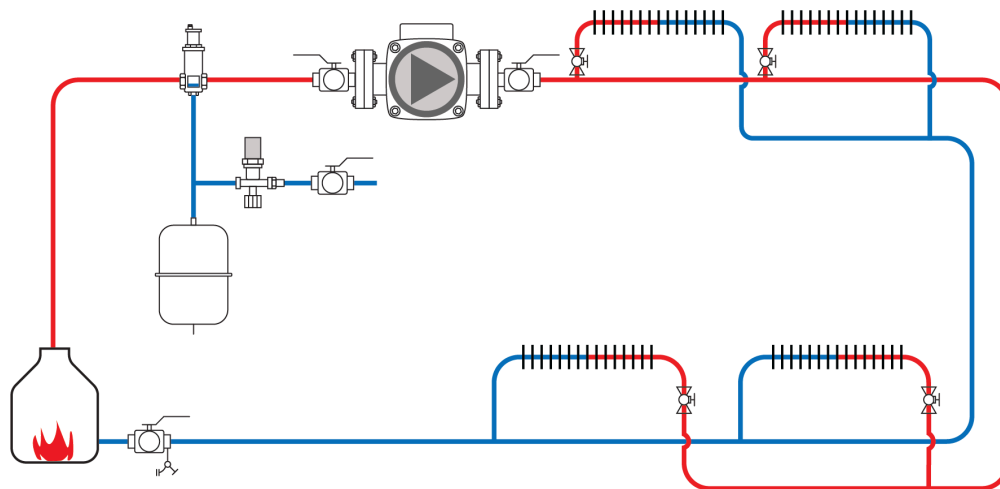


Figure 2

9. What system is shown in Figure 3?
- Series loop

- b. Diversion tee
- c. Direct-return
- d. Reverse-return

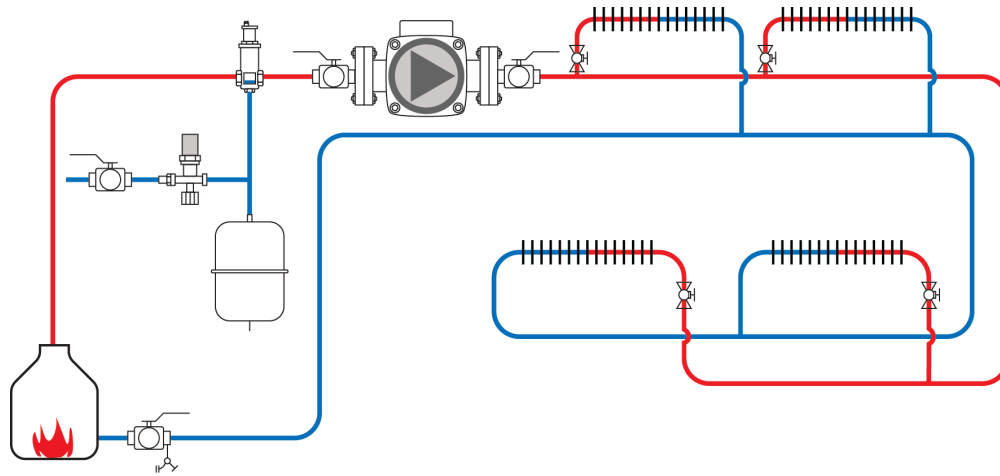


Figure 3

10. What system is shown in Figure 4?

- a. Series loop
- b. Diversion tee
- c. Direct-return
- d. Reverse-return

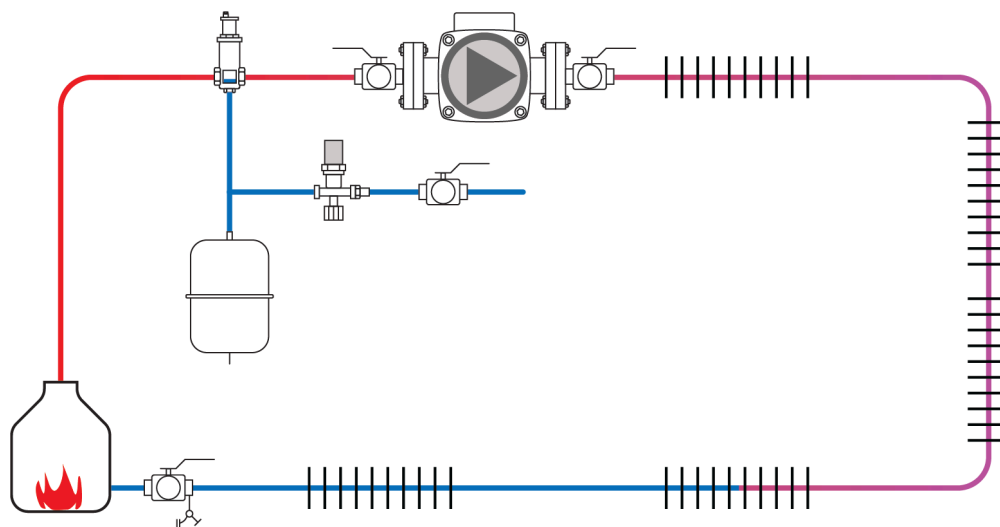


Figure 4

Answer Key: Self-Test B-4.3 (#chapter-answer-key-self-test-b-4-3) is on the next page.

Answer Key: Self-Test B-4.3

1. a. Series loop
2. d. Radiant panel
3. b. Diversion tee
4. d. Reverse-return
5. c. Direct-return
6. c. Venturi
7. b. Diversion tee system
8. d. Reverse-return system
9. c. Direct-return system
10. a. Series loop system

Self-Test B-4.4 Distribution System Installation

Complete Self-Test B-4.4 and check your answers.

Match the definitions in Column B to the correct term in Column A:

Column A	Column B
1. Riser	a. The horizontal pipe that connects a main to a riser
2. Runout	b. A run of pipe with three or more elbows that allow parts of a run to have different slopes and movement without severe stress
3. Spring piece	c. A pipe that connects a heat transfer unit to other parts of a heating system
4. Swing connection	d. An arrangement of pipes and fittings that allows the movement caused by thermal expansion to occur within parts of a piping run without causing excessive stress
5. Expansion loop	e. A vertical pipe connected to runouts on more than one floor
	f. A vertical pipe in a runout that passes down to a heat transfer unit on a lower level
	g. A vertical pipe in a runout that passes up through a floor up to a heat transfer unit

6. Complete the following statement: "Piping runs in a hot-water heating system should _____."

- a. Be almost level or have an upward grade of 4 mm/m ($\frac{1}{2}$ in./10 ft)
- b. Slope down in the direction of the flow
- c. Slope down from the supply pipes and up to the returns
- d. Slope up from the supply pipes and down to the returns

7. What are the fittings in a swing connection?

- a. Elbows and tees
- b. Only 90° elbows
- c. Only 45° elbows
- d. Either all 90° elbows or a combination of 90° and 45° elbows

8. Piping runs should not be placed in outside walls.

- a. True
- b. False

9. Pump circulation can be stopped by air bubbles accumulating at a high point.

- a. True
- b. False

10. Drops to downfed heat transfer units should connect from the _____ of the mains.

- a. Top
 - b. Side
 - c. Bottom
 - d. Top or the bottom
11. Complete the following statement: "Installing zones allows for _____."
- a. Lower installation cost
 - b. Ease of installation
 - c. Greater comfort
 - d. Greater heat transfer
12. Which one of the following factors is not a consideration when selecting zones?
- a. Heat losses
 - b. System layout
 - c. Use patterns
 - d. Floor constructions
13. In multi-storey buildings, why do the higher floors typically require less heat than the lower floors?
- a. Due to different use patterns between storeys
 - b. Because they have additional insulation
 - c. Because they use larger boilers
 - d. Due to the stack effect
14. Complete the following statement: "Rooms that may not be used for long periods should _____."
- a. Have double-glazed thermally broken windows installed
 - b. Not have any heat transfer unit installed
 - c. Be zoned separately
 - d. Be sealed off
15. Which one of the following rooms is normally kept at a higher setpoint temperature than the others?
- a. Dining room
 - b. Living room
 - c. Bathroom
 - d. Bedroom
16. Which one of the following rooms is normally kept at a lower setpoint temperature than the others?
- a. Dining room
 - b. Living room
 - c. Bathroom
 - d. Bedroom

17. Balancing is the process of what?
- a. Balancing flows in circuits
 - b. Balancing temperatures in circuits
 - c. Adjusting the control system
 - d. Adjusting the pressure that enters a hot-water heating system
18. How is the flow through each loop of a split-series loop system balanced?
- a. Adjusting gravity flow control valves
 - b. Adjusting balancing valves
 - c. Adjusting radiator valves
 - d. The size of pipe used in each loop

Answer Key: Self-Test B-4.4 (#chapter-answer-key-self-test-b-4-4) is on the next page.

Answer Key: Self-Test B-4.4

1. e. A vertical pipe connected to runouts on more than one floor
2. c. A pipe that connects a heat transfer unit to other parts of a heating system
3. a. The horizontal pipe that connects a main to a riser
4. b. A run of pipe with three or more elbows that allow parts of a run to have different slopes and movement without severe stress
5. d. An arrangement of pipes and fittings that allows the movement of parts of a piping run caused by thermal expansion without excessive stress
6. a. Be almost level or have an upward grade of 4 mm/m ($\frac{1}{2}$ in./10 ft)
7. d. Either all 90° elbows or a combination of 90° and 45° elbows
8. a. True
9. a. True
10. c. Bottom
11. c. Greater comfort
12. b. System layout
13. d. Due to the stack effect
14. c. Be zoned separately
15. c. Bathroom
16. d. Bedroom
17. a. Balancing flows in circuits
18. b. Adjusting balancing valves

Plumbing Apprenticeship & Trade Resources in BC

A successful career in plumbing requires a strong foundation of skills, knowledge, and workplace safety awareness. Below are key resources to support plumbing apprentices in BC, including educational pathways, trade certifications, workplace safety guidelines, and mental health and wellness support.

Plumbing Apprenticeship & Certification Resources

- **SkilledTradesBC – Plumbing Apprenticeship** (<https://skilledtradesbc.ca/plumber>) – Overview of plumbing training, certification requirements, and apprenticeship pathways in British Columbia.
- **Red Seal Program – Plumber** (<https://www.red-seal.ca/eng/trades/plumbers/overview.shtml>) – National certification program with exam prep guides and trade mobility information.
- **BC Building Codes & Standards** (<https://www.bccodes.ca/>) – Official building and plumbing codes for British Columbia.

Workplace Safety & Regulations

- **WorkSafeBC** (<https://www.worksafebc.com/en>) – Essential safety resources for plumbers, including:
 - Health & Safety – WorkSafeBC (<https://www.worksafebc.com/en/health-safety>)
 - Report Unsafe Working Conditions (<https://www.worksafebc.com/en/contact-us/departments-and-services/health-safety-prevention>)
 - Report a Workplace Injury or Disease (<https://www.worksafebc.com/en/claims/report-workplace-injury-illness>)
 - Submit a Notice of Project Form (<https://www.worksafebc.com/en/for-employers/just-for-you/submit-notice-project>)
 - Get Health and Safety Resources (Videos, Posters, Publications, and More) (<https://www.worksafebc.com/en/resources-health-safety>)
 - Search the OHS Regulations (and Related Materials) (<https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation>)
 - Conduct an Incident Investigation (<https://www.worksafebc.com/en/health-safety/create-manage/incident-investigations/conducting-employer-investigation>)
- **CCOHS: OHS Answers Fact Sheets – Plumber** (https://www.ccohs.ca/oshanswers/occup_workplace/plumber.html) – Safety guidelines and best practices for plumbers in various work environments.

Financial Supports

- **Financial Support (SkilledTradesBC)** (<https://skilledtradesbc.ca/financial-support>) – Information about grants, tax credits, Canada apprentice loans, employment insurance, and the Indigenous Skills and Employment Training

(ISET) program.

- **StudentAidBC** (<https://studentaidbc.ca/>) – Complete post-secondary education through student loans, grants, and scholarships. There is also programs that help with loan repayment.
- **WorkBC (Government of BC)** (<https://www.workbc.ca/find-loans-and-grants/students-and-adult-learners/services-apprentices-and-employers>) – Services for apprentices and employers.

Mental Health & Wellness Support

- **HealthLink BC – Mental Health and Substance Use** (<https://www.healthlinkbc.ca/mental-health-and-substance-use>) – HealthLink BC resources for mental health and wellness support.
- **Here2Talk** (<https://here2talk.ca/>) – Free and confidential counseling services available to all post-secondary students registered at a BC school.
- **Help Starts Here** (<https://helpstartshere.gov.bc.ca/>) – A database with over 2,500 listings of services related to mental health and substance use supports.
- **Hope for Wellness Helpline** (<https://www.hopeforwellness.ca/>) – 24/7 online chat and phone line with experienced and culturally competent counselors available to all Indigenous people in Canada.
 - First Nations Health Authority Mental Health Supports Info Sheet [PDF] (<https://www.fnha.ca/Documents/FNHA-mental-health-and-wellness-supports-for-indigenous-people.pdf>) by First Nations health Authority – List of culturally safe services for Indigenous people.
- **HeretoHelp – BC** (<https://www.heretohelp.bc.ca/>) – Mental health resources, including videos, articles, and support services in BC.
- **BC Construction Industry Rehabilitation Plan** (<https://www.constructionrehabplan.com/>) – Mental health and substance use services for CLRA and BCBT members and their families.
- **Virtual Mental Health Supports (Government of BC)** (<https://www2.gov.bc.ca/gov/content/health/managing-your-health/mental-health-substance-use/virtual-mental-health-supports>) – Virtual services are available for British Columbians who are experiencing anxiety, depression, or other mental health challenges.

Crisis Support

- **Interior Crisis Line Network** – Call 1-888-353-2273 (tel:+1-888-353-2273) for 24/7 emotional support, crisis intervention, and community resource information.
- **Talk Suicide Chat Service** (<https://talksuicide.ca/>) – An alternative if calling is difficult; available for crisis intervention.
- **310Mental Health Support** – Call 250-310-6789 (tel:+1-250-310-6789) for emotional support, information, and resources specific to mental health.
- **1-800-SUICIDE** – Call 1-800-784-2433 (tel:+1-800-784-2433) if you are experiencing feelings of distress or despair, including thoughts of suicide.
- **Opioid Treatment Access Line** – Call 1-833-804-8111 (tel:+1-833-804-8111) between 9 am and 4 pm to connect with a doctor, nurse, or healthcare worker who can prescribe opioid treatment medication that same day.
- **KUU-US Crisis Response Service** – Call 1-800-588-8717 (tel:+1-800-588-8717) for culturally-aware crisis support for Indigenous peoples in BC.
- **Alcohol and Drug Information and Referral Service** – Call 1-800-663-1441 (tel:+1-800-663-1441) to find resources and support.



Emergency Services — For life-threatening situations, call 911 or visit your nearest emergency department.

Version History

This page provides a record of changes made to this learning resource, Plumbing Apprenticeship Level 2, Block B (<https://b-heating-bcplumbingapprl2.pressbooks.tru.ca/>). Each update increases the version number by 0.1. The most recent version is reflected in the exported files for this resource.

Important Notice: This book contains content used with permission from Skilled Trades BC, Trades Training BC, and various third-party contributors, with all third-party content identified and attributed throughout. To create your own version, you must obtain explicit permission from Skilled Trades BC and the respective third-party content owners.

If you identify an error in this resource, please report it using the TRU Open Education Resource Error ([#back-matter-tru-open-education-resource-error-form](#)) Form.

Version	Date	Change	Details
1.0	September, 2025	Plumbing Apprenticeship Level 2 Block B learning resource from STBC content converted to open and freely accessible digital platform and published at TRU.	