Block D: Piping and Components

TRU Open Press

Plumbing Apprenticeship Program Level 1 Series

Block D: Piping and Components

BC Plumbing Apprenticeship, Level 1

SKILLEDTRADESBC

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Plumbing Apprenticeship & Trade Resources in BC 684

Block D: Piping and Components of the Plumbing Apprenticeship Program Level 1 Series features Skilled Trades BC industry-authority content focused on the core installation skills that form the foundation of plumbing systems. This block emphasizes the practical knowledge and techniques apprentices use to assemble, connect, and integrate piping systems accurately and safely within residential, commercial, and institutional settings.

In Block D, apprentices learn how to install pipe and tubing, valves, and fittings, as well as how to safely and effectively penetrate building structures. These competencies support proper system function, durability, and compliance with codes and specifications, while reinforcing precision, planning, and coordination with other trades on the job site.

Plumbing Apprenticeship Program Level 1 Series

The *Plumbing Apprenticeship Program Level 1 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: Safety Related Functions (https://a-safetyfunctions-bcplumbingapprl1.pressbooks.tru.ca)

A-1: Workplace Hazards
A-2: WorkSafeBC Regulations
A-3: Safe Handling of Hazardous Materials
A-4: Personal Safety Practices
A-5: Fire Safety

Block B: Tools and Equipment (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca)

B-1: Use Hand Tools and Measuring Tools
B-2: Use Portable Power Tools and Use
B-3: Use Access Equipment
B-4: Use Rigging, Hoisting, Lifting and Positioning Equipment, and Rigging
B-5: Use Soldering and Brazing Equipment and Oxy-Fuel Cutting Equipment
B-6: Use Welding Equipment

Block C: Routine Trade Activities and Electrical Concepts (https://c-tradeactivities-electrical-bcplumbingapprl1.pressbooks.tru.ca)

C-1: Mathematics and Science
C-2: Electrical Concepts and Principles of Electricity

C-3: Drawings and Specifications
C-4: Codes, Regulations and Standards
C-5: Manufacturer and Supplier Documentation

Block D: Piping and Components (https://d-pipingcomponents-bcplumbingapprl1.pressbooks.tru.ca)

D-1: Install Pipe and Tubing
D-2: Install Valves
D-3: Install Fittings
D-4: Penetrate Structures

Plumbing Apprenticeship Program Overview and Upcoming Resources

- **Plumbing Apprenticeship Program Level 1 Series** (https://openpress.trubox.ca/2024/12/13/plumbing-apprentice-level-1/) can be found in the TRU Open Press Collection.
- **Plumbing Apprenticeship Program Level 2 Series (https://openpress.trubox.ca/2024/04/26/bc-plumbing-apprenticeship-level-2/)** can be found in the TRU Open Press Collection.
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Safety Advisory

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

[From previous 2021 book – confirm this message with Skilled Trades]

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

Acknowledgements

The development of the *Plumbing Apprenticeship Level 1* learning resources was a collaborative effort driven by a commitment to excellence in trades education. These resources 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 contributions, leadership, and guidance have been instrumental in shaping high-quality, industry-aligned training resources. We extend our sincere gratitude for their contributions and ongoing stewardship in advancing the piping trades.

The content for *Block D: Piping and Components* (https://d-pipingcomponents-bcplumbingapprl1.pressbooks.tru.ca/) is adapted from the Piping Trades Apprenticeship Program from SkilledTradesBC (2019 Harmonized).

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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.

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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.

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Camosun College. (n.d.). *Line E – Electrical Fundamentals Competency*. BCcampus. https://collection.bccampus.ca/textbook/Nf7jVbAg/

SkilledTradesBC. (2025). Plumber program outline (Implementation date: August 18, 2025; Last revised: December 16, 2025) [PDF]. Province of British Columbia. https://skilledtradesbc.ca/media/2776/download

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Accessibility

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PART I

D-1 INSTALL PIPE AND TUBING

Plumber Apprenticeship Program – Level 1

Close-up of a plumber's hands installing steel pipes indoors (https://www.pexels.com/photo/plumber-installs-pipe-fittings-6419128/). (Anıl Karakaya/Pexels) Pexels License (https://www.pexels.com/license/)

D-1 Install Pipe and Tubing Introduction

This section introduces the fundamental concepts and materials used in piping and tubing systems. You will learn key terminology and how to identify different types of pipe and tube, along with their distinct qualities, advantages, and limitations. Building on this foundation, the section explores a range of commonly used materials—including copper, cast iron, carbon and stainless steel, brass, thermoplastics, thermoset plastics, glass (Pyrex), and specialty materials—highlighting their properties and typical applications. By the end of this section, you will have the knowledge needed to recognize, compare, and select appropriate piping and tubing for a variety of practical situations.

Learning Objectives

After completing this section, you will be able to:

- Define pipe and tube terminology.
- Identify types of pipe and tube.
- Describe piping and tubing qualities, advantages and disadvantages.
- Describe piping and tubing materials:
  - ▸ Copper
  - ▸ Cast iron
  - ▸ Carbon and stainless steel
  - ▸ Brass
  - ▸ Thermoplastics
  - ▸ Thermoset plastic
  - ▸ Pyrex/glass
  - ▸ Specialty piping materials
- Describe the methods of pipe manufacture for:
  - ◦ Carbon and stainless steel
  - ◦ Cast iron pipe
  - ◦ Copper pipe and tubing
  - ◦ Thermoplastic pipe and tubing
- Identify the types and colour markings on copper tubing.
- Define the term "temper" as applied to copper tubing.
- Know the three methods used to manufacture cross-linked polyethylene (PEX) tubing.
- Identify hangers and supports.
- Identify pipe support anchors and expansion inserts.
- Select and install hangers and supports.
- Identify and select sway bracing, spring, and variable supports.
- Explain the purpose of seismic restraint.
- Identify seismic restraint components.
- Install seismic piping and equipment components, including cable brace attachments.
- Identify the factors leading to piping damage:
  - ◦ Corrosion
  - ◦ Frost
  - ◦ Ultraviolet
  - ◦ Physical
- Apply methods used to protect piping during transportation, storage, installation, and use, including:
  - ◦ Installing pipe in a heated structure
  - ◦ Installing pipe below the frost line
  - ◦ Insulating pipe

    - Utilizing heat trace
    - Winterizing and drainin
    - Constant circulation

- Inspect pipe and tubing before installation to locate potential defects.
- Determine environmental effects.
- Apply inspection techniques, including sounding of cast iron pipe and fittings.
- Interpret markings on pipe and tubing and check against specifications.
- Inspect pipe and tubing before installation to locate potential defects.
- Determine environmental effects.
- Apply inspection techniques, including sounding of cast iron pipe and fittings.
- Interpret markings and check against specifications.
- Identify and apply hazard safety procedures and tools used when installing and assembling pipe and tube (refer to Lines A and B).
- Visually identify and name the various pipe and tube jointing methods.
- Identify and apply the procedures for jointing various types of pipe and tube.
- Identify the correct jointing procedures for specific piping and tubing applications.
- Identify and apply measuring procedures, including inside and outside diameters and lengths.
- Calculate measurements and offsets, applying fitting allowances.

Topic areas covered in this publication are in alignment with SkilledTradesBC Harmonized 2018 Program Outlines.

Resources

- You may be required to reference publications and videos available online at the WorkSafeBC (https://www.worksafebc.com/en) website.
- You may wish to have the IPT's Pipe Trades Training Manual (https://iptbooks.com/product/pipe-trades-handbook/?v=5435c69ed3bc) available as it is referred to throughout this section. This resource may also be useful to keep and refer to throughout your apprenticeship and into your career in the trades.

Terminology

The following terms may be used throughout this section. Note that some glossary terms may be in italics

throughout the section content but are not included in this list. A complete list of terms can be found in the **Glossary.**

- **ABS (acrylonitrile-butadiene-styrene)**: A strong, lightweight plastic used to make pipes and fittings, especially for drainage, waste, and vent systems. (Section D-1.2 (#chapter-d-1-2-describe-the-methods-of-manufacture-of-piping-and-tubing))
- **annealed temper**: A soft and flexible type of copper tubing made by heating the metal and slowly cooling it. (Section D-1.2 (#chapter-d-1-2-describe-the-methods-of-manufacture-of-piping-and-tubing))
- **anode:** A metal through which current flows. (In an electrochemical reaction, the anode is the metal that corrodes.) (Section D-1.4 (#chapter-d-1-3-section-4))
- **armour conduit:** A protective tube or covering placed around piping or tubing to shield it from damage, such as impacts, abrasion, or punctures. (Section D-1.6 (#chapter-d-1-6-section-6))
- **authorities having jurisdiction (AHJ)**: Organizations or officials (such as inspectors) who enforce codes and regulations and approve whether work meets required standards. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **billet**: A solid piece of metal that is heated and shaped into pipe or tubing. (Section D-1.2 (#chapter-d-1-2-describe-the-methods-of-manufacture-of-piping-and-tubing))
- **cathode:** A metal from which current flows. (Section D-1.4 (#chapter-d-1-3-section-4))
- **cathodic protection:** A method used to prevent corrosion by making a metal act as a cathode in an electrical process. (Section D-1.4 (#chapter-d-1-3-section-4))
- **cavitation:** The formation of air bubbles in a liquid that can damage pipes. (Section D-1.5 (#chapter-d-1-5-describe-the-inspection-of-pipes-and-tube-before-installation))
- **centrifugal casting process**: A method of making pipe by pouring molten metal into a spinning mould so it spreads evenly along the inside surface. (Section D-1.2 (#chapter-d-1-2-describe-the-methods-of-manufacture-of-piping-and-tubing))
- **corrosion:** The gradual destruction of material, usually metals, by chemical reaction with its environment. (Section D-1.4 (#chapter-d-1-3-section-4))
- **corrugated Stainless-Steel Tubing (CSST):** A flexible metal pipe used to carry natural gas or propane, designed with ridges so it can bend easily during installation. (Section D-1.6 (#chapter-d-1-6-section-6))
- **crossover method:** A way of tightening bolts in a crisscross pattern to ensure even pressure and a proper seal. (Section D-1.6 (#chapter-d-1-6-section-6))
- **deburring:** The process of removing rough edges from a cut pipe. (Section D-1.5 (#chapter-d-1-5-describe-the-inspection-of-pipes-and-tube-before-installation))
- **drawn temper**: A hard and strong type of copper tubing made by pulling the metal through a die without heating it. (Section D-1.2 (#chapter-d-1-2-describe-the-methods-of-manufacture-of-piping-and-tubing))
- **DWV (drainage, waste, and vent)**: Pipes and fittings used to remove wastewater and allow air to flow in plumbing systems so drains work properly. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **electrochemical reaction:** A reaction caused or accompanied by the flow of electricity and the transfer of electrons between substances. (Section D-1.4 (#chapter-d-1-3-section-4))
- **ERW (electric resistance weld)**: A method of making pipe by heating and welding the edges of steel together using electricity. (Section D-1.2 (#chapter-d-1-2-describe-the-methods-of-manufacture-of-piping-and-tubing))
- **expansion anchors (quick-bolts):** Fasteners that expand inside a hole to hold objects securely in place.

(Section D-1.3 (#chapter-d-1-3-describe-the-methods-of-pipe-and-tubing-support))

- **extrusion**: A process where heated material is pushed through a shaped opening to form pipe. (Section D-1.2 (#chapter-d-1-2-describe-the-methods-of-manufacture-of-piping-and-tubing))
- **friction loss:** The reduction of pressure in a pipe due to resistance as fluid flows. (Section D-1.5 (#chapter-d-1-5-describe-the-inspection-of-pipes-and-tube-before-installation))
- **hose:** Portable and flexible pipe made from flexible material such as natural rubber, synthetic rubbers, plastics and composites with metal reinforcing. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **interference fit:** A tight connection where a pipe is pressed into a fitting so the surfaces bond together, often using solvent cement that softens the material and allows it to fuse. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **IPS (iron pipe size):** Used to identify standard dimensions of a carbon steel pipe which is often referred to as "iron pipe." (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **mandrel**: A tool placed inside a pipe during manufacturing to shape and size it. (Section D-1.2 (#chapter-d-1-2-describe-the-methods-of-manufacture-of-piping-and-tubing))
- **mechanical joint (zip coupling):** A pipe connection that uses a clamp and gasket tightened with bolts or screws to create a seal. (Section D-1.6 (#chapter-d-1-6-section-6))
- **NPS (nominal pipe size)**: This is the approximate inside diameter. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **NPT (national pipe thread):** May be referred to as MPT (male pipe thread) for external threads, and FPT (female pipe thread) for internal threads. (Note that FPT and MPT are not authorized designations according to the ANSI standard.) (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **o-rings:** Round rubber seals placed between pipe parts to prevent leaks. (Section D-1.6 (#chapter-d-1-6-section-6))
- **out-of-round:** When a pipe is no longer perfectly circular in shape. (Section D-1.5 (#chapter-d-1-5-describe-the-inspection-of-pipes-and-tube-before-installation))
- **PEX (cross-linked polyethylene)**: A flexible plastic pipe made stronger by a chemical bonding process. (Section D-1.2 (#chapter-d-1-2-describe-the-methods-of-manufacture-of-piping-and-tubing))
- **polyethylene (PE)**: A type of plastic commonly used to make flexible and durable pipes. (Section D-1.2 (#chapter-d-1-2-describe-the-methods-of-manufacture-of-piping-and-tubing))
- **potable water:** Water safe for human consumption. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **pipe:** Pipe is generally specified by a nominal inside diameter with a constant outside diameter (OD) and a schedule rating that defines its thickness. Pipe is generally manufactured to one of several international and national industrial standards. In general, "pipe" is the more common term in most of the world, whereas "tube" is more widely used in the United States. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **pipe anchors:** Devices used to hold pipes firmly in place and prevent movement. (Section D-1.3 (#chapter-d-1-3-describe-the-methods-of-pipe-and-tubing-support))
- **print-line:** The line of markings printed on a pipe that identifies its size, type, approvals, etc. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **PVC (polyvinyl chloride)**: A strong plastic material used to make pipes for water and drainage systems. (Section D-1.2 (#chapter-d-1-2-describe-the-methods-of-manufacture-of-piping-and-tubing))
- **reaming:** The process of smoothing the inside edge of a pipe after cutting. (Section D-1.5 (#chapter-d-1-5-describe-the-inspection-of-pipes-and-tube-before-installation))

- **rod hanger:** A threaded metal support used to hang pipes from a structure; other common names: hang-up anchors, Sammy super screws, vertigo anchors, hanger mates, and titan anchors. (Section D-1.3 (#chapter-d-1-3-describe-the-methods-of-pipe-and-tubing-support))
- **sacrificial anode:** A metal that is designed to corrode instead of another metal to protect it. (Section D-1.4 (#chapter-d-1-3-section-4))
- **SDR (standard dimension ratio):** A number that compares a pipe's outside diameter to its wall thickness to show how strong it is and how much pressure it can handle. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **SDR number:** SDR number is determined by dividing the outside diameter of the tube or pipe by its minimum wall thickness. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **seamless (SMLS) steel pipe**: A type of steel pipe made from a solid piece of metal with no welded seams, making it strong and able to handle high pressure. (Section D-1.2 (#chapter-d-1-2-describe-the-methods-of-manufacture-of-piping-and-tubing))
- **seismic restraint:** A system used to keep pipes and equipment secure during an earthquake. (Section D-1.3 (#chapter-d-1-3-describe-the-methods-of-pipe-and-tubing-support))
- **standard:** A body of rules or principles established and agreed upon as valid and fundamental in a certain field or industry. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **stray current:** Electrical current that flows along unintended paths and can cause corrosion in pipes and metal components. (Section D-1.4 (#chapter-d-1-3-section-4))
- **sway brace:** A support that prevents pipes from moving side to side. (Section D-1.3 (#chapter-d-1-3-describe-the-methods-of-pipe-and-tubing-support))
- **thermal expansion:** The increase in size of a material when it is heated. (Section D-1.3 (#chapter-d-1-3-describe-the-methods-of-pipe-and-tubing-support))
- **thermoplastic:** A plastic capable of softening or fusing when heated and which hardens once cooled. Can be reheated and melted. Polyethylene and polyvinyl chloride (PVC) are examples of a thermoplastic. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **thermo-set:** A plastic capable of becoming permanently rigid when heated or cured. It cannot be reheated and re-melted. Fibreglass pipe is an example of a thermo-set plastic pipe. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **torque wrench:** A tool used to tighten bolts or nuts to a specific amount of force to ensure a proper and secure connection. (Section D-1.6 (#chapter-d-1-6-section-6))
- **tube:** Most often specified by the outside diameter (OD) and wall thickness, but may be specified by any two of OD, inside diameter (ID), and wall thickness. Although standards exist for tube, it's often made to custom sizes and a broad range of diameters and tolerances. (Section D-1.1 (#chapter-d-1-1-describe-piping-and-tubing-materials))
- **water hammer (hydraulic shock):** A pressure surge or high-pressure shockwave that occurs when water in motion is forced to stop or change direction suddenly. It produces a distinct banging or hammering sound, caused by the shockwave traveling back through the pipe. This effect can damage pipes, joints, and appliances. (Section D-1.3 (#chapter-d-1-3-describe-the-methods-of-pipe-and-tubing-support))

D-1.1 Describe Piping and Tubing Materials

It's important to be able to identify the piping and tubing you'll be working with. The key to this is recognizing the material from which it is made. Modern pipe is generally made from metal, metal alloys, and varieties of plastic. Other specialty piping materials include rubber, synthetic rubbers, glass silicates, and composite materials. In the past, pipe materials included asbestos cement, glazed clay, wood stave, or lead. You may encounter these pipes in older structures and underground, and it's important to be able to identify them. You'll also have to know how to repair, remove, or adapt new piping materials to older pipe.

Your customers will view you as an expert in your field. You can expect to be asked about the piping system you are using, and you will often have to make recommendations for your client.

Pipe versus Tube Terminology

In common usage, the words ***pipe*** and ***tube*** are the same thing. However, in industry and engineering, the terms are uniquely defined—a tube is a pipe with walls that are too thin to be threaded. Tube is typically defined by outside diameter and tighter tolerances, while pipe is defined by nominal inside diameter. Throughout this section, the words pipe and tube may be used interchangeably.

Definitions

It is helpful to know the following terminology when you talk about pipes and tubes:
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DWV (drainage, waste, and vent): Pipes and fittings used to remove wastewater and allow air to flow in plumbing systems so drains work properly.

***hose*:** Portable and flexible pipe made from flexible material such as natural rubber, synthetic rubbers, plastics, and composites with metal reinforcing.

***interference fit*:** The contact made as a plastic pipe is solvent-cemented into the fitting socket. When ABS or PVC plastic pipe and fittings are dry-fitted, the pipe will not easily slide to the bottom of the fitting socket. This is because the fitting socket is tapered slightly to a smaller inside diameter at the base of the socket. The taper causes enough pressure on the solvent-cemented surfaces to cause the ABS surfaces to fuse together. It's a misconception that ABS solvent cement is glue—it's actually a solvent that softens the surfaces it is in contact with. The interference fit forces the surfaces to fuse together.

IPS (*iron pipe size*): Used to identify standard dimensions of a carbon steel pipe, which is often referred to as "iron pipe."

NPS: Nominal pipe size. This is the approximate inside diameter.

NPT: National pipe thread. May be referred to as MPT (male pipe thread) for external threads, and FPT (female pipe thread) for internal threads. (Note that FPT and MPT are not authorized designations according to the ANSI standard.)

***potable water*:** Water safe for human consumption.

***pipe*:** Pipe is generally specified by a nominal inside diameter with a constant outside diameter (OD) and a schedule rating that defines its thickness. Pipe is generally manufactured to one of several international and national industrial standards. In general, "pipe" is the more common term in most of the world, whereas "tube" is more widely used in the United States.

***print-line*:** The line of markings printed on a pipe that identifies its size, type, approvals, etc.

SDR (*standard dimension ratio*): A number that compares a pipe's outside diameter to its wall thickness to show how strong it is and how much pressure it can handle.

SDR *number*: SDR number is determined by dividing the outside diameter of the tube or pipe by its minimum wall thickness. A lower SDR number means thicker pipe walls and higher pressure rating.

***standard*:** A body of rules or principles established and agreed upon as valid and fundamental in a certain field or industry.

***thermoplastic*:** A plastic capable of softening or fusing when heated and which hardens once cooled. Can be reheated and melted. Polyethylene and polyvinyl chloride (PVC) are examples of a thermoplastic.

***thermoset*:** A plastic capable of becoming permanently rigid when heated or cured. It cannot be reheated and re-melted. Fibreglass pipe is an example of a thermo-set plastic pipe.

***tube*:** Tube is most often specified by the outside diameter (OD) and wall thickness, but may be specified by any two of OD, inside diameter (ID), and wall thickness. Although standards exist for tube, it's often made to custom sizes and a broad range of diameters and tolerances.

Codes, Regulations, and Standards

Codes and regulations play a major role in all aspects of the piping trades. In BC, all plumbing installations must conform to the BC Plumbing Code (BCPC) (https://www2.gov.bc.ca/gov/content/industry/construction-industry/building-codes-standards/bc-codes/2024-bc-codes/plumbing). Because the BCPC forms Part 7 of the BC Building Code (BCBC) (https://www2.gov.bc.ca/gov/content/industry/construction-industry/building-codes-standards/bc-codes/2024-bc-codes), the parts of the BCBC that pertain to plumbing—but may not be found within the BCPC—must also be followed. Within the codes are references to standards that pipe, tube and fittings must conform to, and manufacturers build their products so that they can be used within the codes. For example, the BCPC lists Series 160 polyethylene as an acceptable material for water service piping, yet there are municipalities that do not allow anything other than copper tubing for that application. This requirement is applied through enactment of a bylaw specifically for that jurisdiction. All applicable codes, local bylaws, manufacturers' specifications, building specifications and site conditions must be considered when selecting an appropriate pipe material for installation.

Characteristics of pipe and tube must also be considered. These characteristics can include but are not limited to corrosion resistance, pressure rating, UV resistance, heat range, resistance to acids and alkalis, smoothness and

roughness, pipe weight and portability, compatibility with fluids, and cost. ***Authorities having jurisdiction (AHJ)***, typically inspectors and engineers, routinely check that piping materials installed are correct in their application to the documents that they enforce.

Throughout all of the resource literature referred to in this section, we assume conformance to manufacturers' specifications and applicable codes and regulations in all applications of piping, tubing and fittings.

Metal Pipe and Tubing Standards (Including Steel Pipe Standards)

Nominal pipe size (NPS) is a North American set of standard sizes for pipes used for high or low pressures and temperatures.

Pipe size is specified with two non-dimensional numbers:

- A nominal pipe size (NPS) for diameter based on inches and a schedule (Sched. or Sch.) for wall thickness.
- NPS is often incorrectly called national pipe size, due to confusion with the term national pipe thread (NPT).
- The European designation equivalent to NPS is ***DN (diameter nominal)***, in which sizes are measured in millimetres.
- The term ***NB (nominal bore)*** is also frequently used interchangeably with NPS.

Piping Dimension Standards

Piping and tubing are required to meet specific dimensional requirements. This ensures that piping and fittings will be interchangeable. There are three basic standards that determine the final dimensions of commonly used piping and tubing:

- Piping (plastic, metal, other)—iron pipe size (IPS)
- Copper water tubing—copper tubing size (CTS)
- Copper (ACR) air conditioning and refrigeration tubing

Piping and tubing are described by their *nominal pipe sizes* (NPS). Nominal pipe sizes are approximate inside diameters measured in inches. Piping and tubing may have the same NPS but have different actual dimensions depending on material. For example, a $\frac{1}{2}$" NPS iron pipe, $\frac{1}{2}$" NPS copper water tube, and $\frac{1}{2}$" NPS refrigeration tube will all have different outside diameters (OD).

For a given NPS, iron piping has the largest outside diameter to ensure that the wall thickness will allow threading (Figure 1).

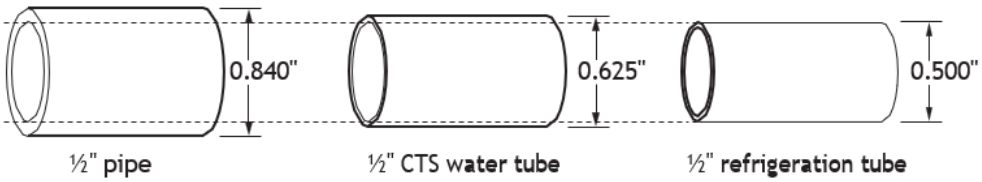


Figure 1 *Actual sizes of NPS 1/2″ piping and tubing* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Pipe Size Standards

Steel and iron were the first materials used in the manufacture of piping. Iron pipe size (IPS) is the original standard developed for piping. It's still the basic standard for all pipe of any material (e.g., metal, plastic, vitreous clay) that has the same outside diameter and nominal size as the equivalent iron or steel pipe. Iron pipe size standards demand that the outside diameters of a pipe must be the same for all pipe of the same nominal size.

Pipe Thread Standards

Most piping is threaded, and the actual size, depth, angle, and pitch of threads for pipe are set by the ***National Pipe Thread Tapered (NPT)*** standard. This ensures that any pipe made to IPS standards will mate with the same threaded fittings.

You will find many different fittings and adapters to connect all types of piping. Copper, steel, and brass pipe (not tubing) as well as ABS and PVC plastic pipe may all be made to the same IPS standard. If the pipes are threaded, they can be joined to each other with IPS threaded fittings, regardless of each component's material. The effect of electrolytic action will still have to be considered when choosing a fitting to connect different metal pipes.

Unlike the straight thread pattern found on bolts, piping used for the delivery of gases or fluids under pressure has a threaded section that narrows to create a seal (Figure 2). This is called a "tapered thread". The seal provided by a threaded pipe joint depends upon the diminishing seal created by the threads and sometimes on the presence of a sealing coating, such as thread seal tape (Teflon tape), or a liquid or paste applicant such as "pipe dope". Pipe dopes and tapes are applied to male (external) threads to lubricate the mating of the threads. Pipe dopes and tapes reduce friction, allowing the joint to be properly tightened to specifications without binding.

Unlike straight threads, pipe threads are tapered to create a seal. Sealants such as thread tape or pipe compound are used to prevent leaks.

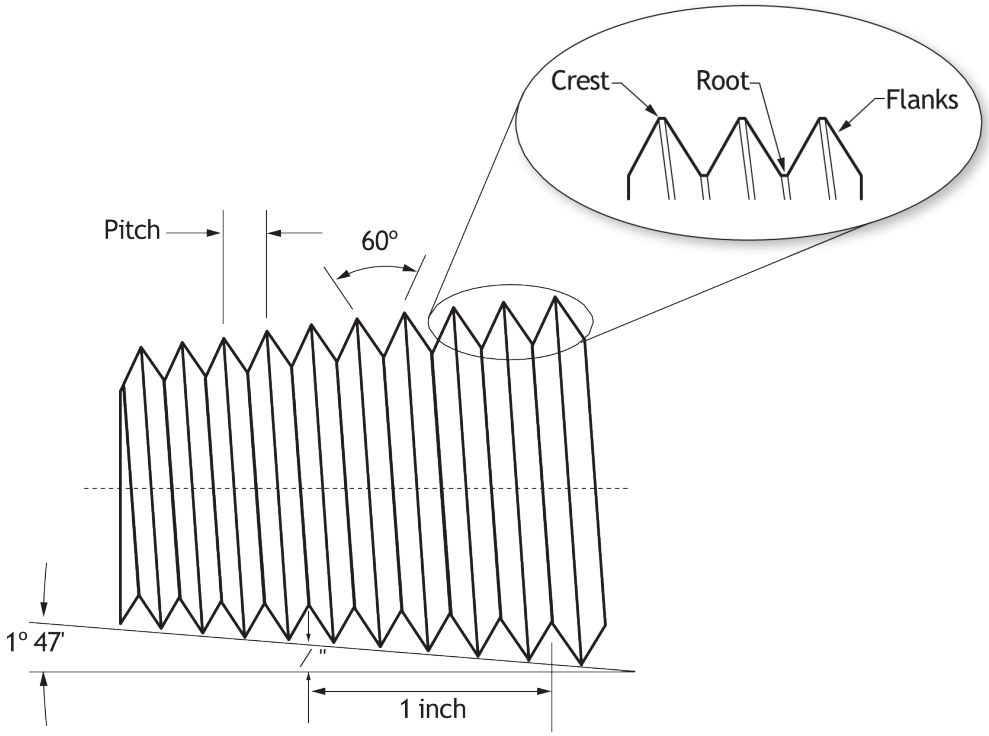


Figure 2 *NPT tapered thread (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

National Pipe Thread

The standard developed in North America for tapered threads is ANSI/ASME standard B1.20.1 and is known as National Pipe Thread (NPT). It sometimes is still referred to as American Standard Pipe Thread (ASPT).

The rate of taper for all NPT threads is $\frac{1}{32}$ " per inch (1° 47′), and the grooves that create the threads are formed at 60-degree angles. The thread pitch is measured in inches. The root and crest are flat to accommodate thread sealant.

Commonly used threaded pipe sizes are $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$ and 2 inch. Sizes smaller than $\frac{1}{8}$„ are occasionally used for compressed air, while sizes larger than 2″ are less common, due to the use of alternative methods of joining that are more common with these larger sizes.

The outside diameters of all pipe sizes up to 16″ are listed in Table 1. Note that for nominal pipe sizes (NPS) greater than 12″, the outside diameter is equal to the nominal pipe size.

Table 1: Standard Pipe Dimensions (inches)

NPS (inches)	Outside diameter	Wall thickness		
		Schedule 40	Schedule 80	Schedule 160
0.5	0.840	0.109	0.147	0.187
0.75	1.050	0.113	0.154	0.218
1	1.315	0.133	0.179	0.250
1.25	1.660	0.140	0.191	0.250
1.5	1.900	0.145	0.200	0.281
2	2.375	0.154	0.218	0.344
2.5	2.875	0.203	0.276	0.375
3	3.500	0.216	0.300	0.600
3.5	4.000	0.226	0.318	NA
4	4.500	0.237	0.337	0.531
5	5.563	0.281	0.375	0.625
6	6.625	0.280	0.432	0.719
8	8.625	0.322	0.500	0.906
10	10.750	0.365	0.594	1.125
12	12.750	0.406	0.688	1.312
14	14.000	0.438	0.750	1.406
16	16.000	0.500	0.844	1.594

You do not have to memorize the dimensions of each NPS category presented in these tables. Review the tables and notice the standard dimensions and how they vary across the different wall thickness standards and between NPS sizes. There are also standards that determine the weight of pipe per lineal foot. The dimensions and wall thickness noted in these tables are only allowed to vary a few percent from the established values.

Standard Wall Thickness

The NPS pipe sizes shown in Table 1 have varying wall thickness, with Schedule 40 pipe having the thinnest walls, and

Schedule 160 the thickest. There is also an increase in wall thickness for each larger pipe size. This is due to the need to increase wall thickness as the diameter increases to maintain the same pressure rating of the pipe.

Schedule numbers are modern classifications for the original weight classes of iron and steel pipe (Table 2). Originally, iron pipe was available in two standard weights, and steel piping was available in three weights. For example, cast iron soil pipe was initially sold in service weight (SW) and extra heavy (XH). Steel pipe was made in three weights: standard, extra-strong (heavy), and double extra-strong (extra-heavy). These weight classes were directly related to the wall thickness of the piping and the service application.

In an effort to standardize the increasing range of wall thickness in iron and steel piping, standards agencies developed schedule numbers from 5 to 160. These numbers indicate approximate values of the pressure-stress ratios times 1000. Standard weight steel pipe is equivalent to Schedule 40. Extra-heavy cast iron pipe is equivalent to Schedule 80.

Table 2: Oxygen Pressure–Temperature Comparison

Schedule Number	Weight Classification
40	standard weight
80	extra-strong (heavy)
160	double extra-strong (heavy)

Stainless steel piping in IPS sizes is classified by a separate class of schedule numbers that range from 5S to 80S.

A more versatile standard was developed that directly relates pipe dimensions to pressure ratings. This standard or rating system is called standard dimension ratio (SDR). SDR is the ratio of the average outside diameter to the minimum wall thickness measured in inches.

$$\text{SDR} = \frac{\text{outside diameter (OD)}}{\text{minimum wall thickness}}$$

Theoretically, different sizes of piping made of the same material, with the same SDR, should have the same pressure ratings. For example, 1″ and 6″ PVC pressure pipe with an SDR 26 rating are both suitable for 1.1 MPa (160 psi). Figure 3 shows a cross-sectional drawing of two different sizes of plastic pipe: NPS 1 and NPS 2. Each pipe is made of the same kind of plastic. Notice the increased wall thickness of the larger diameter pipe. When the outside diameter is divided by the wall thickness, the ratio or SDR is the same. Each pipe has an SDR of 11, which means that both sizes of pipe can be used at pressures up to 160 psi.

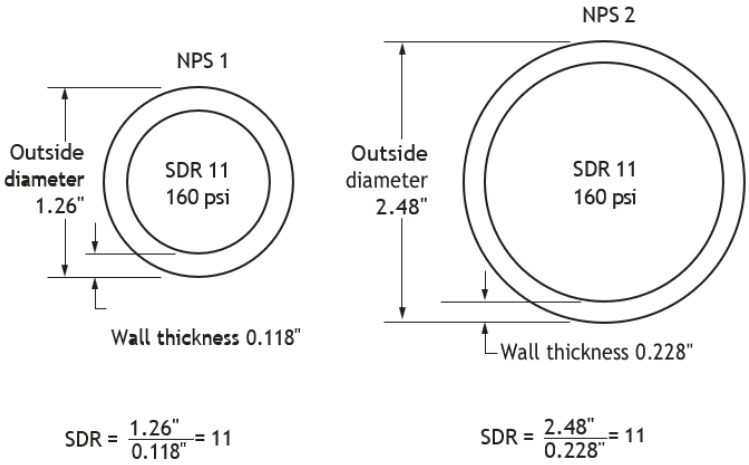


Figure 3 *NPS 1 and NPS 2 plastic pipe, both SDR 11, rated for 1.1 MPa (160 psi) (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Plastic pipe, such as CPVC and PVC, is sold in a wide range of wall thickness and pipe diameters. The standard schedule classifications are used for piping that matches the dimensions of iron or steel piping. For piping that does not match IPS standards, the SDR classification is preferred.

Each different SDR number has a corresponding pressure rating for each kind of material. For example, one type of polypropylene is available in three SDR ratios:

- SDR 32
- SDR 17.6
- SDR 11

Metal Piping

The previous sections described how pipe is identified and sized using systems such as IPS, schedule numbers, and SDR. These sizing systems apply across many different types of pipe, regardless of the material from which the pipe is made.

Once pipe has been identified by size and pressure rating, it is also classified by the material used in its manufacture. Different materials have different physical, chemical, and mechanical properties that affect their strength, durability, corrosion resistance, and suitability for specific applications.

The following sections introduce the common types of pipe materials used in the piping trades, beginning with metal piping and progressing to specific materials such as copper, steel, and plastics.

Metal piping may be made of pure elements or a mixture of elements called alloys. Alloys are used to improve pipe corrosion resistance, durability, strength, and other qualities.

Copper is an example of a pure metal. Copper tubing is claimed to be 99.9% pure copper.

Bronze is an alloy made of two elements: copper and tin. Brass is another alloy made primarily of copper and zinc.

Piping and Tubing and the Use of Alloying Metals

The chemical, physical, and mechanical properties of many metals are altered by the addition of alloying metals. The range of possible additions and proportions is virtually endless.

For example, iron may be mixed with varying amounts of carbon, silicon, manganese, sulphur and phosphorus to improve the pipe or tubing resistance to corrosion.

Nickel, chromium, magnesium, molybdenum, titanium and vanadium are all substances that will increase the hardness and tensile strength of a pipe. Chromium, nickel and titanium will increase an alloy's resistance to corrosion or staining. Tungsten and molybdenum will increase the melting point of all metals.

Copper Tubing

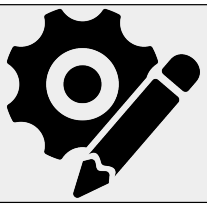
Copper piping and tubing is made from 99.9% pure copper. Copper piping is used in underground water service, hot and cold potable water systems, hot water heating systems, refrigeration and DWV systems.

Copper piping and tubing has the following characteristics:

- Does not rust
- Smoothness of interior (even at fittings)
- Manufactured with various wall thickness but standard outside diameters
- Available in hard tubing or available in soft (annealed) tubing that is very flexible
- Lightweight, malleable, and easy to work with

- Copper potable water tubing is available in sizes from $\frac{1}{4}$" –12"

- Copper DWV tubing is available in sizes from 1 $\frac{1}{4}$" – 8"



See *IPT's Pipe Trades Handbook and Manual* for examples of other pipes with print lines.

Nickel and Nickel Alloys and Uses

Figure 4 *Permendur (https://commons.wikimedia.org/wiki/File:Permendur_rod.jpg) (Nickel-cobalt alloy/Wikimedia Commons) CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0/deed.en)*

Nickel and nickel alloys are used in heavy industry such as marine and ship building, pulp and paper manufacturing, medical gas systems, and chemical manufacturing. Nickel and copper nickel alloys come in several types.

The basic metals used are copper and nickel—other metals are added in varying proportions. The different alloys of copper nickel have different characteristics tailored to specific installation environments. The examples of nickel and copper nickel provided in this information are only a partial list of types and uses. Further information about alloys can be found on manufacturers' websites.

There are several grades of nickel piping including:

- Nickel pipe 200 ASTM/ASME SB standard
- Nickel pipe 201 ASTM/ASME SB standard
- Nickel pipe 205 ASTM/ASME SB standard

Monel is a nickel alloy and is produced in grades such as Monel 200, 400, and K 500 ASTM/ASME SB standard. Monel alloy uses include:

- Chemicals, fats, and fertilizers manufacturing
- Sugar mills and distilleries
- Cement industries
- Shipping
- Paper industries
- Pumps

Inconel is a nickel alloy and is produced in grades such as Inconel, 600, 601, and 825 ASTM/ASME SB standard. Inconel characteristics include:

- Nonmagnetic
- Corrosion- and oxidation-resistant
- Strong and durable structure

- Butt-weld and forged fittings available or can be manufactured with short lead times

Hastelloy is a nickel alloy and is produced in grades such C-22, C-276 (UNS N10276) standard pipe ASTM/ASME.

Hastelloy uses include:

- Marine, power, chemical processing, pollution control, paper processing, waste disposal
- Sour gas applications (NACE MR0175)
- Flue gas desulfurization (FGD) applications for scrubbers, dampers and ducts

Hastelloy C-22 tubing is available up 2″ OD in welded and $\frac{1}{2}$„ OD seamless construction. Seamless pipe is available up to 6″. Larger sizes are available in welded construction.

Copper Nickel Alloy Types

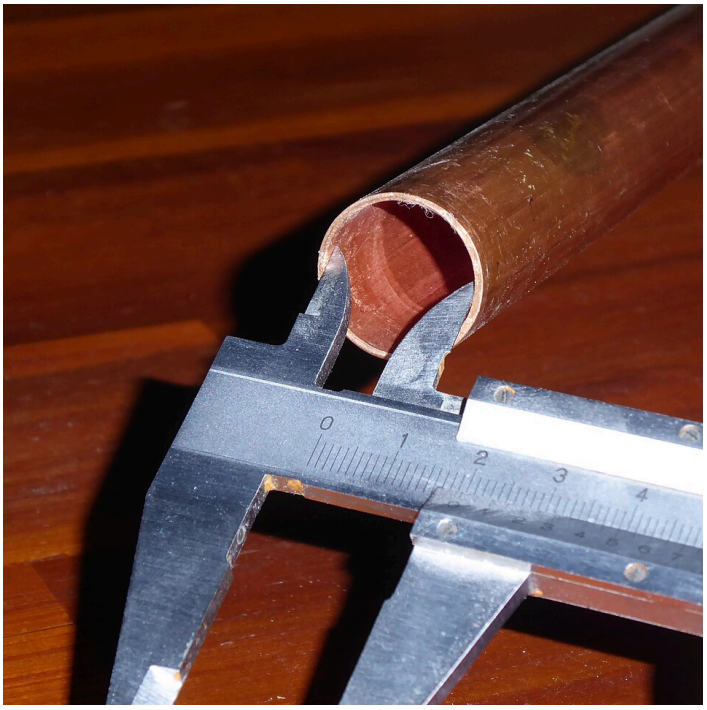


Figure 5 *Copper pipe (https://commons.wikimedia.org/wiki/File:Messschieber_misst_Rohrinnendurchmesser.jpg) (Rhetos/Wikimedia Commons) CC0 1.0 Public Domain (https://creativecommons.org/publicdomain/zero/1.0/deed.en)*

Copper nickel alloy type ASTM B111 90-10 is widely used in sea water applications. It has very good corrosion resistance to clean or moderately polluted water.

Copper Nickel Alloy Type

ASTM B111 70-30 is preferred for severe operating conditions. It has excellent resistance to impingement and erosion-corrosion by suspended solids in sea water. 70- 30 copper nickel is virtually immune from stress-corrosion cracking. It can be sensitive to deposit attack and is therefore not recommended for stagnant or slow-moving water.

Copper Nickel Alloy Uses

Copper nickel alloy has the following uses:

- Water desalination plants, especially in the most critical areas such as the heat reject and brine heater stages of power station condensers
- Chemical, petrochemical, and food processing industries
- Applications where top surface corrosion resistance is required
- Sea water corrosion-resistant assemblies

Brass Pipe

Brass piping is made from varying proportions of copper and zinc. Brass piping is very expensive. It is used in some hot and cold water supply lines and some drainage systems.

Brass pipe has the following characteristics:

- Versatile
- Very soft so can be threaded easily
- Very resistant to corrosion and rust
- Smooth inner walls reduce blockages in piping
- Can withstand high pressures (up to 7 MPa or 1000 psi)
- Difficult to puncture
- More ductile than copper and bronze

Brass pipe is available in sizes ranging from $\frac{1}{8}$ – 12″ (same sizing as steel piping) and standard lengths of 6 m (20′).

Aluminum Pipe and Tubing

Figure 6 *Aluminum Pipes (https://www.pexels.com/photo/metal-tubes-on-stack-15508177/) (Zakhar Vozhdaienko (https://www.pexels.com/@zakhar/)/Pexels) Pexels license (https://www.pexels.com/license/).*

Seamless aluminum piping is inexpensive and used primarily in irrigation systems. It is permitted in drainage systems if it is lined with plastic and in above-ground venting systems. This pipe was used in DWV systems for a short time but is no longer acceptable according to current plumbing codes.

Aluminum DWV pipe:

- Must be protected from corrosion
- Has relatively high tensile strength
- Lightweight, malleable, and ductile

Cast Iron Piping (Cast Iron Soil DWV Pipe)

Figure 7 *Cast iron (https://commons.wikimedia.org/wiki/File:Machines_de_Marly._Détail_tuyauterie_en_fonte_sur_la_colline_de_Bougival.jpg) (Moonik/Wikimedia Commons) CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/deed.en)*

Cast iron piping, sometimes referred to as mechanical joint or MJ, is an alloy of iron, carbon, and silicon. It may also contain varying amounts of manganese, sulphur and phosphorus to increase its corrosion resistance. Grey cast iron piping is used in drainage, sewer, and venting systems. Cast iron soil pipe cannot be used in a potable water system.

Cast iron piping qualities include:

- Resists corrosion; non-flammable
- Coated with pitch to protect from rust
- Durable and relatively inexpensive
- Does not easily transmit the sound of running water; much quieter than copper or plastic
- Heavier than plastic or copper
- Withstands high temperatures but not high pressures
- No-hub cast iron soil pipe is supplied in 3 m (10′) lengths

Ductile Cast Iron Water Pipe (Ductile Water Main)

Figure 8 *Ductile pipes for drinking water (https://commons.wikimedia.org/wiki/File:Cast-iron_pipes_for_drinking_water.jpg) (Cjp24/Wikimedia Commons) CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0/deed.en)*

Ductile iron pipe is a type of cast iron pipe used for potable water distribution. It's made from ductile iron. Ductile cast iron is produced by a technique known as centrifugal casting. The molten ductile iron is poured into a rapidly spinning water-cooled mold. Centrifugal force causes the molten iron to spread evenly around the circumference of the mold. Ductile iron will resist corrosion, however, over longer periods of time, the build-up of corrosion products inside the pipe can restrict the flow. Ductile cast iron water main is lined with a portland cement and sand mix mortar. The mortar is centrifugally applied during manufacturing. The mortar lining extends the life of the water main. A variety of other linings are available to reduce or eliminate corrosion including polyurethane and polyethylene. The exterior of the pipe is coated with bituminous coating to protect the pipe during shipping and installation.

In some jurisdictions, the ductile iron can be wrapped in a polyethylene sleeve. The sleeve of polyethylene completely wraps the pipe and the bell of any joints. The sleeve inhibits galvanic corrosion by physically separating the pipe from the surrounding soils.

Ductile water main characteristics:

- Very strong
- Fracture-resistant
- Nominal pipe sizes vary from 3 – 64″, in increments of at least 1 inch
- Manufactured exclusively from scrap steel
- Can be recycled

Spigot and sockets involve a normal pipe end (the spigot) being inserted into the socket (or bell) of another pipe or fitting. This is called a "push-joint" or "slip-joint". A gasket and the pipe are lubricated before assembly. The joints provide some flexibility, allowing the pipe to resist ground movement stresses. Any bends, tees, or valves will require either a restrained joint or, thrust blocks.

Duriron Pipe

Duriron pipe is a high-silicon-content acid-resistant cast iron pipe. It's available in hub and spigot ends or mechanical joint no hub ends. Duriron pipe and fittings can be used wherever acids, solvents, bleaches, detergents, or otherwise aggressive fluids are present. Duriron is ideal for use in chemical processing plants, school, and industrial laboratories.

Duriron characteristics:

- Outstanding corrosion resistance
- Excellent resistance to sulfuric, nitric, hydrochloric and acetic acids
- Resistant to both oxidizing and reducing solutions
- Is not appreciably affected by either acid concentration or temperature
- Tensile strength is less than most metals
- Suitable for applications up to 500°F (260°C)
- High abrasion resistance
- Density and wall thickness muffles sound from drainage
- Bell & spigot pipe is available in 2-inch through 15-inch diameters
- Mechanical joint pipe and fittings is available in $1\frac{1}{2}$„ -inch through 4-inch
- Available in a split flange deign in sizes 1-inch to 8-inch

Duriron bell & spigot joints should be assembled using virgin lead and Red Stripe Sealite A312 acid- resistant rope packing. Mechanical joint couplings should be installed by alternately tightening the two nuts and bolts to a minimum of 9 ft-lbs and a maximum of 11 ft-lbs torque.

Wrought Iron Piping

Wrought iron pipe was used for water supply in older houses. It comes either "black" or galvanized. Joints are made by threading pipe into cast iron fittings—unlike screw threads, pipe threads are tapered. Wrought pipe can be identified by a raised cross-hatch pattern on one side or the other. Wrought iron pipe is no longer used in water systems.

Carbon Steel Pipe

Figure 9 *Carbon pipes (https://pixabay.com/photos/steel-pipes-steel-factory-6967964/) (Bakhrom Tursunov/Pixabay) Pixabay content license (https://pixabay.com/service/license-summary/)*

Carbon steel is steel where carbon is the main alloy component. Carbon steel pipe is commonly referred on the job as "black iron pipe." Carbon steel pipe manufactured with a zinc coating is called galvanized iron pipe. Carbon steel pipe can also be manufactured with a plastic coating for use in corrosive environments or underground. Carbon steel pipe is used in steam and hot water heating systems, fuel-gas piping systems and fire sprinkler systems.

Carbon Steel Types

ASTM A53 is a carbon steel alloy used for structural steel pipe. The alloy specifications are set by ASTM International, in specification ASTM A53/A53M [1]. A53 pipe is suitable for structural or pressure applications. A53 pipe comes in three types and two grades:

- A53 Type F is longitudinally furnace butt welded or continuous welded (Grade A only).
- A53 Type E is longitudinally electric resistance welded (Grades A and B).
- A53 Type S is seamless pipe, produced by hot working, and possibly cold finishing, the steel (Grades A and B). ASTM A53 Type S is now currently an outdated specification and has been replaced by ASTM A106 specification for seamless carbon steel pipe.

  ▸ Available from $\frac{1}{8}$" – 48″ diameter and larger, from stock, in Schedule 5 through Schedule 160, standard, extra-heavy, and double extra-heavy.
  ▸ Threaded, bevelled, and grooved ends available from stock.
  ▸ Tube and tubing in carbon, stainless steel, aluminum and other alloys in sizes from hypodermic to 48″ and larger. Available in rigid lengths and coils, depending on application.

Seamless Steel Pipe and Tubing

Figure 10 *Seamless Steel Pipe (https://www.pexels.com/photo/close-up-photo-of-stainless-steel-pipe-8853524/) (Los Muertos Crew (https://www.pexels.com/@cristian-rojas/)/Pexels) Pexels license (https://www.pexels.com/license/)*

Seamless (SMLS) steel pipe is made from a solid round steel billet that is heated and pushed or pulled over a form until the steel is shaped into a hollow tube. The seamless pipe is then finished to dimensional and wall thickness specifications. Seamless steel finishes include hot rolled, cold drawn, turned, and roto-rolled. After the end finishing is complete, all pipes are then pressure- tested. A final visual inspection and labelling is completed, and an external coating can then be applied.

Characteristics of seamless steel pipe:

- Used for steam boilers and pipelines for installations with high and supercritical steam conditions
- Used in oil and gas, chemical, and automotive industries
- Ultra strength and durability
- Can be used for corrosion-resisting applications
- In sizes from $\frac{1}{8}$„ – 26″ OD
- ASTM A106/A106M – 10 standard specification for seamless carbon steel pipe for high- temperature service

Stainless Steel

Stainless steel is used primarily when corrosion or oxidation is a problem. Over 50 years ago, it was discovered that the addition of chromium to steel would impart corrosion and oxidation resistance to the steel.

Stainless steel is available from $\frac{1}{8}$„ – 24″ diameter in Schedule 5 through to double extra-heavy and beyond. Also available is an inside diameter pulp and paper specified pipe.

Specialty grades are available, including high-nickel alloys such as Hastelloy C-276; carbon alloys such as Chrome-Moly P22, WPL6; aluminum alloys such as 6061T6, 5083H112; and stainless alloys such as 317L, 321, and 347.

Stainless steel alloys usually have a chromium content of at least 10%.

Grades of Stainless Steel

There are different grades of stainless steel:

- Austenitic: these grades (such as 302, 304, 308, 316, etc.) are also available with a lowered carbon content (designated with an "L", such as 304L or 316L).
- Martensitic (such as 410 and 416).
- Ferritic (such as 409 and 430).

Depending on the grade, stainless steel is made up of iron and:

- Carbon (approximately 3–10%)
- Nickel (0–22%)
- Chromium (4–27%)
- Molybdenum (0 –4%)

Qualities of stainless steel:

- Corrosion-resistant
- Oxidation-resistant
- Heat-resistant
- Improved strength

Identify Stainless Steel Grades

Austenitic Grade of Stainless Steel (300 Series)

Austenitic grades are those alloys that are commonly in use for stainless applications. The austenitic grades are not magnetic. The most common austenitic alloys are iron-chromium- nickel steels, widely known as the 300 series. The austenitic stainless steels, because of their high chromium and nickel content, are the most corrosion-resistant of the stainless group, providing unusually fine mechanical properties. They cannot be hardened by heat treatment but can be hardened significantly by cold-working.

Straight Grades

The ***straight grades*** of austenitic stainless steel contain a maximum of 0.08% carbon. There is a misconception that

straight grades contain a minimum of 0.03% carbon, but the specification does not require this. As long as the material meets the physical requirements of straight grade, there is no minimum carbon requirement.

L Grades

L grades of austenitic stainless steel are used to provide extra corrosion resistance after welding. The letter L after a stainless steel type indicates low carbon (as in 304L). The carbon is kept to 0.03% or under to avoid carbide precipitation. Participation of carbon in stainless steel occurs when the steel is heated to temperatures in the critical range (800 – 1600°F). The carbon moves to the welded area and combines with the chromium resulting in reduced corrosion resistance of the welded joint.

- L grades are more expensive.
- L grades are used where annealing after welding is impractical, such as in the field where pipe and fittings are being welded.

H Grades

H grades of austenitic stainless steel contain a minimum of 0.04% and a maximum of 0.10% carbon and are designated by the letter H. H grades are primarily used when the material will be used at extreme temperatures, because the higher carbon helps the material retain strength at extreme temperatures.

Martensitic Grades of Stainless (400 Series)

The ***martensitic grades*** are straight chromium steels containing no nickel (414 has 2% nickel).

Martensitic grades of stainless steel were developed to provide a group of stainless alloys that would be corrosion-resistant and hardened by heat treating. They are magnetic.

The martensitic grades are mainly used where hardness, strength, and wear resistance are required.

Ferritic Grades of Stainless Steel (400 Series)

Ferritic grades have been developed to provide a group of stainless steel to resist corrosion and oxidation, while being highly resistant to stress corrosion cracking. These steels are magnetic but cannot be hardened or strengthened by heat treatment. They can be cold-worked and softened by annealing. As a group, they are more corrosion-resistant than the martensitic grades but are generally inferior to the austenitic grades. Like martensitic grades, these are straight chromium steels with no nickel. They are used for decorative trim, sinks, and automotive applications, particularly exhaust systems.

Corrugated Steel

This piping is used mainly for municipal applications such as storm sewers, storm water drainage, under-drains, culverts, and similar uses.

Corrugated pipes are not normally used for the conveyance of sanitary or industrial wastes.

Plastic Pipe and Tubing

It's important to be able to identify and install plastic pipe and tubing. Plastic piping is increasingly popular because of its versatility and ease of installation. Some codes limit its use in water supply piping within buildings. Plastic materials are generally divided into two groups: ***thermoplastics*** and ***thermosetting resins***. Thermoplastics (such as ABS and PVC) can be repeatedly reformed by heating. Thermosetting resins (such as fibreglass) cannot be reshaped after they have been formed and cured. Most plastic piping materials are thermoplastics.

Polyethylene Plastics

Figure 11 *Polyethylene Pipe lengths (https://commons.wikimedia.org/wiki/File:Polyethylene_Pipe_lengths.jpg) (GordonJ86/Wikimedia Commons) CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0/deed.en)*

Polyethylene thermoplastic is made from petroleum. The method of processing determines the type of polyethylene used for different purposes including piping and tubing. Piping made from polyethylene is a cost-effective solution for a broad range of piping problems in municipal, industrial, marine, mining, landfill, duct, and agricultural applications. It has been tested and proven effective for above ground, surface, buried, floating, and sub-surface marine applications. Polyethylene (PE) is widely used in underground water and gas service and field irrigation systems. Cross-linked polyethylene tubing is used for water supply systems and hydronic heating.

Polyethylene piping has the following characteristics:

- Usually black (to prevent breakdown from sunlight) but also available in yellow or orange
- Extremely high-impact strength, yet flexible enough to be coiled
- High resistance to chemicals
- Low melting point and low temperature resistance, up to 54°C (130°F)

Polyethylene Pipe Qualities

In most piping systems, aging increases the pipe surface roughness, which increases flow resistance. Polyethylene (PE) pipe resists typical aging because it does not rust, rot, corrode, tuberculate, or support biological growth—it also resists the adherence of scale and deposits. In some cases, moderate flow velocities are sufficient to prevent deposits. For systems using a low velocity, it may be enough to introduce occasional high velocity flow in order to remove sediment and deposits.

Low-flow-rate gravity-flow pipelines can be cleaned with a water-jet or by forcing a soft (plastic foam) pig through the pipeline. Don't use bucket, wire, and scraper-type cleaning as these methods can damage PE pipe.

There are several types of polyethylene used to manufacture polyethylene pipe, including:

- High-density polyethylene (HDPE)
- Medium-density polyethylene (MDPE)
- Low-density polyethylene (LDPE)
- Linear low-density polyethylene (LLDPE)

You are not expected to memorize all types—focus on general properties and applications.

High-Density Polyethylene (HDPE)

High-density polyethylene or polyethylene high-density (PEHD) is a polyethylene thermoplastic made from petroleum. HDPE's plastic identification code (PIC) is 2. A plastic product's PIC is the small number printed within the recycling diagram somewhere on its surface. The HDPE has benefited from discussions about possible health and environmental problems caused by PVC and polycarbonate associated Bisphenol-A. HDPE's main use has been for underground gas piping.

Medium-Density Polyethylene (MDPE)

MDPE is less dense than HDPE. MDPE has good shock and drop-resistance properties. Stress cracking resistance is better than that of HDPE. MDPE is typically used in shrink film, packaging film, carrier bags, and screw closures. MDPE may be used for gas pipe and fittings when approved for that use.

Low-Density Polyethylene (LDPE)

LDPE is a thermoplastic made from petroleum. LDPE is commonly recycled and its "recycling number" (PIC) is 4. LDPE is used to manufacture juice and milk cartons, playground slides, and plastic wraps. LDPE is not used for piping.

Linear Low-Density Polyethylene (LLDPE)

LLDPE has penetrated almost all traditional markets for polyethylene—it's used for plastic bags and sheets, plastic wrap, stretch wrap, pouches, toys, covers, lids, pipes, buckets and containers, covering of cables, and flexible tubing. (It can be made much thinner than LDPE.)

LLDPE can be recycled into other things such trash can liners, lumber, landscaping ties, floor tiles, compost bins and shipping envelopes.

The following are examples of polyethylene materials used in the piping industry. Refer to the manufacturer's specifications for the product to ensure that the pipe you use meets the appropriate standards, applicable code requirements, and job specifications.

There are several categories of polyethylene pipe:

- CSA series, for building/plumbing code-related installations
- Standard series for non-CSA applications.
- Other polyethylene pipe products lines for specialty installations such as geothermal, ice rinks, submersible pump drop, irrigation, storm drainage, National Sanitation Foundation (NSF) uses, and utility uses

CSA Series Polyethylene Piping

The CSA series of polyethylene is general purpose pipe. It's available in either low-density polyethylene (LDPE) or high-density polyethylene (HDPE) grades manufactured to *CSA B137.1* standards.

CSA Series 75 PSI B137.1

This is a general light-duty service suitable for potable water.

Characteristics:

- Lightest wall thickness
- Black in colour
- Limited to 75 psi at 73.4°F
- Joined with gear clamps and insert type fittings
- Available in coils from 100′ – 500′ and reels up to 3000′
- Not allowable for use within the scope of the *Plumbing Code*

- Available in sizes $\frac{1}{2}$ -inch to 2-inch
- Carbon black pigment for ultraviolet protection

CSA Series 100 PSI B137.1

This is a general-duty service suitable for potable water. Characteristics:

- Heavier wall thickness than series 75 PSI
- Manufactured from LDPE
- Black in colour
- Limited to 100 psi at 73.4°F
- Joined with gear clamps and insert type fittings
- Available in coils from 100 '– 500′ and reels up to 3000'
- Not allowable for use within the scope of the Plumbing Code

- Available in sizes $\frac{1}{2}$ -inch to 2-inch
- Carbon black pigment for ultraviolet protection

CSA Series 160 PSI Copper Tube Size (CTS) B137.1 Municipal Water Service

CSA series 160 polyethylene pipe is specifically used for water service piping. Series 160 is copper tube size (CTS). It has its own size designation and will not accept normal polyethylene insert fittings, although fittings are available to adapt from one to the other. A yellow stripe that runs the full length of the pipe identifies some manufacturers' series 160 pipe. The yellow stripe is part of the pipe wall and permanently identifies it as the specific manufacturer's pipe.

In Canada, polyethylene water pipe and fittings must be certified to *CAN/CSA-B137.1*, Series 160, with a rated working pressure of 1034 kPa (150 psi).

Characteristics:

- Non-corroding and resists most acids, salt solutions, alkalis, fats, and oils
- Black or black with a yellow stripe
- Available in 100′, 200′, and 500′ coils as well as in 1000′ reels.
- Manufactured to copper tube size (CTS)
- Will not accommodate normal polyethylene insert fittings
- Resists decomposition, oxidation, tuberculation and microbiologically induced corrosion
- Connections of brass or plastic compression fittings are readily available
- Requires a stainless steel insert or a specially designed (copper tube size) plastic insert to reinforce the pipe joints
- Sequential markings every two feet
- Expansion rate is 0.87″ per 100′ of pipe for every 10°F change
- Rated at 160 psi @ 72°F cold water use only
- *Plumbing Code* restricts the use to a water service only

CSA Series 200 PSI Copper Tube Size (CTS) B137.1 Municipal Water Service

Characteristics:

- Non-corroding and resists most acids, salt solutions, alkalis, fats and oils
- Black in colour
- Manufactured from HDPE
- Available in 100′, 200′, and 500′ coils as well as in 1000′ reels
- Manufactured to copper tube size (CTS.)
- Will not accommodate normal polyethylene insert fittings
- Resists decomposition, oxidation, tuberculation and microbiologically induced corrosion
- Connections of brass or plastic compression fittings are readily available
- A stainless steel insert or a specially designed (copper tube size) plastic insert to reinforce the pipe joints
- Sequential markings every two feet

Non-CSA Standard Polyethylene Pipe

Non-CSA standard polyethylene is used in water distribution applications that do not require CSA approval.

Standard Series 75 PSI LDPE

Characteristics:

- Black in colour
- Manufactured from low-density polyethylene
- Available in sizes $\frac{1}{2}$-inch to 2-inch
- Available in 100'–500′ coils and 1000–3000′ reels
- Limited to 75 psi at 73.4°F
- Joined with gear clamps and insert-type fittings

Standard Series 100 PSI LDPE

Characteristics:

- Black in colour
- Manufactured from low-density polyethylene
- Available in sizes $\frac{1}{2}$-inch to 2-inch
- Available in 100 '–500′ coils and 1000–3000' reels
- Limited to 100 psi at 73.4°F

- Joined with gear clamps and insert-type fittings

Other Polyethylene Applications

The following describe some other polyethylene tubing applications.

Ice Rink PE Linear Low-Density Polyethylene or Low-Density Polyethylene

Manufactured using extrusion method in accordance with CSA-B137.1.

Characteristics:

- Working pressure 70 psi at 73.4°F (23°C)
- 1-inch diameter
- Black in colour
- Limited to 70 psi at 73.4°F
- Available in 2000'–5000′ reels only
- Available in two wall thickness: standard wall and thin wall

Polyethylene Medium-Density Gas Pipe

Characteristics:

- Durable
- Corrosion resistance
- Not affected by hydrocarbons
- CSA B137.1 for water pipe and B137.4 for gas pipe
- Canadian General Standards Board CGSB 41 and 61 pipe polyethylene for transport of liquids
- NSF and Plastic Pipe Institute PPI PE 2406
- Available in a variety of sizes in coils or limited straight lengths
- Limited to 100 psi at 73.4°F
- Yellow in colour

Geothermal HDPE

Geothermal HDPE is manufactured by extrusion from high-density polyethylene (HDPE). Characteristics:

- Durability
- Stress crack resistance

- Sizes from $\frac{1}{2}$ –24″
- Pipes come in sticks, coils, and large reels
- Green in colour (black)
- Limited to 160 psi at 73.4°F
- NSF standard

Marking example for a geothermal HDPE pipe, printed with yellow permanent print stating the following:

- NSF geothermal logo
- Identification manufacturer
- The appropriate SDR rating
- Product trade name
- All relevant standards
- Manufacturing date
- Incremental footage marking every two feet
- Design temperature rating
- Production shift designation
- Identification of PE-3408 high-density resin

Pump Drop Polyethylene

Pump drop polyethylene pipe for submersible pump installations has two use designations:

LLDPE 200′ Depth Installations

- Manufactured by extrusion to CSA B137.1 standard Series 75 and 100
- Up to 200′ deep
- Available in coils from 300–1500 feet
- Available from $\frac{1}{2}$ -inch to 2-inch
- Blue in colour
- Pipe marking includes a printed count-down numbering on the pipe

MDPE 600′ Depth Installations

- Manufactured by extrusion to CSA B137.1 standard Series 160
- Up to 600′ deep
- Available in coils from 300–1500 feet
- Available from 1-inch to 1 $\frac{1}{4}$ -inch

- Blue in colour
- Pipe marking includes a printed count-down numbering on the pipe

Corrugated HDPE Municipal Storm Drainage

Dual-Wall HDPE Corrugated Pipe for Municipal Storm Drainage

HDPE corrugated municipal storm drainage pipe is manufactured from HDPE. It is available to move stormwater and wastewater.

Characteristics:

- Flexible pipe
- Durability
- Joint integrity
- Long-term cost-effectiveness
- Ability to support and distribute live and dead load Contact manufacturers for approval standards.

Cross-Linked Polyethylene (PEX Tubing)

Cross-linking is a chemical reaction that occurs between polyethylene polymer chains. Currently, three methods for producing cross-linked polyethylene (PEX) tubing exist:

- Engel or peroxide method (PEX-A)
- Silane method (PEX-B)
- E-beam (electron beam) or radiation method (PEX-C)

All three processes generate tubing that is cross-linked to varying degrees, and all meet the ASTM, NSF and CSA standards for use in potable water and heating applications.

Engel Method (PEX-A)

The PEX tubing industry considers this tubing superior because the cross-linking is done during the manufacturing process when polyethylene is in its amorphic state (above the crystalline melting point). Because of this, the degree of cross-linking reaches around 85%, resulting in a more uniform product with no weak links in the molecular chain.

Silane Method (PEX-B)

PEX-B tubing is crosslinked after the extrusion process by placing the tubing in a hot water bath or steam sauna. The

degree of crosslinking for PEX-B is typically around 65 to 70%. This method is not as evenly cross-linked as the PEX-A method, nor does it have the same degree of thermal memory, which allows kinked tubing to be reshaped with the use of a heat gun.

E-beam Method (PEX-C)

PEX-C uses an electron beam to change the molecular structure of the tubing (i.e., cross-link) after the extrusion process. The PEX-c method requires multiple passes under the beam to reach a 70 to 75% degree of cross-linking. Side effects of this process are discolouration due to oxidation (from natural white to yellow, unless other pigment is added), and a slightly stiffer product.

PEX-A Distinctions

The properties in PEX-A tubing make it the most flexible PEX on the market. This allows the tubing the tightest bend radius available—as little as 3 $\frac{1}{2}$" for $\frac{1}{2}$" tubing. Its flexibility also greatly reduces the instance of kinked tubing. If there is the occurrence of kinked tubing, PEX-A tubing has thermal memory. This allows the repair of kinked tubing with a careful shot of heat from a heat gun. Shape memory allows PEX-A tubing to expand and then shrink back to normal size, this offers unique opportunity for various types of fitting connections.

Colour Coding of PEX Tubing

The colours used for PEX tubing vary from opaque, white, blue, red and variations of these colours. The best way to identify PEX is via the pipe markings. Typically, red PEX tubing is used for hot water while blue is used for cold.

PEX characteristics:

- Typically has less internal friction than metal pipe
- Less expensive than metal pipe
- Flexible and can be bent into a radius angle to provide less restrictive flow
- Expected lifetime of upward of 50 years
- Susceptible to ultraviolet degradation when exposed to direct sunlight See *IPT's Pipe Trades Handbook and Manual.*

Oxygen Barrier PEX

PEX tubing used in radiant heating system applications with ferrous metal parts was found to allow oxygen absorption through the PEX tubing wall. The solution to this problem is to apply an oxygen barrier shield during the manufacturing process. This shield is a thin layer of plastic film that slows down the rate of oxygen diffusion through the piping walls. It doesn't prevent diffusion. This PEX

tubing is identified by markings such as “OXY guard” or “Oxygen barrier.”

Composite Metal and Plastic Piping

Two kinds of composite metal and plastic piping are:

- Polyethylene/aluminum/polyethylene (PE/AL/PE)
- Cross-linked polyethylene/aluminum/cross-linked polyethylene (PEX/AL/PEX)

Both of these polyethylene composite pipes have three layers. The inside and outside layers are made of high-density polyethylene, tightly bonded with melt adhesive to the mid-layer, the longitudinally overlapped welded aluminum core. All layers are co-extruded in a one-step patented manufacturing process. The polyethylene inside and outside layers are hygienic, non-toxic and smooth. Its middle layer of aluminum serves as an oxygen barrier, stopping the oxygen diffusion through the cross-linked polyethylene layers.

Characteristics:

- Holds a bend better, because the shape memory of the PEX is offset by the aluminum.
- The pipe is available in $\frac{1}{2}$ -, $\frac{5}{8}$ -, $\frac{3}{4}$ – and 1-inch (14, 16, 20, and 25 mm) nominal diameter sizes.
- Available in 3.7 m (20′) straight lengths or coils up to 305 m (1000′).
- Hot-water piping is orange and cold-water piping is blue.
- Joints buried in concrete are not recommended—consult manufacturers’ documentation.

Standards:

- PEX/AL/PEX pipe must comply with ASTM F 1281-98a.
- Produced from polyethylene compound complying with the requirements of ASTM D 1248 for P33, Class A material.
- Grade 3003 aluminum must comply with the requirements of ASTM B 209.
- Both PE/AL/PE and PEX/AL/PEX pipe and fittings used for potable water systems must conform to CAN/CSA-B137.9.
- PE/AL/PE pipe and fittings must not be used in a hot water system.

Pipe markings, at minimum 1.5 m (5′) intervals, include:

- Manufacturer’s name
- Product designation (name)
- Material designation (PEX/AL/PEX) or (PE/AL/PE)
- Nominal size
- Potable water designation
- Appropriate standard designation (CAN/CSA-B137.10)
- Pressure and temperature limitations

Polyamide

Polyamide (PA) is a newer thermoplastic piping material used for underground fuel gas distribution such as natural gas. The PA piping systems possess a higher hydrostatic stress rating than the traditional PE piping systems. Like PE piping systems, PA systems are available in a broad array of sizes and with a full complement of fittings. The PA piping systems are joined using heat fusion methods. PA is typically yellow in colour, which has become the standard for underground gas lines.

Standards: CSA B137.12-09 Polyamide-11 (PA-11) piping systems for gas services

Characteristics:

- Durable
- Available in straight lengths of 164 m (50′) or in coils to more than 76 m (250′)
- Extruded in diameters ranging from 2 – 6″
- Corrosion-free
- Chemical-resistant
- Suitable for use in hydrocarbon contaminated soils without de-rating
- Higher operation pressure than other plastic pipe
- Coiled pipe that can be ploughed or laid in trenches
- Ability to be squeezed off to stop flow
- Polyamide-11 (SDR 11)[GGA1] and polyamide-12 (SDR 12)[GGA2] are available for underground gas piping. A high SDR pipe has a low-pressure rating and low SDR pipe has a high-pressure rating.

Markings:

- Manufacturer's name
- Product designation (name)
- Material designation (polyamide PA-11)
- Nominal size
- SDR number
- Potable water designation
- Appropriate standard designation (CAN/CSA- 137.12-09)
- Pressure and temperature limitations

Polybutylene

Polybutylene (PB) plastic pipe is grey-coloured flexible tubing first introduced in the 1970s. Polybutylene was installed in many residential buildings. The pipe has since been discontinued, and PEX (cross-linked polyethylene) piping has taken its place. Polybutylene pipe is no longer manufactured. There were issues with it that resulted in class action lawsuits.

Polypropylene (PP)

Figure 12 *Hdpe pipe installation (https://commons.wikimedia.org/wiki/File:Hdpe_pipe_installation.jpg) (Tomascastelazo/Wikimedia Commons) CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/deed.en)*

Polypropylene (PP) is used in piping systems where resistance to corrosion and chemical leeching is required. It's widely used in the petroleum industry for wastewater disposal lines, low-pressure gas gathering systems and crude oil flow piping. It's acid-resistant and is used for laboratory and industrial drainage piping. PP has resilience against most forms of physical damage, including impact and freezing, and is widely used where contents being transported need to maintain high purity.

Polypropylene characteristics:

- High strength and rigidity qualities for use in potable plumbing, hydronic heating, cooling and reclaimed water systems
- Environmental benefits
- May be joined by heat fusion rather than solvent cement
- Brown, white, blue or black in colour
- Corrosion- and chemical-resistant
- Suitable for high temperature, pressure and impact applications
- Brittle below −27 °C (−l0 °F)
- Polypropylene is identified with "recycle number" 5
- CSA standard: B137.11-09

Acrylonitrile-butadiene-styrene

Acrylonitrile-butadiene-styrene (ABS) DWV is available in two types: solid wall schedule 40 and cellular core wall. ABS pipe is used for DWV plumbing systems in residential, commercial and some industrial buildings. It can be used both above and below ground. This pipe meets the requirements of CSA B181.1 and ASTM D 3965 standard.

ABS DWV Cellular Core and Solid Wall

Cellular core ABS has the same working characteristics as standard ABS solid wall DWV but is less expensive. This lightweight, inexpensive DWV pipe has pipe walls that are made up of small air pockets. The inside and outside diameter surfaces consist of a hard ABS shell.

ABS cellular core pipe does not appear any different than solid wall ABS pipe. The weight of each cellular core pipe is lighter than its respective solid wall partner. When looking at the ends of the cellular core pipe, you can see that it has air bubbles in the middle layer. ABS DWV solid pipe has no air bubbles in the pipe wall; consequently, it is heavier than ABS cellular core pipe.

Characteristics of ABS pipe:

- Black in colour
- Lower resistance to chemicals than polyvinyl chloride (PVC)
- Easy to cut and join
- Available in 1 $\frac{1}{4}$" to 6" diameters and typically 3.7 m (12') lengths
- Strong at low temperatures
- Weaker than PVC
- Can be damaged by exposure to sunlight
- High temperature expansion ratio
- Canadian standard for ABS DWV pipe is CAN/CSA-B181.1, "ABS Drain, Waste, and Vent Pipe and Pipe Fittings."

There may be some restriction on the depth of burial of ABS cellular core, especially under vehicle traffic. You should consult the local authority having jurisdictions (AHJ) before installing in such situations.

Polyvinyl Chloride

Polyvinyl chloride (PVC) piping is a very popular thermoplastic used primarily in pressure systems such as water service, irrigation systems, and industrial process piping. Some PVC piping is used in DWV systems.

Characteristics:

- Available in various colours
- Will not react with many strong acids, alkalis, salt solutions, alcohol, and other chemicals
- No taste or odour added to substances carried by PVC
- Resistant to fungi, bacterial action, and corrosive effects of soil
- Withstands high pressures and temperatures
- High tensile strength
- Not permitted when pipes carry hot water

- PVC piping is not permitted for any compressed air application
- Canadian standard for PVC pipe is CSA B137.3-09
- Comes in Schedule and SDR sizing

Colour Codes

PVC materials can be made in many colours, as there is no established colour coding at this time. Always read the pipe markings to identify the correct use—do not rely on the colour of the pipe to indicate proper application.

Colours used include the following:

- White and grey used for irrigation and potable water systems
- Green and blue shades for water and sewer utility and service water lines
- Specific unique colours used by utility companies such as telephone or electrical (shades of orange/pink)

PVC Sewer Pipe

Figure 13 *PVC nonpressure pipe (https://commons.wikimedia.org/wiki/File:PVC_nonpressure.jpg) (Стрелец Игорь/Wikimedia Commons) CC BY 3.0 (https://creativecommons.org/licenses/by/3.0/deed.en)*

PVC sewer pipe has thinner walls than Schedule 40 DWV PVC. PVC sewer pipe is available in standard length of 3 m (10′) including the bell end. PVC sewer comes in sizes 3 – 6″. PVC is available with solvent ends and with either solid or perforated walls. It is usually white in colour.

Solid wall PVC pipe is used to collect wastewater and storm water from the building drains and convey it to the municipal sewer lateral at the property line.

Perforated pipe is used in septic fields and for foundation perimeter drains or curtain drains to intercept ground water drainage. The perforation holes are $\frac{5}{8}$„ in diameter. The perforations are located at 4 o'clock and 8 o'clock (on 5″ centres), and the print line is located at 12 o'clock. This allows you to ensure the perforations are oriented correctly.

Clear Plastic PVC

Typical applications for clear PVC include process, sight glass, and dual containment piping as found in chemical processing. Clear PVC is used for high-purity applications, food processing, pharmaceuticals, laboratory use, waste treatment and plating.

Applications and use:

- Used in applications involving fluid transfer where visual monitoring of process lines is required
- Generally corrosion-resistant to most acids, bases, salts, aliphatic solutions, oxidants, and halogens
- Available in iron pipe sizes from $\frac{1}{4}$„ –12″
- Can be used at temperatures up to and including 140°F
- Pressure rating varies with the schedule and pipe size from 70 – 570 psi
- Belled-end pipe has tapered sockets to create an interference type fit

Markings:

- Manufacturer's name
- Appropriate ASTM and or CSA standard
- Pipe size
- Schedule 40 or schedule 80
- Date and time of manufacture
- Temperature and pressure limitations

Chlorinated Polyvinyl Chloride

Chlorinated Polyvinyl Chloride (CPVC) is a thermoplastic used in process piping, hot water lines, and other applications where temperatures may exceed those that PVC piping can withstand.

Characteristics:

- Either cream, red, or green in colour
- High resistance to chemicals
- High impact strength
- High tensile strength: more than 13.7 MPa (2000 psi) at 100°C (212°F)
- Withstands high temperatures and pressures
- Canadian standard for CPVC pipe is: B137.6-09

CPVC for Fire Sprinklers

CPVC used for fire sprinkler systems must be a rigid chlorinated polyvinyl chloride compound, Type IV Grade I, with a cell classification of 23447 as defined in ASTM D1784. The compound and the finished product must be orange in colour and be approved by the National Sanitation Foundation (NSF) for use with potable water.

Corrosion-resistant fire sprinkler pipe, IPS sizes $\frac{3}{4}$ –3″, for use in wet automatic fire sprinkler systems.

When installed in accordance with the manufacturer's installation instructions, this pipe is listed by Underwriters Laboratories (UL) for use in: light hazard occupancies as defined in the *Standard for Installation of Sprinkler Systems (NFPA 13)*; residential occupancies up to and including four storeys in height (NFPA 13R); and residential occupancies as defined in the *Standard for Sprinkler Systems in One and Two Family Dwellings and Mobile Homes* (NFPA 13D). CPVC fire sprinkler pipe is UL-listed for use in return air plenums (NFPA 90A), system risers per *NFPA 13 Light Hazard, 13R and 13D*, exposed installations, garages per *NFPA 13R*, and for use as underground fire service mains (NFPA 24) when installed in accordance with the manufacturer's installation instructions.

CPVC Dimensions

CPVC fire sprinkler pipe must be manufactured to standard dimension ratio (SDR) 13.5 dimensions in strict accordance to the requirements of ASTM F442 for physical dimensions and tolerances.

Each production run of pipe manufactured in compliance to this standard must also meet the test requirements for materials, workmanship, burst pressure, flattening, and extrusion quality defined in ASTM F442. Furthermore, this pipe must consistently meet or exceed the physical performance test requirements of the appropriate approval/listing agency(s) follow-up procedures established for the product.

Specialty Piping and Tubing

Piping may also be made from substances such as clay, borosilicate (glass), or fibreglass.

Glass Piping (Pyrex Pipe)

Glass piping is usually made of borosilicate glass, which is also used to manufacture tough, durable, chemical glassware. Glass pipe is used in industries such as food processing, chemical and pharmaceutical production, and pulp and paper manufacturing. Short lengths of glass piping may be inserted in opaque piping to serve as sight-flow indicators.

Glass piping qualities:

- Very breakable when dropped or over-tightened
- Extremely resistant to all chemicals (except hydrofluoric acid, phosphoric acid, and some strong alkalis)
- Withstands extremely high and low temperatures
- Very durable
- Has extremely smooth inside surfaces, which reduces pressure loss due to friction and discourages scale build-up

Fibreglass Pipe

Fibreglass-reinforced pipe (FRP) is made from vinyl ester and polyester resins, glass, and reinforcement materials. FRP piping materials are manufactured by winding processes that employ epoxy resins reinforced with continuous glass filaments. The resins used are thermosetting (they undergo chemical reactions as they cure that are irreversible), resulting in superior temperature capabilities, while the filament reinforcement makes the piping components far more capable mechanically than ordinary non-reinforced thermoplastics. The result is enhanced performance and lighter weight.

Fibreglass-reinforced plastic pipe (FRP) characteristics:

- Corrosion resistance
- Extremely hard surface that resists erosion
- Abrasion resistant barrier on the exterior of the pipe as well as the interior
- Durable, resists cracking and crazing of the resin when subjected to heavy design loads
- Heavy exterior coat of resin containing an ultraviolet stabilizer to impart long-term resistance to the effects of sunlight and other weathering elements
- Available in standard sizes 2″ to 36″ diameter
- Pressure ratings: 50, 100 and 150 psi
- Corrosion barrier: 0.100″ (100 mils)
- Resin: corrosion-resistant vinyl ester

Fibreglass pipe uses:

- Motor fuel underground piping—available in diameters of 2–6″.
- Municipal, chemical and industrial applications, including transmission of acids, caustics and solvents, and for cooling tower lines, wastewater treatment process lines, raw water inlet and discharge lines. Pipe diameters range depending on the manufacturer.
- Oil-field production lines, gas gathering lines, tank battery hookups, and salt water disposal/ injection. Standard diameters are available up to 16 inches with pressures up to 3500 psi.
- While sewer and drainage piping continues to be dominated by concrete, there are many areas where FRP is the preferred choice. For example, concrete pipe deteriorates rapidly in sewage due to hydrogen sulfide attack. Hydrogen sulfide erodes the upper surface of the pipe and will eventually cause a cave-in. FRP is unaffected by hydrogen sulfide or purging with caustic or hypochlorite to suppress sulfide odour. As a result, FRP pipe has been used as a liner in large diameter (48 “–60”) concrete pipe.

Vitrified Clay Piping

Vitrified clay piping is no longer widely used but may still be found in building drains. Vitrified clay piping qualities:

- Extremely breakable
- Acid resistant (suitable for use in soil)

Plastic-lined Metal Piping

Plastic-lined piping is lined with thermoset plastics such as polytetrafluoroethylene (PTFE) or polyvinylidene fluoride (PVDF). It's quite expensive and is used primarily for transporting or containing highly-corrosive or ultra-pure fluids in chemical or pulp and paper plants.

Plastic-lined metal pipe qualities:

- Performs well over wide range of operating temperatures
- Very durable with high tensile strength

Asbestos-Cement Piping

Figure 14 *Industrial Concrete Pipes in Rural Landscape (https://www.pexels.com/photo/industrial-concrete-pipes-in-rural-landscape-30762650/) (Andy Coffie/Pexels) Pexels License (https://www.pexels.com/license/)*

Asbestos-cement pipe is constructed by mixing asbestos fibres with cement. This pipe has been used for water mains, outside sewers, storm sewers, rainwater leaders, drainage and vent systems. Asbestos-cement is no longer available but may be found in existing systems.

Due to health concerns, before working on this type of piping, check WHMIS and WorkSafeBC regulations and follow provincial regulations for the handling of the product.

Corrugated Stainless Steel Tubing

Corrugated gas tubing is easily distinguished by a flexible yellow polyethylene jacket on the outside. Gas connectors will often have a coating on the outside—not a jacket. Corrugated stainless steel tubing (CSST) will also be identified as such on the jacket itself. The general rule for CSST is that it must be installed in accordance with the manufacturer's instructions. Before installing this CSST piping, you must first complete the manufacturer's training program.

Standards: *ANSI LC1-2005, CSA 6.26-2006*, "Fuel Gas Piping Systems Using Corrugated Stainless Steel Tubing (CSST)."

Characteristics:

- Flexibility over rigid piping
- Does not require intermediate joints and is capable of being installed in one continuous run
- Easily avoids existing obstacles
- Well-suited for locations that are prone to seismic activity because the tubing is able to move as the ground or the structure shifts
- Must be properly bonded/grounded

Typical corrugated stainless steel tubing system (CSST) specifications:

- Made of type 304 alloy; ASTM A240.
- An annealing process tempers the steel, giving it added flexibility and ease of bending
- Suitable for use with elevated pressure systems
- The ANSI LC1 standard rates CSST for use at pressures up to 5 psi
- CSST fittings have standard NPT threads and may be used in combination with all approved fuel gas piping materials with the pipe threads as the interface
- System components such as manifolds, tees and stub-outs may be fabricated from other approved materials to be used with CSST flexible gas piping.

Corrugated stainless steel tubing manufacturers have also developed a lightning-resistant system. The product has a unique layer of metal mesh, designed to dissipate heat and electricity. The mesh is placed between two jackets of semi-conductive polymer. Fittings have been designed to ensure seamless continuity with the mesh with a feature that bites through the first layer of semi- conductive polymer and into the metal mesh. This creates electrical continuity throughout the system, eliminating the need for manufacturer required bonding.

Reinforced Hydraulic Tubing (Hydraulic Hose)

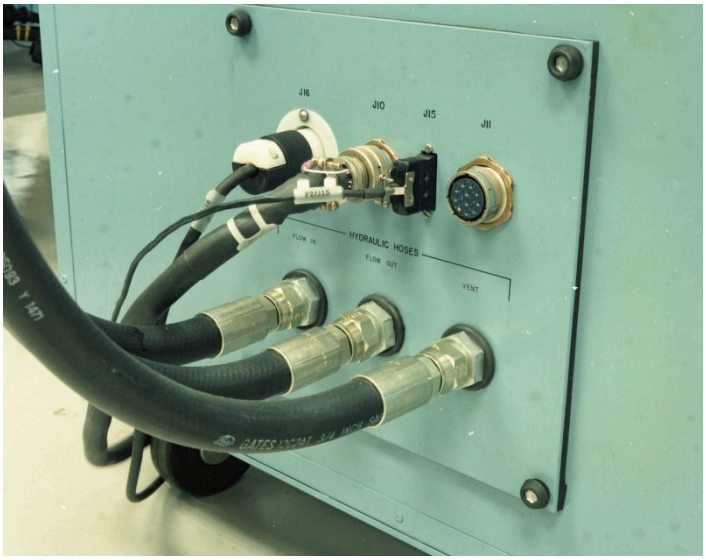


Figure 15 *Hydraulic hose connection (https://commons.wikimedia.org/wiki/File:23_0051283_Convair_Negative_Image_-_Hydraulic_hose_connection_points_(53889743769).jpg) (San Diego Air & Space Museum Archives/Wikimedia commons) No known copyright restrictions (https://sandiegoairandspace.org/collection/image-collection)*

Unlike metal tubing, hose is flexible, so it is used primarily to allow relative motion between components at either end of the hose assembly and to simplify routing and installation. It's much easier to route a hose assembly over, under, around, or through a series of obstacles than it is to bend and install a rigid tubing assembly. Furthermore, replacing a hydraulic line by fabricating a rigid tube assembly often is more costly and time consuming than making a hose assembly.

A hydraulic hose is built up with rubber and steel layers. A rubber interior is surrounded by multiple layers of woven wire, for reinforcement, and rubber as shown in Figure 15. The exterior is designed for abrasion resistance. Hydraulic hoses generally have steel fittings swaged on the ends.

Reinforced hydraulic hose applications:

- Oil lines
- Hydraulic jacks
- Antifreeze and water fluids
- Natural and propane gas and liquids

Sample manufacturer's specifications for hydraulic hose:

- For high-pressure hydraulic oil lines
- Meets SAE 100R16 requirements and performance requirements of EN 857 2SC
- M2T hose has smaller exterior dimensions and significantly tighter bend radius
- Tube: black, oil resistant, synthetic rubber (Nitrile—Type C)
- Reinforcement: two braids of high-tensile steel wire
- Tubing cover: black; oil-, abrasion-, and weather-resistant; synthetic rubber (modified nitrile)
- Dual green stripe lay-line

- Temperature range: -40 °F to +212 °F (-40 °C to +100 °C)

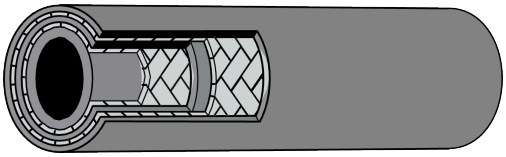


Figure 16 *Hydraulic hose (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Self-Test D-1.1: Describe Piping and Tubing Materials

Complete Self-Test 1.1 and check your answers.

If you are using a printed copy, please find Self-Test D-1.1 (#chapter-self-test-d-1-1) and Answer Key (#chapter-answer-key-self-test-d-1-1) in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://d-pipingcomponents-bcplumbingapprl1.pressbooks.tru.ca/?p=1924#h5p-1 (https://d-pipingcomponents-bcplumbingapprl1.pressbooks.tru.ca/?p=1924#h5p-1)

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- Plumber: Competency D-1 Prepare Pipe
- Steamfitter: Competency D-4 Layout and Install Piping and Tubing
- Sprinkler Fitter: Competency D-1 Prepare Pipe and Tubing

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D-1.2 Describe the Methods of Manufacture of Piping and Tubing

This section introduces the materials and manufacturing methods used to produce common piping and tubing in the trades. You will learn how pipes are made from carbon and stainless steel, cast iron, copper, and thermoplastic materials, and how these processes affect their strength, durability, and use. The section also explains how to identify different types of copper tubing, including their colour markings, and defines the term "temper" as it applies to copper. In addition, you will explore the three main methods used to manufacture cross-linked polyethylene (PEX) tubing, helping you understand how material properties relate to real-world applications in plumbing systems.

Carbon Steel Pipe

Schedule steel pipe and tube are types of steel pipe. Both are made from mild carbon steel and undergo similar manufacturing processes, in which strips of steel are passed through rollers until they form the desired shape. Then the seam is electrically welded. This process is shown in Figure 1. The tube is rolled at a high temperature, while the pipe is cold-rolled. Both tubing and pipe can be galvanized to protect them from corrosion.

The standard methods of manufacturing steel pipe are:

- Butt weld
- Electric resistance weld
- Seamless pipe
- Spiral weld pipe

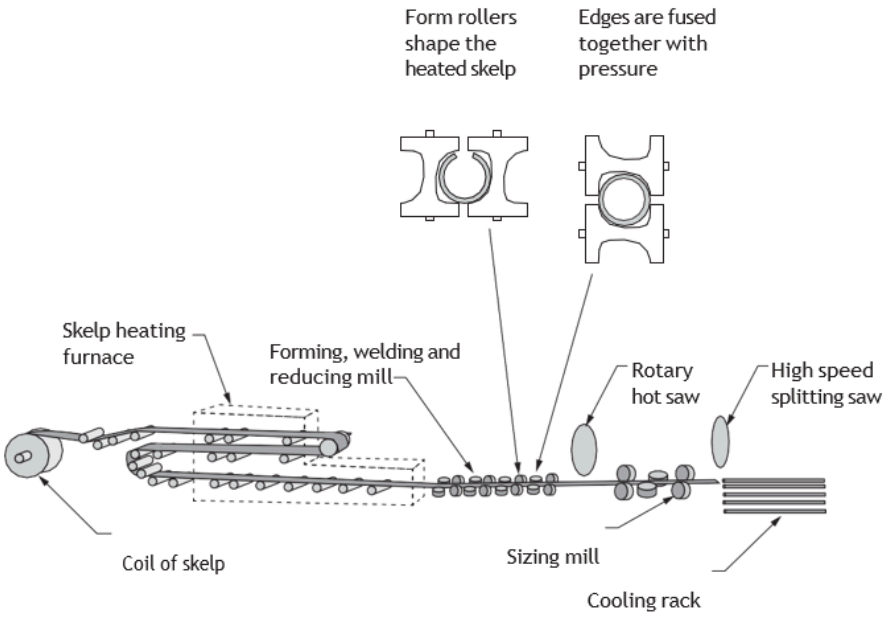

Figure 1 *Procedure to form schedule steel pipes and tubes* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Electric Resistance Weld

The processing of ***electric-resistance welded pipe (ERW)*** starts with coiled ribbon of steel plate called a ***skelp***. The ribbon is pulled through a series of rollers, which gradually form it into a cylindrical tube. As the edges of the plate come together, an electric charge is applied, heating the edges so they can be welded together. Electric resistance welded pipe is a high-speed production product that can be made in continuous lengths over 100 ft long.

Typically for light construction purposes, the *ERW pipe* is approximately 6.4 m (21 ft) long, plus or minus 25.4 mm (1 in).

Pipe can be ordered with end finishes. For example, it can be:

- Threaded and coupled
- Threaded without couplings
- Plain end
- Bevelled for welding
- With grooved ends
- Special order

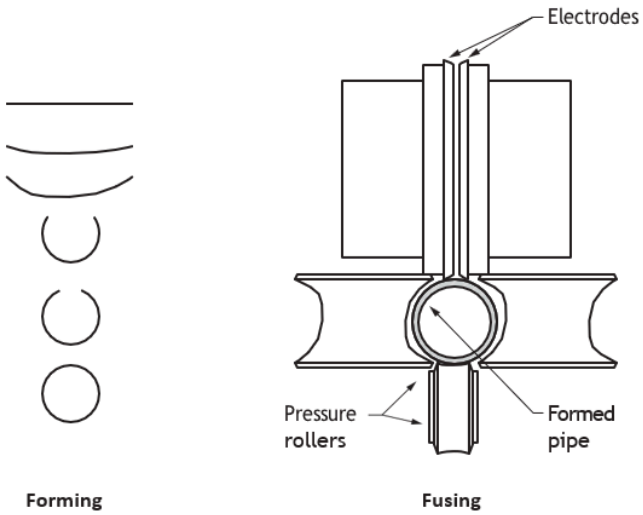

Figure 2 *Electric resistance weld process (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

You can also refer to *IPT's Pipe Trades Handbook and Manual* for an image of the electric resistance weld.

Seamless Steel Pipe Manufacturing

Seamless pipe is made when steel in a solid, cylindrical shape, called a ***billet*** or a ***tube round***, is heated and then either pushed or pulled (while being rapidly rotated) over a ***mandrel*** with a piercing point positioned in the centre. This produces a hollow tube or "shell." The tube is then further finished until it becomes the desired size and wall thickness. Since the pipe is formed while heated, it is normalized and has a consistent steel cellular pattern (or microstructure) throughout its circumference.

Seamless pipe is made in sizes from $\frac{1}{8}$ –26″ and is widely used in the construction, oil refining, chemical, and petrochemical industries.

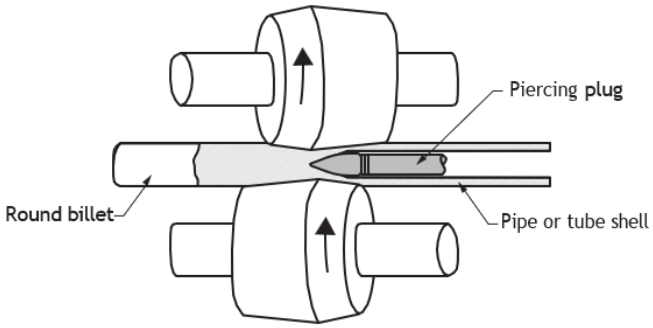

Figure 3 *Seamless pipe piercing process (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

For larger sizes of seamless pipe (over 16 in – 400 mm) a rotary expander is used to enlarge the pipe.

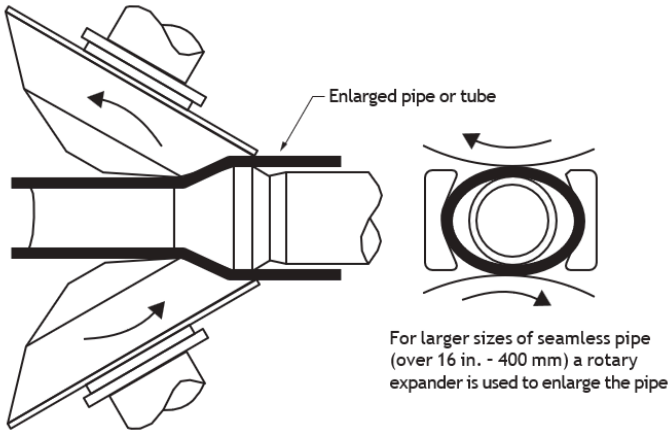

Figure 4 *Seamless steel pipe process after being formed over a mandrel (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Fusion Welding Process

Another process for producing pipe is ***fusion welding*** (sometimes called "*continuous weld*") and is produced in sizes $\frac{1}{84.5}$„ . Fusion-weld pipe begins as coiled steel ribbon (skelp). Successive coils of steel are welded end-to-end to form a continuous ribbon of steel. The ribbon of steel is then flattened and straightened and then fed into a gas furnace, where it's heated to the required temperature for forming and fusing. Forming rollers at the end of the furnace shape the heated skelp into an oval. The edges of the skelp are then firmly pressed together by the rollers, fusing the steel and creating a forged weld. Final sizing rollers form the pipe to its required dimensions.

Spiral-welding Process

Spiral-weld pipe is a steel pipe with a ***double submerged arc weld (DSAW) seam*** in a spiral form along the entire length of the pipe. This process allows for large-diameter pipe production. The outside diameter is determined by the angle of the de-coiled steel against the forming machine head. The more acute the angle, the greater the diameter. The production of large, hot-rolled coils of sufficient width and the development of dependable non-destructive testing methods has enabled this product to be placed in more demanding service. Spiral-weld pipe can be rolled in exact lengths up to 115 feet in either ID or OD dimensions up to 144 inches. There is a minimum tonnage required for rolling. Because the manufacturing process is slow, it gives the contractor an advantage of short term changes to the order. This same slow production can also be a disadvantage when large tonnages are needed with a short lead time. Spiral-weld pipe is produced to limited specifications.

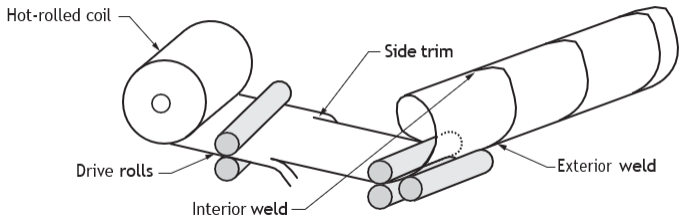

Figure 5 *Spiral weld pipe* (BC Industry Training Authority, 2019). *CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Double Submerged Arc Weld Process

Submerged arc welded (SAW) pipe derives its name from the process wherein the welding arc is submerged in ***flux*** while the welding takes place. The flux protects the steel in the weld area from any impurities or contaminants in the air when heated to welding temperatures. When both inside welds and outside welds are performed, the welding is accomplished in separate processes and the pipe is considered to be ***double submerged arc welded (DSAW)*** pipe.

There are three common types of pipe produced by the DSAW process.

- U&O process
- Rolled
- Spiral-weld

U&O Process

The***U&O process*** uses a “U” press, then an “O” press to form a complete cylinder from 40′ long steel plates. The cylinder is then welded inside and outside by the submerged arc process by using as many as five welding wires. The primary use of this type of large pipe is gas and oil transmission fields.

Rolled and Welded Process

The ***rolled and welded method*** of manufacturing is also called the ***pyramid roll method*** because it uses three rolls arranged in a pyramidal structure. The steel plate is rolled back and forth between the pyramid rolls until the cylinder is formed. The cylinder is then moved to the welding stations. Most pyramid rolls are 20′ long or less. Greater lengths can be ordered. This process can produce large pipe diameters, either **ID** or **OD**.

Cast Iron Pipe and Fittings

The basic raw materials used to produce cast iron soil pipe and fittings are scrap iron, scrap steel, alloys, coke, and limestone. These materials are melted in a ***cupola furnace*** to produce molten iron.

The casting of melted cast iron from the furnace into soil pipe and fittings is done by pouring the molten cast iron into casting moulds for fittings and using a ***centrifugal casting process*** for pipe. Metal moulds used in centrifugal pipe casting machines are spun on rollers and externally cooled by water.

Coatings are applied to the metal mould’s surface preventing sticking of the molten cast iron. As the cylindrical metal moulds spin, specific amounts and weight of molten cast iron are poured in. Centrifugal force distributes the molten cast iron to the inside surfaces of the spinning cylinder. The molten cast iron is allowed to cool and is removed from the metal cylinder as cast iron pipe. The cast iron pipe and fittings are inspected, tested, and dip coated to provide a smooth finish and protective coating. The finished pipe and fittings are ready for storage for shipment.

Cast iron soil pipe fittings may be produced by two different static casting processes: one process casts fittings in sand moulds and the other method employs permanent metal moulds.

First, moulds are made, then molten cast iron is poured into each mould. After the cast iron has cooled, the fittings can be removed from the moulds. The fittings are cleaned, inspected, tested and coated the same way as the pipe.

Figure 6 *Cast iron pipe and fittings* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Copper Tube Manufacturing Process

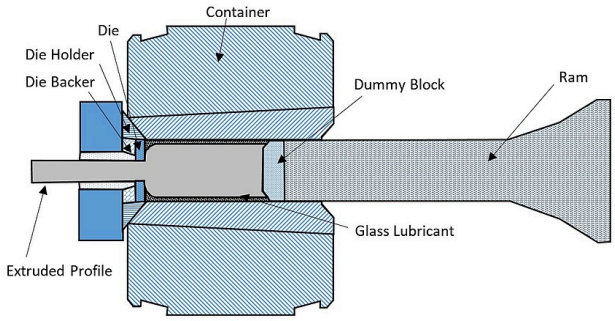

Figure 7 *Schematic of metal extrusion process* (*https://commons.wikimedia.org/wiki/File:Schematic_of_metal_extrusion_process.jpg*) (*Vivekverma239/Wikimedia Commons*) CC0 1.0 (*https://creativecommons.org/publicdomain/zero/1.0/deed.en*)

Copper and copper alloy tube is manufactured by the ***extrusion method***. A headed copper billet is heated then forced through a die orifice and over a ***mandrel*** to form a hollow tube. The mandrel is held in position within the die orifice.

Another method uses ***rotary piercing***. One end of a heated cylindrical billet is fed between rotating work rollers and is driven forward toward a piercing plug. In the mid-1960s, welded copper tube produced from strip without the use of a filler metal became commercialized.

Temper describes the strength and hardness of the tube. ***Drawn temper*** is often referred to as "hard," while ***annealed temper*** is called "soft."

Product Specifications (ASTM)

- Copper tube is a minimum of 99.9% pure copper.
- The copper used for tube supplied is deoxidized with phosphorus.

- Types K, L, M, DWV, and medical gas tube are designated by ASTM standard nominal inside diameter sizes. The actual outside diameter is always $\frac{1}{8}$" larger than the standard size designation.
- Copper used in medical gas and air conditioning and refrigeration systems is ordered degreased and capped. The plastic capped ends stay on the pipe until just before installation.
- Each copper tube type represents a series of sizes with different wall thicknesses. Type K tube has thicker walls than Type L tube, and Type L walls are thicker than Type M, for any given diameter. All inside diameters depend on tube size and wall thickness.
- Copper tube for air-conditioning and refrigeration field service (ACR) is designated by actual outside diameter.

"Temper" describes the strength and hardness of the tube. In the piping trades, drawn temper tube is often referred to as "hard" tube, and annealed as "soft" tube.

Table 1 identifies the six standard types of copper tube and their most common applications. The table also shows the ASTM standard appropriate to the use of each type along with a listing of its commercially available lengths, sizes and tempers.

Table 1: Standard Types of Copper Tube and Common applications

Tube Type	Colour Code	Standard	Application (See note 1)	Commercial Available Lengths (See note 2)		
Type K	Green	ASTM B 88 (See note 3)	• Domestic water service and distribution • Fire protection • Solar • Fuel/fuel oil • HVAC • Snow melting • Compressed air • Natural gas • Liquefied petroleum (LP)gas • Vacuum	Straight Lengths		
				0.25″ to 8″	20′	20′
				10″	18′	18′
				12″	12′	12′
				Coils		
				0.25″ and 1″	–	60′
					–	100′
				1.25″ and 1.5″	–	60′
				2″	–	40′
					–	45′
Type L	Blue	ASTM B88	Domestic water service and distribution Fire protection Solar Fuel/fuel oil Natural gas Liquified petroleum (LP) gas HVAC Snow melting Compressed air Vacuum	Straight Lengths		
				0.25″ to 10″	20′	20′
				12″	18′	18′
				Coils		
				0.25″ to 1″	–	60′
					–	100′
				1.25″ to 1.5″	–	60′
				2″	–	40′
					–	45′

Type M	Red	ASTM B88	Domestic water service and distribution Fire protection Solar Fuel/fuel oil HVAC Snow melting Vacuum	Straight Lengths		
				1.25″ to 12″	20′	N/A
DWV	Yellow	ASTM B 280	Drain, waste, vent HVAC Solar	Straight Lengths		
				0.25″ to 8″	20′	N/A
ACR	Blue	ASTM B 280	Air conditioning Refrigeration Natural gas Liquefied petroleum (LP) gas Compressed air	Straight Lengths		
				$\frac{3}{8}$„ to 1 $\frac{1}{8}$„	20′	N/A
				Coils		
				$\frac{1}{8}$„ to 1 $\frac{5}{8}$„	20′	(See note 4)
OXY, MED OXY/MED OXY/ACR ACR/MED	K) Green (L) Blue	ASTM B 819	Medical gas Compressed medical air Vacuum	Straight Lengths		
				$\frac{1}{4}$„ to 8″		

1. There are many other copper and copper alloy tubes and pipes available for specialized applications. For information on these products, contact the Copper Development Association, Inc.
2. Individual manufacturers may have commercially available lengths in addition to those shown in this table.
3. Tube made to other ASTM standards is also intended for plumbing applications, although ASTM B 88 is by far the most widely used. ASTM *Standard Classifications* B 698 lists six plumbing tube standards including B 88.
4. Available as special order only.

Plastic Pipe Manufacturing

Acrylonitrile-Butadiene-Styrene (ABS)

***Acrylonitrile-butadiene-styrene* (ABS)** cell core is made using an extruding head that allows air to be inserted in the middle of the pipe. It uses less resin and creates a less expensive pipe that doesn't affect the structure of the pipe and its resistance to pressure.

Polyethylene Pipe

***Polyethylene* (PE)** pipe is produced by heating raw plastic pellets and forming them through an extrusion process. Colour pigments are added depending on the application (e.g., yellow for gas, black for general use). The essential steps of polyethylene (PE) pipe and fitting production are to heat the raw pellet material into a particular shape and hold that shape during the cooling process. This is necessary to produce solid wall and profile wall pipe as well as compression and injection moulded fittings. All diameters of solid wall PE pipe are continuously extruded through an annular die.

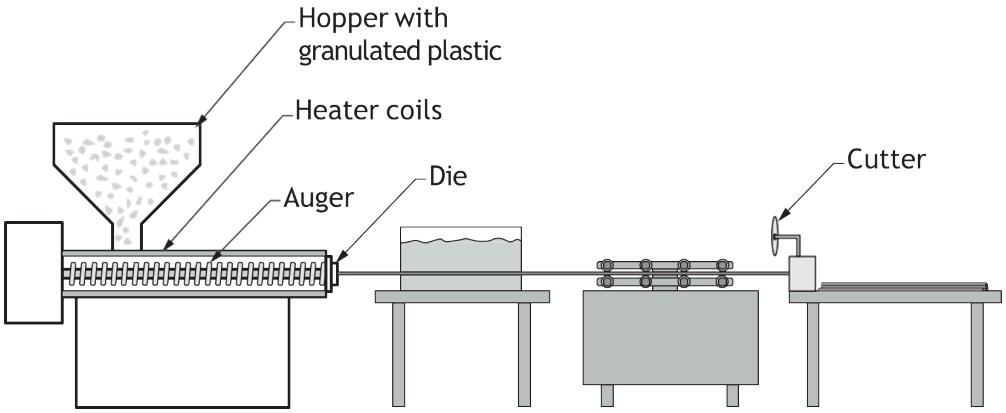

Figure 8 *PE manufacture extrusion method (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The raw material is typically supplied to the pipe producer as non-pigmented pellets. PE pellets are stabilized for both heat and UV protection. Usually, colour pigment is added to the pipe at the producer's facility. In North America, the most common colours are black and yellow. The choice of colour will depend upon the intended application and the requirements of the pipe purchaser. Carbon black is the most common pigment used for water, industrial, sewer and above-ground uses. Yellow is reserved exclusively for natural gas applications, although black with yellow stripes is also permitted for this application. Other colours are used for telecommunications and other specialty markets.

Cross-Linked Polyethylene

Cross-linked polyethylene* (PEX)** is a polymeric material formed by chemically joining of individual polyethylene (PE) molecules in a process called ***cross-linking.

There are three main methods used to accomplish the molecular cross-linking:

- **PEX-A *(peroxide method)*** is produced by the peroxide (Engel) method. This method performs "hot" cross-linking, while the polyethylene is above its melting point before extrusion. The process takes slightly longer than the B and C methods because the molecular plastic polymer has to be kept at high temperature and pressure for long periods during the extrusion process. This PEX is the only type of PEX that can be kinked and fully repaired using low heat.
- **PEX-B *(silane method)*** is produced by the silane method, also called the "moisture cure" method. In this method, cross-linking is performed after the extrusion process, producing cross-links between a cross-linking silane related agents. After installation, PEX-B has the same properties as PEX-A.
- **PEX-C *(electron beam method)*** is produced through electron beam processing after extrusion in a "cold" cross-linking process. This process has lower uniformity of cross-linking than the PEX-A especially at tube diameters over one inch (2.5 cm). When the process is not controlled properly, the outer layer of the tube may become brittle. However, it's the cleanest, most environmentally friendly method because it does not involve other chemicals to create the cross-linking.

PEX Piping Qualities

- PEX tubing and PEX fittings come in sizes ranging from $\frac{1}{4}$" – 2" in diameter in North America, whereas in Europe, PEX pipe is available in sizes up to 6".
- Manufactured to copper tubing size OD controlled (CTS-OD) dimensions.
- Sold in coils and straight lengths.
- The wall thickness is based upon SDR 9 values, which yield pressure ratings of 160 psi at 73°F and 100 psi at 180°F.
- Some manufacturers have their tubing rated to 200°F with an 80 psi maximum working pressure.
- Some PEX fittings should only be joined to specific PEX tubing, as recommended by the pipe manufacturer.

PVC Pipe Manufacturing

The technology of the ***Polyvinyl chloride* (PVC)** pipe manufacturing processes is extensive and involved. It can be traced from oil or gas wells through petrochemical plants to the PVC compounding operations and finally to the automated extrusion, moulding and fabrication operations before a finished PVC product is ready for testing, inspection, and delivery.

The raw plastic PVC compounds are prepared and heated. The heated elastic plastic is extruded into the pipe-forming die under high pressure (2000—5000 psi). In the pipe extrusion die, the hot plastic material is moulded into a cylindrical shape. As it leaves the extrusion die at the exit orifice, the material is extremely hot (about 400°F), flexible, and pliable. In this state, the hot plastic is formed with dimensional accuracy into a finished product and then cooled into a solid state. The extruded PVC pipe is drawn away from the extruder into cooling tanks where it's cooled by chilled water. By the time the pipe emerges from the end of the cooling tanks, it has cooled to a temperature where it can be handled without distortion. After leaving the cooling station, the pipe travels through a printing station. Pertinent product and process information is printed on the PVC pipe. Beyond the printer, the pipe is automatically cut to the correct length. The ends are trimmed to specifications depending on its intended use.

Self-Test D-1.2: Describe the Methods of Manufacture of Piping and Tubing

Complete Self-Test 2 and check your answers.

If you are using a printed copy, please find Self-Test D-1.2 (#chapter-self-test-d-1-2-describe-the-methods-of-manufacture-of-piping-and-tubing) and Answer Key (#chapter-answer-key-self-test-d-1-2) in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://d-pipingcomponents-bcplumbingapprl1.pressbooks.tru.ca/?p=1926#h5p-2 (https://d-pipingcomponents-bcplumbingapprl1.pressbooks.tru.ca/?p=1926#h5p-2)

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- Plumber: Competency D-1 Prepare Pipe
- Steamfitter: Competency D-4 Layout and Install Piping and Tubing

- Sprinkler Fitter: Competency D-1 Prepare Pipe and Tubing

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- **Figure 7** Schematic of metal extrusion process (https://commons.wikimedia.org/wiki/File:Schematic_of_metal_extrusion_process.jpg) by Vivekverma239 from Wikimedia Commons is used under a CC0 1.0 (https://creativecommons.org/publicdomain/zero/1.0/deed.en) public domain license.

D-1.3 Describe the Methods of Pipe and Tubing Support

Pipe Support

The installation of pipe and piping equipment requires proper support. Pipe support can be accomplished in a number of ways:

- Pipe hangers
- Pipe anchors
- Pipe guides
- Inserts and expansion shields
- Brackets and clamps
- Seismic braces (sway bracing)
- Accessories including sleeves, saddles, and shields
- Pipe slide-plates

Piping support must support the weight of the pipe and equipment, including the contents. Hangers and supports must be designed to accommodate pipe movement from expansion or contraction, as well as vibration seismic activity. The hangers and supports must keep the pipeline in alignment and maintain a specific position related to slope, level, plumb, or any other required design position.

Most piping installations are governed by codes and specifications. For example, requirements for hanger spacing, size, and ***seismic restraint*** are stated in various codes, including plumbing codes, fire sprinkler codes, and gas codes. In every case, the maximum allowable spacing of pipe hangers is clearly stated. Regardless of the maximum spacing allowed, when pipe sags, additional support should be added to ensure proper alignment and support. Job site engineered specifications and manufacturers' instructions should be followed where code regulations are not sufficient.

Pipe hangers and supports can be broadly classified into the following categories:

- Rigid hangers/supports
- Variable effort supports/hangers
- Constant effort supports/hangers
- Spring-loaded sway braces
- Dynamic restraints/rigid struts
- Snubbers/shock absorbers

Code Examples for General Hanger and Support Installation Guidelines

Pipe supports for nominally horizontal piping should be supported and sized as follows:

1. Where hangers are used to support nominally horizontal piping they shall be:

a. Metal rods of not less than:
    i. 6 mm diameter to support piping 2″ or less in size
    ii. 8 mm diameter to support piping 4″ or less in size
    iii. 13 mm diameter to support piping over 4″ in size
b. Solid or perforated metal straps of not less than:
    i. 0.6 mm nominal thickness and 12 mm wide to support piping 2″ less in size
    ii. 0.8 mm nominal thickness and 18 mm wide to support piping 4″ or less in size

2. Where a hanger is attached to concrete or masonry, it shall be fastened by metal or expansion- type plugs that are inserted or built into the concrete or masonry.
3. Underground horizontal piping shall be supported on a base that is firm and continuous under the whole of the pipe.
4. Underground horizontal piping that is not supported on a base that is firm and continuous under the whole of the pipe, may be installed using hangers fixed to a foundation or structural slab, provided that the hangers are capable of keeping the pipe in alignment and supporting the weight of the pipe, its contents, and the fill over the pipe.
5. Where a vent pipe that may be subject to misalignment terminates above the surface of a roof, it shall be supported or braced.
6. Piping shall be provided with support that is capable of keeping the pipe in alignment and bearing the weight of the pipe and its contents.
7. Nominally horizontal piping that is inside a building shall be braced to prevent swaying and buckling and to control the effects of thrust.
8. The design and installation of every piping system shall include means to accommodate its expansion and contraction caused by temperature changes, movement of the soil, and building shrinkage.
9. Where piping is installed underground, the backfill shall be carefully placed and tamped to a height of 300 mm.
10. Where asbestos-cement drainage pipe or vitrified clay is located less than 600 mm below a basement floor and the floor is constructed of other than 75 mm or more of concrete, the pipe shall be protected by a 75 mm layer of concrete installed above the pipe.
11. Where piping passes through or under a wall, it shall be installed so that the wall does not bear on the pipe.
12. Where piping may be exposed to freezing conditions, it shall be protected from the effects of freezing.
13. Plumbing, piping, and equipment exposed to mechanical damage shall be protected.
14. Piping may need to be protected against condensation.

Refer to the actual code related to your piping trade. Information not found in the code can be found by consulting the engineer-designed systems or the specific manufacturer's installation requirements.

Structural Restrictions for Hangers and Supports

The type of hangers and supports chosen will also depend upon the makeup of the building's structural components. When using "redi-rod" (threaded rod) for hangers within a wood-framed structure, you will undoubtedly require brackets and plates that are secured to the structure using wood screws. Concrete and steel structures, on the other hand, will have support components that are clamped onto steel or drilled into concrete.

Concrete buildings that are ***post-tensioned*** usually do not allow drilling into the underside or topside of suspended slabs, so the supports and holes for piping must be cast in place, requiring careful preplanning of piping routes to avoid interference with other trades. Drilling or coring into a post-tensioned structure can be extremely dangerous to anyone in the vicinity, and the associated hazards and prohibitions are normally explained on-site through a first-day orientation session for any workers new to the site.

General Installation Guidelines for Hangers and Supports

For each hanger piping installation, you'll be required to select and install the appropriate types of hangers and supports. Many factors must be considered when selecting these hangers, supports, and fasteners. General installation guidelines exist. However, you should always refer to the appropriate code requirements, job site specifications, and manufacturer's instructions.

Selecting Hangers, Supports, and Fasteners

Use the following general guidelines to select, install, and size hangers, supports, and fasteners:

- Refer to job specifications for the correct type of hanger.
- Consider pipe movement such as expansion, contraction, or vibration.
- Establish the type of pipe and the weight of the material and its contents.
- Identify the piping material regarding contact between the hanger and the material the hanger is made of. Contact between dissimilar metals can result in ***electrolytic action*** between hangers and piping.
- Consider whether the piping will be insulated.
- Identify the building structure material (e.g., concrete, steel, or wood).
- Select the correct fastener type and installation method. For example, wood screw, lag screw, bolts, or beam clamp.
- Refer to the manufacturer's maximum load capacity requirements for each hanger and fastener.
- Never exceed the maximum load capacity of the hanger or fastener.
- Refer to the job plans to determine the correct position of each hanger and support. In many cases, a chalk-line or string line can help establish hanger and fastener positions for long pipe line lengths.
- If seismic restraint/sway-bracing is required, determine the correct positioning as stated by governing codes such as the ***Fire Sprinkler Code*** (https://www.nfpa.org/codes-and-standards/nfpa-13-standard-development/13).
- Ensure that each hanger is tight to the pipe and supporting the pipe as it should be.
- For vertical piping, ensure vertical riser clamps or similar support is spaced and located as required by the code or job site specifications.
- Select hangers that can be adjusted when adjustment of piping heights is required.

Once you have a general idea of the type and size of hangers, supports, and fasteners you will require, consult the manufacturer's catalogues for further details. Most catalogues will include detailed sketches of the important dimensions to be considered when selecting each type of hanger.

Types of Pipe Support

The following images show common types of pipe support.

Figure 8 *Fasteners and pipe supports (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 9 *Non-insulated pipe hangers*

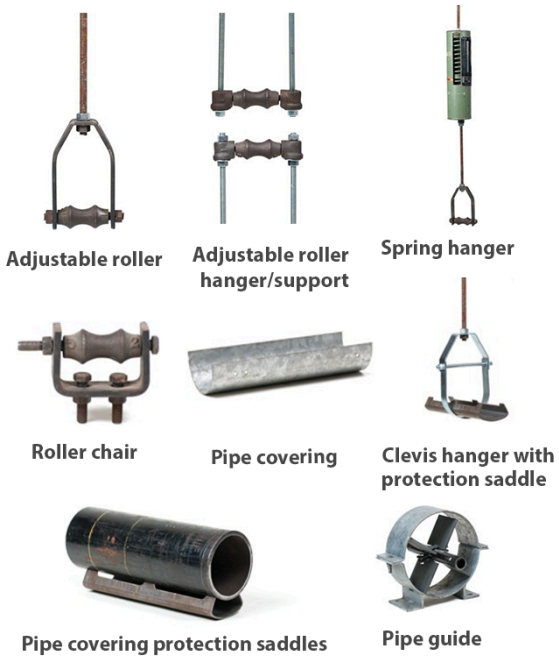


Figure 10 *Pipe hangers and supports (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pipe saddles are used to support the pipe and protect the pipe insulation from being crushed by the pipe hanger. They also provide protection beneath the insulation. Standard lengths for pipe saddles range from 9″ to 12″. Custom radii, gauges, and lengths are available.

Sliding Pipe Saddle Insulation Protection

A sliding pipe saddle minimizes weather barrier damage caused from pipe movement.

a. Inner saddle adheres to the insulation barrier and moves with the piping, while sliding on the ***PTFE (poly-tetra-fluoro-ethylene)*** surface below (see Figure 11, component C).
b. Ribbed lower saddle remains stationary on the pipe hanger.

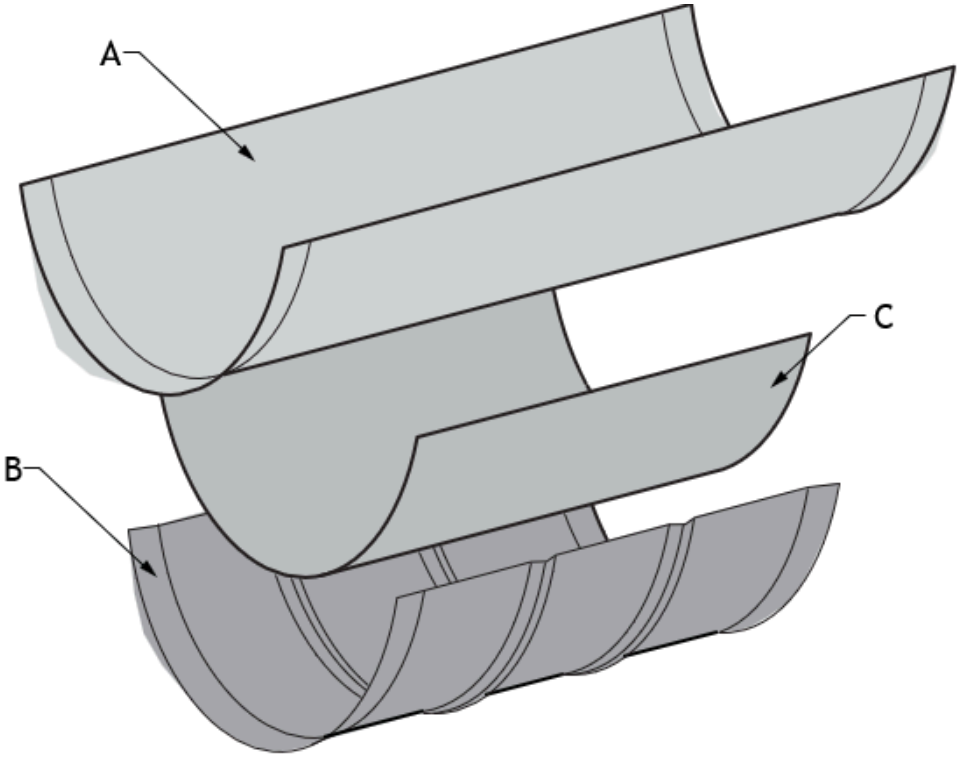


Figure 11 *Sliding pipe saddle detail (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The PTFE layer is laminated to the lower saddle providing a minimal friction surface for the upper saddle to slide against.

Gliding Pipe Saddles

Figure 12 show the use of a gliding (sliding) pipe saddle on a large insulated exterior pipe line. The saddle allows the pipe to expand and contract easily over the pipe supports. This saddle reduces or eliminates damage to the pipe jacketing and the vapour barrier under it.

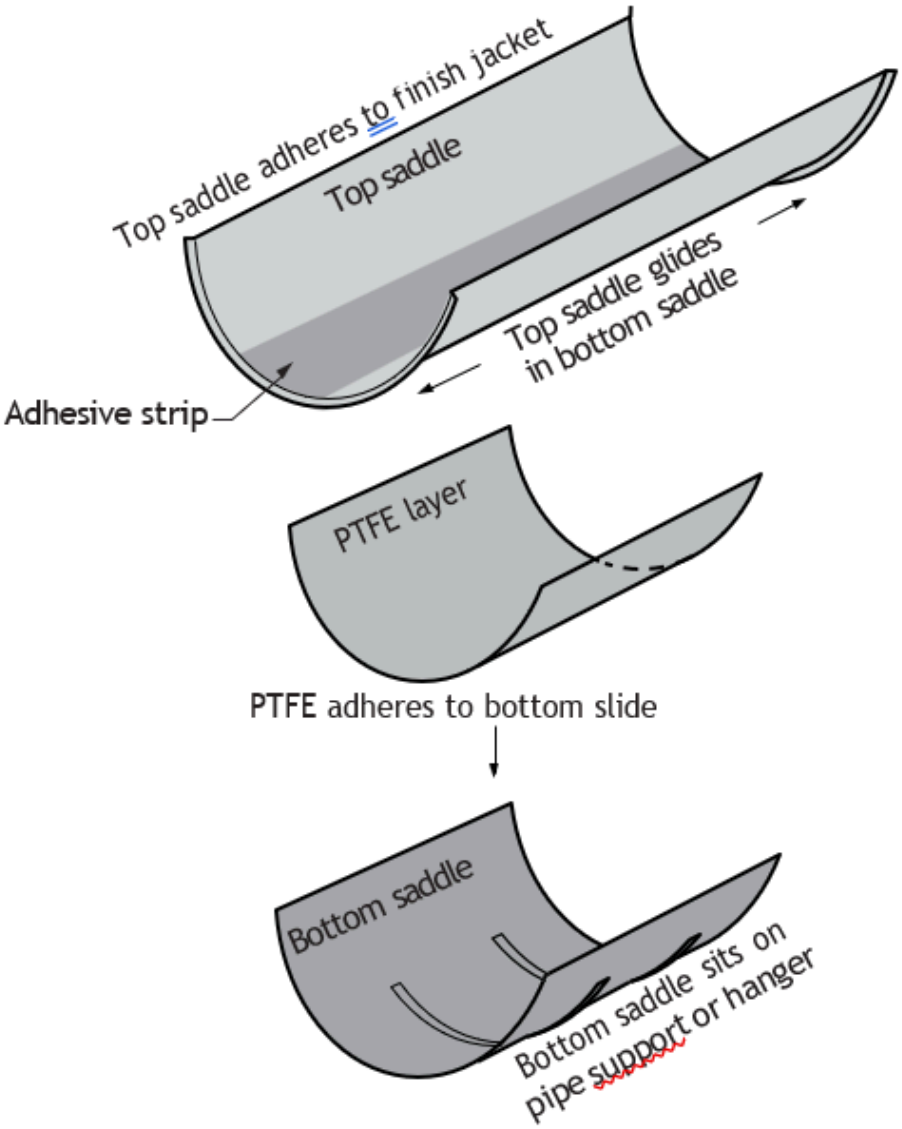


Figure 12 *Gliding saddle components (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 13 *Sliding pipe saddle installation (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pipe Anchors

Pipe anchors are used to secure piping systems and prevent unwanted movement. Engineer specifications governing codes and manufacturers' instructions will dictate the correct use of pipe anchors. Various thread type and diameter sizes are available. Pre-drilling holes of the correct size is required before installation to insert the anchors. The required drill bit sizes are specified by the manufacturer's packaged instructions.

The following images show equipment for anchoring pipe.

Figure 14 *Pipe anchoring equipment (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Drop-in Anchor

The steel drop-in is a machine bolt anchor available zinc plated carbon steel in bolt sizes $\frac{1}{4}$ – $\frac{3}{4}$„ . It can be used in solid concrete, hard stone (granite), and solid block. A hand setting tool is required.

Figure 15 *Drop in anchor (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Applications and uses of pipe anchors:

- Pipe hanger support
- Suspending conduit and lighting, cable trays and strut, and concrete formwork
- Can be installed flush-mounted or below the base material surface

Concrete drop-in anchor installation:

1. Confirm the location for the insert to be installed to ensure you're not drilling into concrete that has encased electrical or other components.

2. Drill hole into the concrete with a carbide tipped masonry drill matching the bit size with the outside diameter of the drop-in anchor being used. Check the hole for the correct depth.
3. Clean out concrete dust from the hole using a wire brush, compressed air, or a blowout bulb.
4. Thread the bolt into the anchor. Drive the anchor into the hole, flush with the surface of the concrete. Remove bolt.
5. Using the proper setting tool for the anchor, expand the anchor by inserting the setting tool into the anchor and setting it with several solid hammer blows. The anchor is set properly when shoulder of the setting tool is flush with the top of the anchor.
    a. To set the anchor below the surface, drill the hole deeper than the anchor length. Thread the bolt into the anchor. Hammer the anchor into the hole until the bolt head is the desired depth. Remove the bolt and set the anchor with the setting tool, as described above.

Figure 16 *Anchor-setting tool (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Drop-In Concrete Anchor Spacing

As a general rule, the expansion industry has established a minimum standard of ten anchor diameters for spacing between anchors and five anchor diameters from an unsupported edge. When vibration or sudden impact is part of the load condition, spacing between anchors should be increased.

Expansion Anchors

Expansion anchors, sometimes referred to as *quick-bolts* are threaded fastener studs, with specially formed ends, used to attach machinery components to concrete. A specifically sized hole is drilled into a concrete slab, and an anchor with its split collar is gently tapped into the hole. As the nut tightens onto the material that the bolt is meant to fasten to the concrete, the natural tendency is to pull the bolt back out of the hole. However, the split collar binds between the sides of the concrete hole and the tapered end of the bolt, causing the bolt/collar to bind and hold fast. Once the bolt/collar combination is embedded, it will not be possible to extract it, and it must be cut off using an angle grinder if removal is necessary. The use of a *quick-bolt* eliminates the need for a concrete anchor and threaded rod combination.

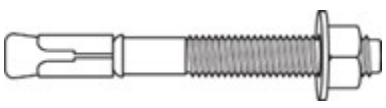


Figure 17 *Quick-bolt (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Expansion Inserts

Figure 18 *Single expansion insert (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The single expansion insert is a single-action machine bolt expansion anchor. It can be used in solid concrete, hard stone (granite), and solid block and brick.

General applications and uses:

- Pipe hangers
- Suspending conduit and lighting
- Cable trays and strut

Single expansion insert installation:

1. Confirm the location for the insert to be installed to ensure that you're not drilling into concrete that has encased electrical or other components.
2. Drill a hole using a carbide tip drill bit of the manufacturer-recommended diameter. The depth should be equal to, or slightly deeper than, the length of the expansion shield (anchor).
3. Clean out the hole of all dust and cuttings.
4. Place the single expansion insert, nut end first, into the hole. The top end of the anchor should be flush or slightly below the base material surface.
5. Place the object to be fastened over the anchor in the base material and bolt it into place. The bolt should engage $\frac{2}{3}$ of the threads of the anchor.

Precast Insert Hanger Anchors

The cast-in place insert is designed for pre-planned fastening in concrete. The insert provides rustproof threaded metal inserts in precast, pre-stressed or poured-in-place concrete. Install with bolts through holes in steel forms or by means of reusable concrete insert plugs on wood forms.

Figure 19 *Pre-cast hanger anchor insert (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pre-cast anchor applications:

- Heavy machinery
- Pipe hangers support
- Duct work

Wood Form Cast-in-place Insert

The wood form concrete insert is installed onto wooden forms used to support newly poured concrete floor slabs, roof slabs, or walls. Refer to *D-4 Penetrate Structures* (#part-d-4-penetrate-structures) for information on use of this type of insert. The six-sided impact plate offers resistance to rotation within the concrete as the threaded rod is being installed.

Figure 20 *Wood form cast-in-place insert* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Figure 21 *Installation* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Wood form cast in-place insert applications and uses:

- Hanging pipe and sprinkler systems
- Overhead utilities
- HVAC ductwork
- Strut channels

Roof Deck Insert

Metal deck insert anchors are designed for installation through the pre-drilled metal composite deck used to support a newly poured concrete floor or roof slab. Depending upon the size chosen, the protective sleeve protrudes below the surface of the deck, allowing overhead attachment of threaded rod or bolts.

Roof deck insert applications and uses:

- Hanging pipe and sprinkler systems
- Overhead utilities
- HVAC ductwork
- Strut channels

Figure 22 *Roof deck insert (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Rod Hangers

A ***rod hanger*** is an all-steel threaded anchor system for suspending threaded rod. These hangers can be used in a variety of base materials, including poured concrete, steel joists and beams, and wood frame columns and beams. Drill bits and installation tools are required as per manufacturer's specifications. (For example, carbide bits are required for drilling concrete.) Rod hangers have several other common names: hang-up anchors, Sammy super screws, vertigo anchors, hanger mates, and titan anchors.

Rod hanger applications and uses:

- Hanging pipe and sprinkler systems
- Lighting systems, suspended ceilings
- Suspended conduit and cable trays
- HVAC ductwork and strut channels
- Mounting security equipment

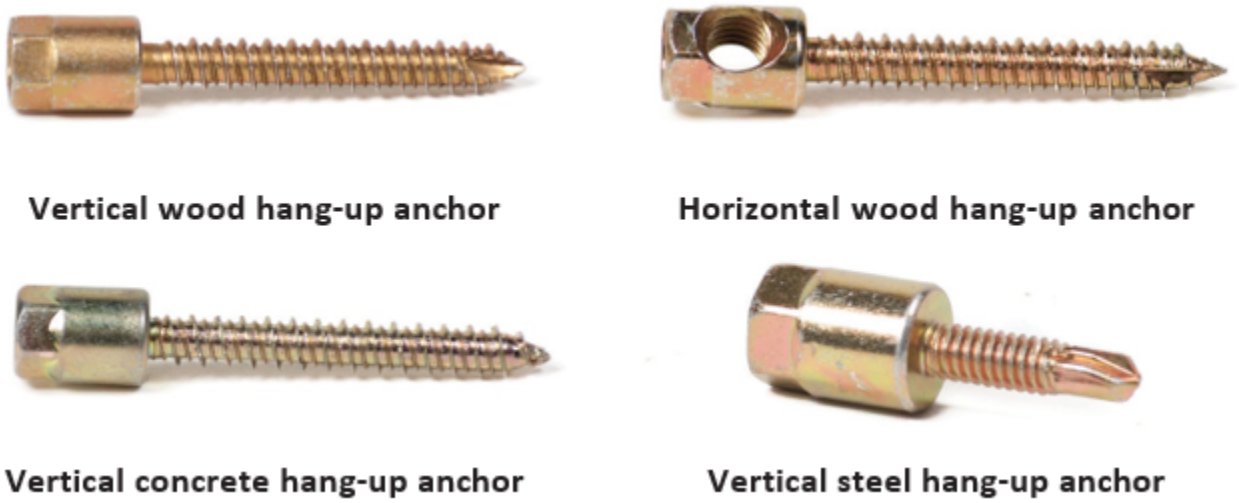


Figure 23 *Rod hangers (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 24 *The screw on the right is fluted to help thread into wood (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

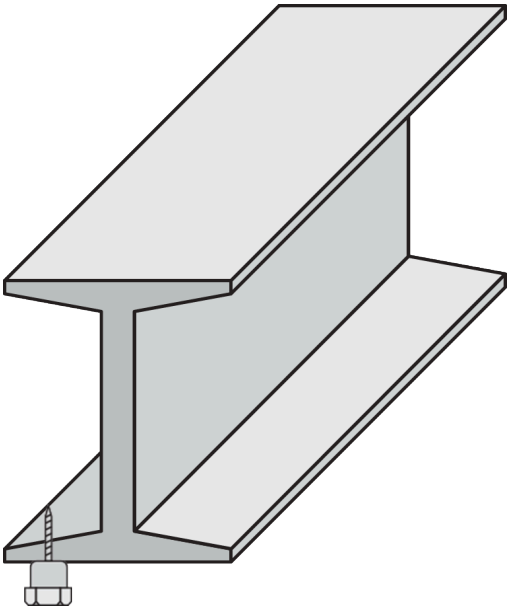


Figure 25 *Rod hanger set vertically into steel (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

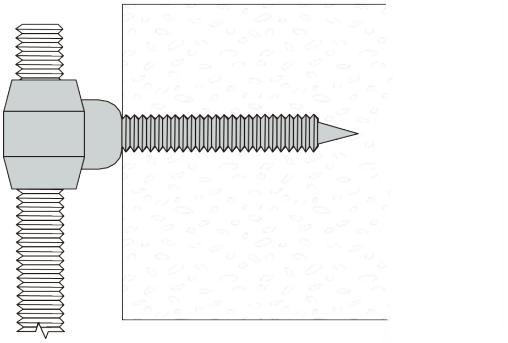


Figure 26 *Rod hanger set horizontally into concrete (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Rod Hanger Installation

1. Drill a hole into the base material using the drill bit provided with the screws. The hole must be at least $\frac{1}{4}$" deeper than the anchor embedment.
2. Place the object to be fastened over the hole.
3. Insert the point of the anchor into the hole and drive the screw in using a nut drive or number 3 bit tip. Do not over-torque the screw.

Light-duty and Hollow Wall Anchors

Light-duty and hollow wall anchors have restricted use for supporting pipe and heavy equipment. In most cases, these anchors do not have the holding power of expansion or drop-in hangers. In the piping trade, these anchors can be used only for light-duty applications such as mounting light-weight components. They can be used in concrete, block, tile, wallboard and brick with a sheet metal, wood or lag screw.

Applications and uses:

- Mounting accessories such as control boxes or towel racks
- Attaching light-weight, small diameter piping to hollow block walls
- Wiring and similar attachments

Figure 27 *Light-duty anchors*

Self-Drilling Drywall Anchor Installation

1. Insert a Phillips screwdriver into head of the anchor.
2. Press the point of the anchor into the wallboard, while turning the anchor clockwise until it is seated flush with the wall.
3. Place the fixture over the hole and tighten the proper size sheet metal screw. A minimum thread engagement of 1″ is recommended.

Residential Hanger Attachment Methods

Strap iron (often called *plumber's tape* or *metal hanger strap*) is a thin, flexible strip of metal (typically galvanized steel), used in plumbing to support and secure piping systems. It usually comes in rolls or flat lengths and features pre-punched holes along its length, allowing it to be easily fastened with screws, nails, or bolts. Strap iron is commonly used in residential and commercial plumbing installations where pipes need to be suspended, stabilized, or restrained.

Shown below are several methods of pipe support used in wood-frame buildings.

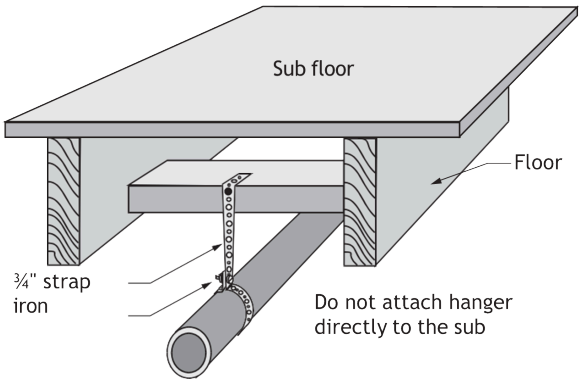


Figure 28 *Pipe attached by a hanger to the wood blocking between the joist (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The *Plumbing Code* (https://www2.gov.bc.ca/gov/content/industry/construction-industry/building-codes-standards/bc-codes/2024-bc-codes/plumbing)will designate the correct size and gauge of strap iron.

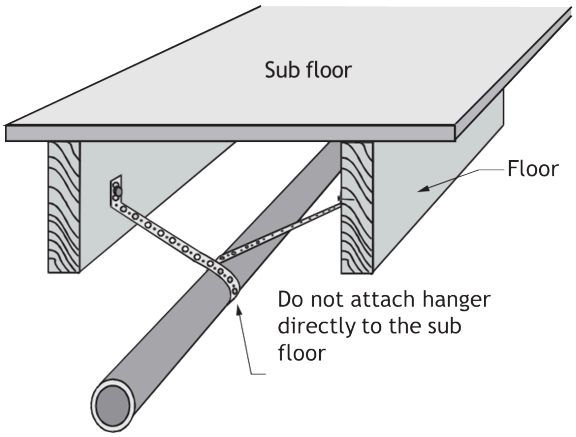


Figure 29 *Pipe attached with hangers to the floor joists (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Although the method shown in Figure 29 is acceptable, it requires more strap iron than in the method shown in Figure 28.

Note: When using hanger strap iron to support piping in drop ceilings and crawl spaces, cross bracing is required to prevent the pipe from swaying.

Sometimes wood blocking is used to support the piping when the piping is located within the joist space, as shown in Figure 30.

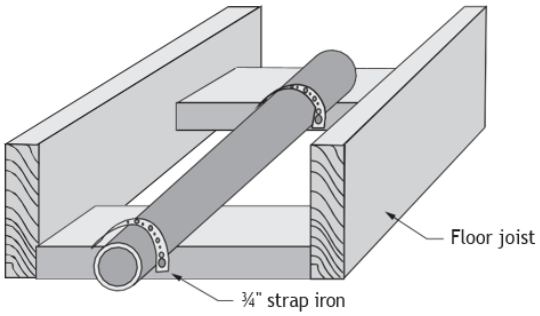


Figure 30 *Wood blocking to support piping (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hanger supports on residential applications of wood-frame construction are commonly applied with perforated hanger strap. This method is less expensive than using manufactured hanger supports. This strapping allows for flexibility in design of the support. The metal hanger strap installation must be capable of supporting the pipe and holding it in position.

Clevis Hanger with Double Nuts

Figure 31 shows a ***clevis type hanger*** with double nuts used on the hanger rod. The purpose of the double nuts is to reduce any swinging motion by holding the pipe more rigidly and reducing the tendency for vibration to loosen the nuts supporting the hanger.

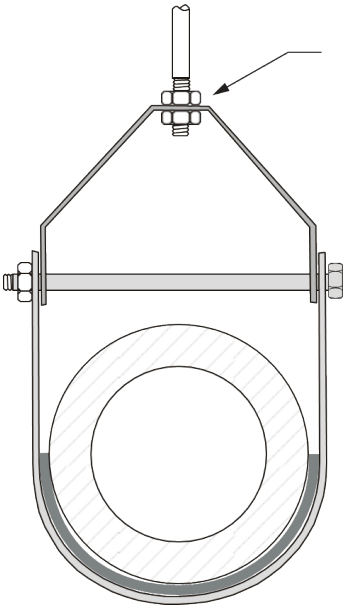


Figure 31 *Clevis hanger with double nuts (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

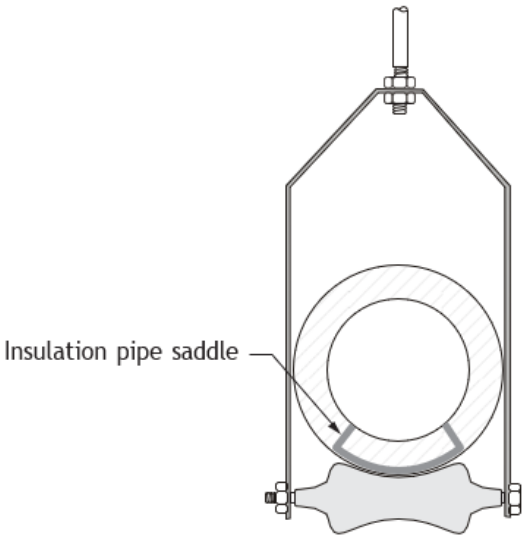


Figure 32 *Insulation pipe saddle (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The steel pipe saddle provides a solid surface for the pipe to move on the rollers without damaging the insulation.

Scissor Beam Clamp

A ***scissor beam clamp*** (Figure 33) is used to create a temporary overhead anchor point on steel beams for lifting and rigging applications, such as attaching hoists, lighting rigs, or pipework. It gets its name from the "scissor" action used

to clamp onto the beam's flanges, where twisting a spigot secures the clamp. This method allows for non-permanent installation, which avoids weakening the beam, and is ideal for lifting, construction, and industrial maintenance.

Figure 33 *Scissor beam clamp (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Expansion and Contraction of Hangers and Supports

The movement and shifting of suspended pipe can cause damage or failure if not properly controlled. Detailed below are several methods for achieving this control.

- *Sway braces* are used to restrain pipe movement.
- A *spring sway brace* allows controlled movement and returns the pipe to its original position.
- A *hydraulic shock arrestor* protects piping from sudden forces such as water hammer or seismic activity.

Sway Braces

Sway braces are used for controlling and restraining pipe movement, as shown in Figure 34.

Figure 34 *Basic sway brace designed to restrain movement in two directions (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Spring Sway Brace

A ***spring sway brace*** is a special type of variable effort restraint and is built around a standard or non-standard spring. It's used to restrain piping or equipment but is not intended to support. A swing sway brace has a pre-loaded spring, which allows both compression and extension movements of the pipe. By installing a spring sway brace, the pipe's position can move to accommodate forces acting upon it, then return to its neutral position once those forces have stopped.

Figure 35 *Spring sway brace (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hydraulic Shock Arrestor and Sway Suppressors

The ***hydraulic shock arrestor*** protects pipelines and equipment from the effect of shock loads caused by wind loads, pipe bursts, ***seismic activity***, ***water hammer***, and other sudden forces. When subjected to sudden movements, the shock arrestor "locks" momentarily and forms a rigid connection.

Figure 36 *Hydraulic shock and sway suppressors* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Spring and Variable Supports

Spring supports are used to support piping and related components that are subject to ***thermal expansion***. For minor vertical travel, a ***variable spring support*** (Figure 37) is typically used for relatively small displacements (up to about 75 mm). A ***constant spring support*** should be used for greater levels of thermal expansion (Figure 38).

The constant spring supports provide continuous support throughout the total movement of the pipe.

Figure 37: *Variable spring supports* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Constant spring supports provide continuous support along the total travel of the pipe.

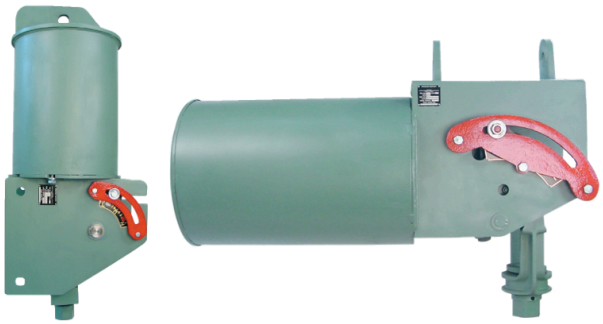


Figure 38 *Constant spring support (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The constant spring support is designed and manufactured based on the principle of a compression spring working in conjunction with a ***bell crank lever***, which balances the spring and load movements, resulting in a constant supporting effort throughout all pipe movement.

Model R lifting lugs:
To help alleviate the problem of lifting large size Constant Supports into position for installation, this product is available with lifting lugs (if requested) on sizes ten and larger.

Lifting Lugs (Figure 81-H): Not available on Type F.

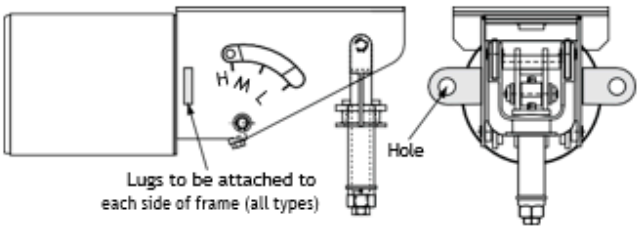
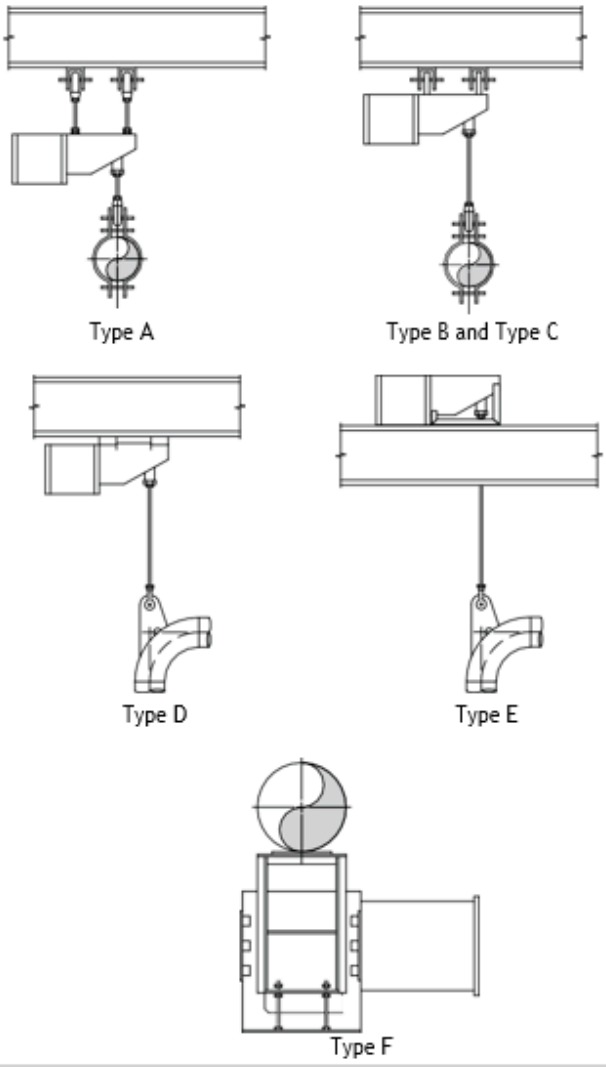


Fig. 81-H (Horizontal): Typical Applications



Lifting Lugs (Fig 80-V):

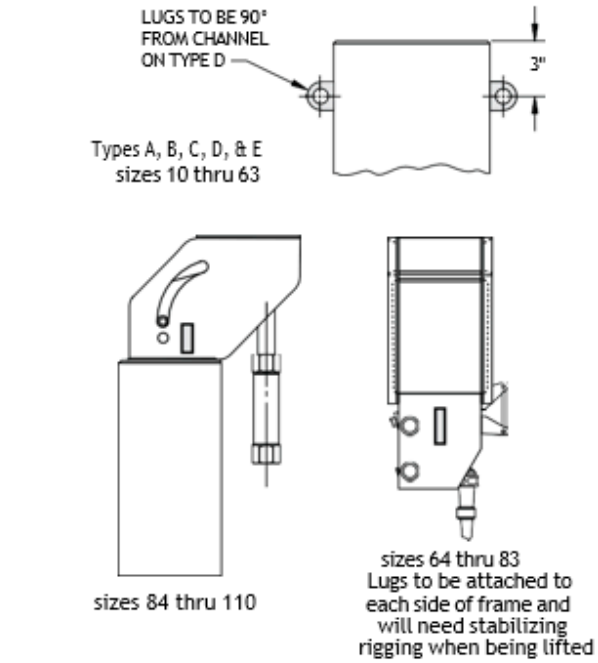


Fig. 80V (Vertical): Typical Applications

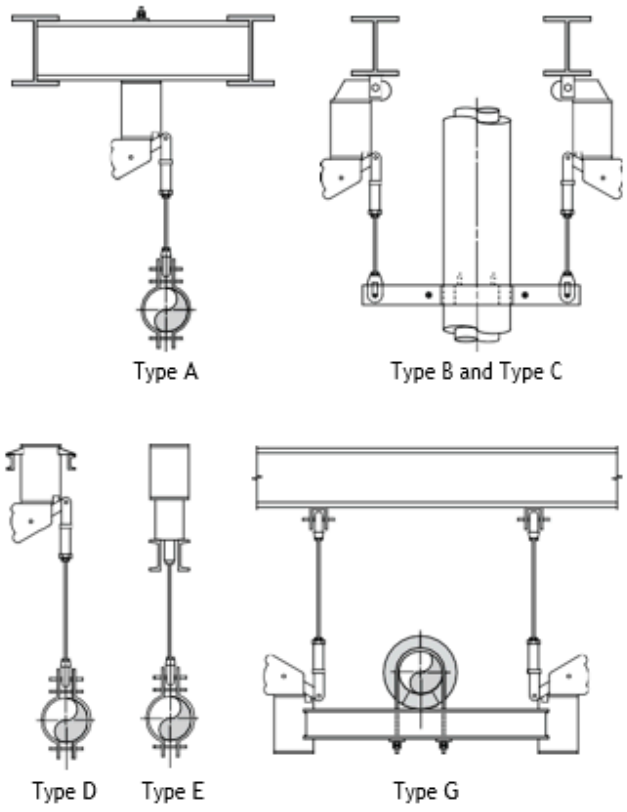


Figure 39 *Constant spring support installation orientations (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Slide Plates

Slide plates are used to provide a surface with a low ***coefficient of friction*** so that it can be attached to a supporting structure. The slide plate provides support while allowing the supported equipment to move freely. Slides plates can consist of an upper slide plate and a lower slide plate component that work together as a unit. They can be manufactured for a variety of applications, including the support of piping, heavy equipment such as pressure vessels, and structural steel members.

Figure 40 *Spring isolator supports under an outdoor refrigeration condenser unit (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Seismic Restraint of Mechanical, Electrical, and Plumbing Systems

During an earthquake, the shaking and rolling of the ground is transmitted to the building. The piping and equipment supported by the building's structure will be adversely affected by this movement. Unrestrained piping and equipment can rip apart, fail, or break loose. Fires, explosions, and flooding are common during earthquakes due to ruptured gas lines, fire sprinkler systems, and plumbing systems. As a tradesperson, you're responsible for the correct placement and installation of *seismic restraints*.

Seismic restraint refers to the components and systems used to keep mechanical, electrical, and plumbing systems secured in place while allowing movement with the building's structure. The goal is to maintain system operation during seismic activity, or at least until the structure itself fails.

Seismic Engineering Specification and Code Requirements

Building codes, plumbing codes, gas codes, and fire sprinkler codes all deal with support and seismic regulations. The *Fire Sprinkler Code* has extensive requirements for the installation and positioning of seismic restraints. Currently, plumbing and gas codes have more limited specific requirements. Where engineered systems are used, engineering practices and specifications must also be followed.

Basic seismic installation guidelines:

- Conform to *Building Code* requirements.
- Follow engineered job specifications.
- Follow manufacturer installation instructions.
- In the absence of regulations, follow proven trade practices.
- In **all** cases, check with the *authority having jurisdiction* (AHJ).

Guidelines for seismic restraint:

- The seismic restraints' positions should be coordinated so as not to interfere with each other or the positing of building equipment and structural components.
- Seismic restraint attachments to the building structure must always be strong enough to carry the imposed loading by the piping during seismic activity.

Seismic Supports for Piping Systems and Equipment

Beam Clamp with Strap

A ***beam clamp*** with a restraint strap or safety strap prevents the clamp from walking (slipping) off the beam during seismic events. Restraint straps are required for sprinkler installations in all seismic regions.

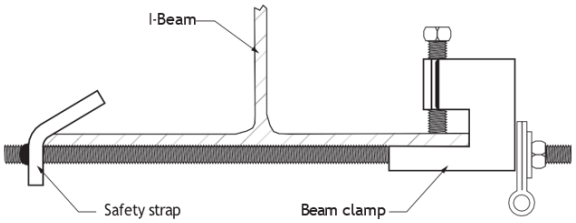


Figure 41 *Beam clamp with safety strap (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figures 42–44 show acceptable ways and means of installing seismic attachments. It's important to note that engineered specifications, Code requirements, and manufacturer instructions must be adhered to.

Figure 42 *Sway brace attached to riser clamp and concrete structure (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 43 *Riser clamp on pipe attached to concrete wall structure (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 44 *Pipe attachment to concrete by use of a spring hanger (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The hangers are close together so that each section of pipe is supported.

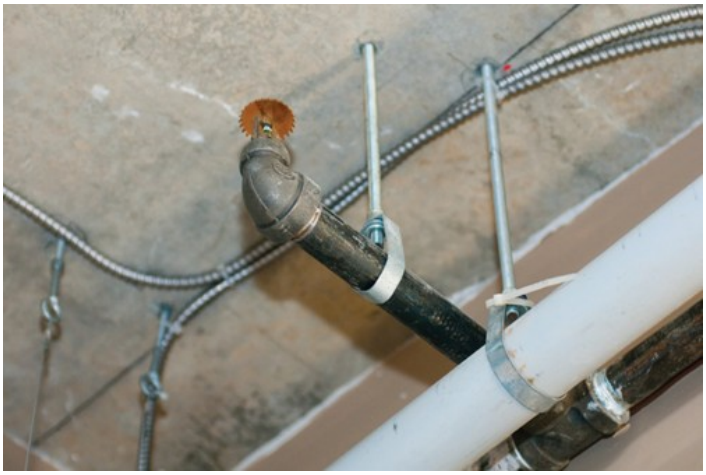


Figure 45 *Ring hanger use below concrete slab in parking area (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Cable-Brace Attachment

Cable-brace attachments must be installed in a straight line between attachment points and must not bend or wrap around other components (Figure 46).

Figure 46 *Seismic cable-bracing in a straight line between the anchor points and pipe attachment (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Power-actuated or *power-driven fasteners*, such as ***powder shot pins***, must not be used for ***tensile load applications*** unless specifically approved for seismic use.

Proper attachment of the mechanical, electrical, and plumbing system components and their seismic restraints is important in order to maintain the building's functionality following an earthquake. It's your responsibility to ensure that seismic components, supports and restraints have been properly installed.

Figure 47 *Cable attachment to pipe (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Seismic Restraint Components

The following components are commonly used to support and anchor pipes (Figures 48–52):

- *Sway brace*
- *U-clamp*
- *Clevis bracket*

Figure 48 *Sway brace attachment to threaded pipe sway brace (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 49 *U-clamp pipe to sway brace attachment (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 50 *U-clamp on a pipe and sway brace pipe and attachment assembly (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

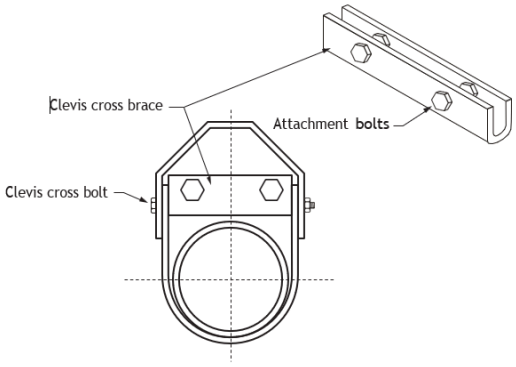


Figure 51 *Clevis cross brace bracket (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 52 *Sway brace on a fire sprinkler system (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pipe Support and Anchor Accessories

The following images show accessories used in supporting and anchoring pipes.

Figure 53 *U-bolt (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

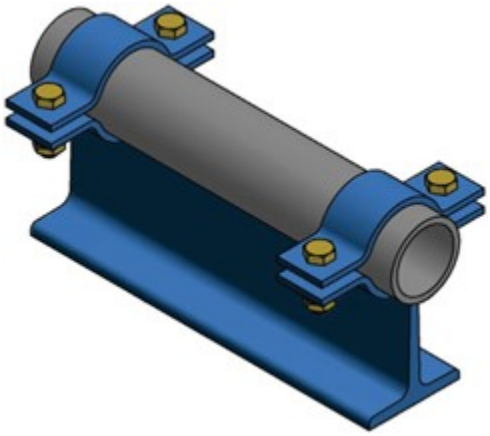


Figure 54 *Pipe shoe (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 55 *Rod connector (turnbuckle) (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 56 *Top attachment support*

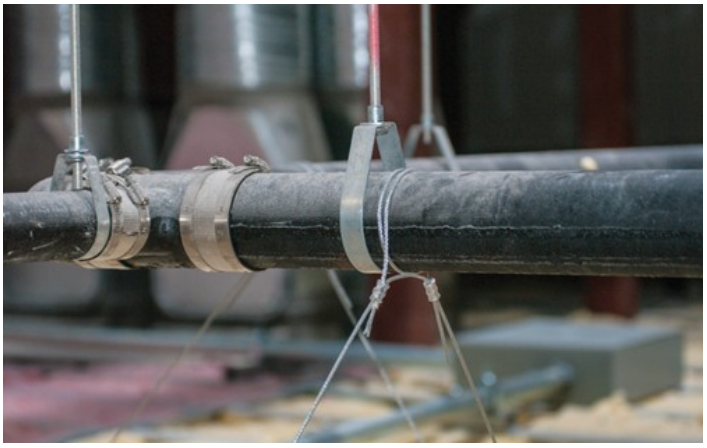


Figure 57 *Seismic suspension and restraint cables (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 58 *Site-fabricated (Unistrut) channel bar floor pipe support (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Seismic Bracing of Water Storage Heaters

Suggested guidelines for hot water storage heaters:

- Consult the ***authority having jurisdiction (AHJ)*** for any local requirements.
- Secure both the top and bottom of the hot water storage heater using heavy-gauge metal strapping.
- Position the tank so that there is approximately 25–50 mm (1–2 in) between the water heater and the wall. If the distance is greater than 50 mm, attach a wooden block to the wall studs with long lag screws to prevent the heater from sliding backwards.
- Wrap heavy-gauge metal strapping 1 $\frac{1}{2}$" times around the tank:
  - Start by placing the strapping at the back of the tank.
  - Bring it to the front and then take it back to the wall.
  - Secure this strapping to the wall studs or the wood block using longer lag screws with oversized washers. (If securing into concrete, use expansion bolts.)
- Replace all copper and metal piping with flexible natural gas and water line connectors.
- The gas and water lines should have flexible pipes—these may be safer than rigid pipes during an earthquake.
- Remind the customer to check the straps regularly for tightness.

Figure 59 *Hot water storage heater with seismic restraint using manufactured strapping (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 60 *Close up of seismic strap connection (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Residential Applications of Pipe Support

You are responsible for designing simple methods to provide adequate support and seismic restraint where possible. The *Building Code* does not specifically address every situation that occurs on a job site. You need to consider the effects of wood shrinkage and final settlement over time as the structure ages, particularly for wood-frame structures.

Figure 61 *Residential application of pipe clips used to support and hold PEX tubing (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 62 *Wood-frame installation showing the use of stub-out supports (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 63 shows the use of strap iron to support the ABS trap arm.

Figure 63 *Strap iron support (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 64 *Tub spout stub-out with wingback 90 deg elbow (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 65 *Plastic clips used to prevent rattling of pipes (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 65 shows the use of ***plastic clips and grommets***. The plastic grommet protects the pipe from contact with the sharp edges of the metal stud framing. Avoiding contact between dissimilar metals is important to prevent ***galvanic corrosion*** that can occur in the presence of moisture.

Figure 66 *Copper clips (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 66 shows the use of plastic tape wrap to isolate the copper trap arm from the dissimilar steel stud. Also shown is the use of a rise clamp to support the vertical cast iron soil pipe.

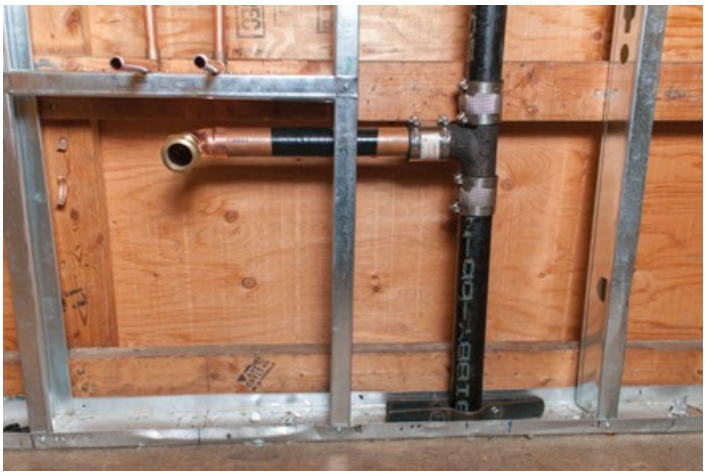


Figure 67 *Plastic tape wrap and rise clamp (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hangers and supports guidelines for ABS piping:

- Hangers and straps shall not compress, distort, cut, or abrade the piping and shall allow free movement of pipe.
- Pipe exposed to damage by sharp surfaces shall be protected.
- Support all ABS piping at intervals of not more than 4′ (1219 mm), at end of branches, and at change of direction or elevation.
- Supports shall allow free movement but shall restrict upward movement of lateral runs so as not to create reverse

grade.

- Vertical piping shall be supported at each storey or floor level.
- Alignment of vertical piping shall be maintained between floors with the use of a mid-storey guide.
- Support trap arms in excess of 3′ (914 mm) in length as close as possible to the trap.
- Water closet rings shall be securely fastened with corrosive resistant fasteners to the floor with the top surface $\frac{1}{4}$″ (6.4 mm) above the finished floor.

Self-Test D-1.3: Describe the Methods of Pipe and Tubing Support

Complete Self-Test 1.3 and check your answers.

If you are using a printed copy, please find Self-Test D-1.3 (#chapter-self-test-d-1-3-describe-the-methods-of-pipe-and-tubing-support) and Answer Key (#chapter-answer-key-self-test-d-1-3) in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://d-pipingcomponents-bcplumbingapprl1.pressbooks.tru.ca/?p=1929#h5p-3 (https://d-pipingcomponents-bcplumbingapprl1.pressbooks.tru.ca/?p=1929#h5p-3)

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://d-pipingcomponents-bcplumbingapprl1.pressbooks.tru.ca/?p=1929#h5p-15 (https://d-pipingcomponents-bcplumbingapprl1.pressbooks.tru.ca/?p=1929#h5p-15)

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- Plumber: Competency D-1 Prepare Pipe
- Steamfitter: Competency D-4 Layout and Install Piping and Tubing
- Sprinkler Fitter: Competency D-1 Prepare Pipe and Tubing

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D-1.4 Describe the Methods of Protecting Piping

It's important to understand the factors that can cause damage to piping. A damaged pipe results in reduced life expectancy (of the pipe) or failure of the piping system. Pipe can deteriorate for many reasons, including installation practices, environmental conditions, and the contents being transported. This damage can be reduced by protecting the pipe through the proper selection and installation of piping systems.

Factors Leading to the Need for Pipe Protection

Piping systems need to be protected from damage caused by the following:

- Mechanical damage during storage, handling, and installation
- Improper burial and trenching, vehicle traffic above ground, and ***buoyancy*** issues
- Freezing or excessive heat
- Environmental conditions such as corrosive soil, air pollutants, oxidation, electrolysis, and exposure to sunlight
- Damage as a result of the type of fluids being conveyed (internal damage)

Basic Methods Used to Protect Piping and Piping Systems

- Pipe coatings
- Pipe tapes and wraps
- Geotextile pipe protection
- Protective casings (a pipe placed inside a larger pipe)
- Electrolysis (galvanic) protection and dielectric protection
- Freeze protection through insulation, heat tracing, frost boxes, and circulation lines
- Protective plates and pipe sleeves

Pipe can also be protected by selecting the appropriate pipe material (e.g., steel, copper-nickel, cast iron, plastic). Each pipe material has unique characteristics that help it resist specific working conditions.

Preventing mechanical damage from seismic activity, pipe ***expansion***, and vibration is covered in D-1.5 Describe the Inspection of Pipes and Tube Before Installation (#chapter-d-1-5-describe-the-inspection-of-pipes-and-tube-before-installation).

Corrosion Protection: Internal and External Pipe Coatings

Typical regulations and specifications require that pipelines are treated with coatings that:

- Electrically isolate the external surface of the pipeline from its environment
- Have sufficient adhesion to resist under-film migration of electrolyte
- Are sufficiently ductile to resist cracking

- Resist damage from soil stress and normal handling
- Are compatible with cathodic protection
- Resist deterioration due to the environmental conditions and service temperature
- Resist harmful rays such as ultraviolet light

Internal and External Pipe Protection

Internal pipe protection is accomplished by applying protective coatings such as:

- Polyethylene lining
- Internal polymer coating
- Cement/sand coating
- Corrosion inhibitors

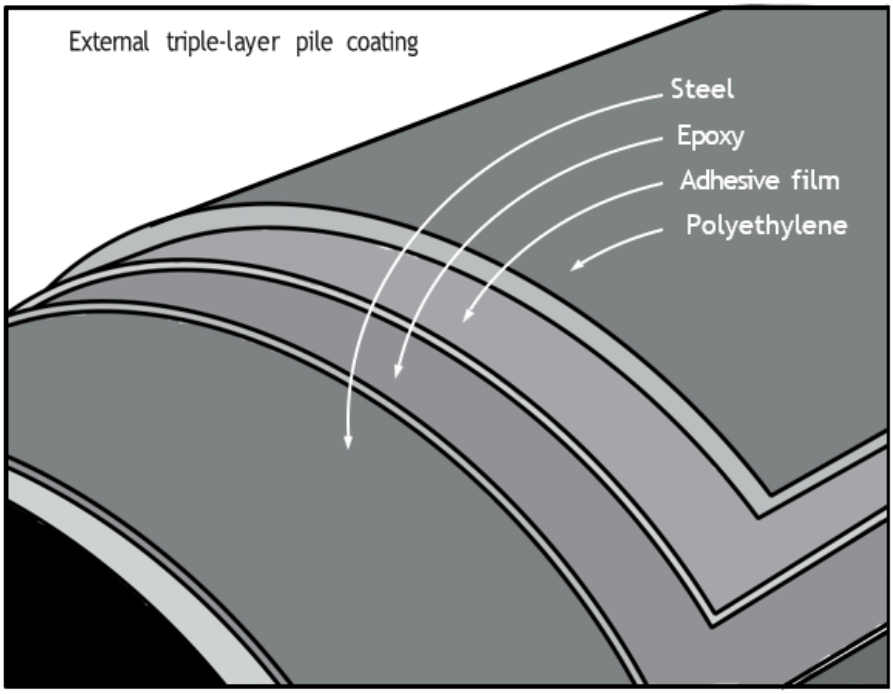


Figure 1 *External pipe coating tape/wrap* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Pipe Coating Types and Methods

Liquid Coatings

Liquid coatings have the following uses and advantages:

- Ideal for pipeline rehabilitation and coating repairs

- Suitable for field applications such as large recoating projects or short pipe sections
- Available in formulations that are 100% solids with no ***volatile organic compounds (VOCs)***
- Often do not require a primer and allow for ***high-build single-coat application***
- Can be applied with either spray or brush

The selection of pipe coatings is usually done by project design engineers.

Pipe coatings are applied to piping to protect the pipe from the degrading effects of the environment they are installed in. The types of protective coatings and the materials that make up the composition of the coating depend on the type of pipe and the damage that the pipe is going to be subject to. The methods used when applying these coatings is dependent on the manufacturer's application instructions and the type of pipe material it is applied to.

Mastic elastomeric coatings (soils saturated with oil and gasoline) may be used as a general-purpose coating for underground ***corrosion*** protection of all fabricated steel products, such as pipes, tanks, conduits, cylinder casings, and structural steel.

Other Mastic Coatings

Coal-tar-based epoxy combines the superior moisture resistance of coal tar with the excellent chemical and abrasion resistance of epoxy. Environments include chemical plants, flood gates, locks and dams, sewage plants, bridge and piling structures, and pipelines. Coal-tar-based is also used for immersion service and in atmospheric conditions where abrasion and chemical resistance are needed. It is used in industries such as sewage and water treatment, chemical processing, marine, offshore exploration, oil and gas distribution, and public utilities.

Rubberized mastic is a cold-applied coating with high electrical resistivity designed to protect underground steel pipes, tanks and other structures against corrosion.

Tape and Wrap Coatings

The external surfaces of steel pipe can be protected from corrosion by external pipe coatings. Pipe coatings include both liquid and powder coatings, pipe wraps and tapes, and can be applied at the factory or on the job. Factory-applied coatings are usually more reliable since they're applied in a controlled environment.

Figure 2 *Moisture sealing a pipe casing (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Geotextile Pipe Protection

Figure 3 *Geotextile-GSI (https://commons.wikimedia.org/wiki/File:Geotextile-GSI.JPG) (Marilyn475/Wikimedia Commons) Publi (https://en.wikipedia.org/wiki/en:public_domain)c (https://en.wikipedia.org/wiki/en:public_domain) Domain (https://en.wikipedia.org/wiki/en:public_domain)*

Geotextile sacrificial wrap provides protection for surface coating during backfilling operations and is often placed around the pipe prior to placement in the ***trench***.

Pipe Casing

Figure 4 *Steel casing pipe (https://pxhere.com/en/photo/1607653#google_vignette) (annawaldl/Pixabay) Content License (https://pixabay.com/service/license-summary/)*

Pipe casing is a method to protect a pipe by encasing the transporting pipe within a larger pipe. Pipeline casing filler is a petrolatum-based corrosion-preventative compound used to fill the void between the transporting and external pipes. It prevents corrosion by displacing water that is present in the casing and by preventing water from re-entering the casing.

Rock Guards

Rock guards are used to protect pipe protective coating from damage from soils with rocky backfill. The product is available in rolls or pads for varying diameters of pipe.

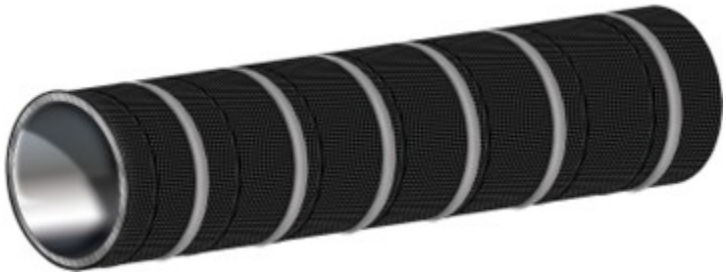


Figure 5 *Rock guard (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Transmission Sleeve

A transmission sleeve is used for field application at a joint in a pipe with existing pipe protection. (For example, an

underground welded gas line.) The transmission type sleeve system provides corrosion protection and bonding on pipelines ranging from operating temperatures up to specified temperatures. They are designed to bond to the existing pipe protection.

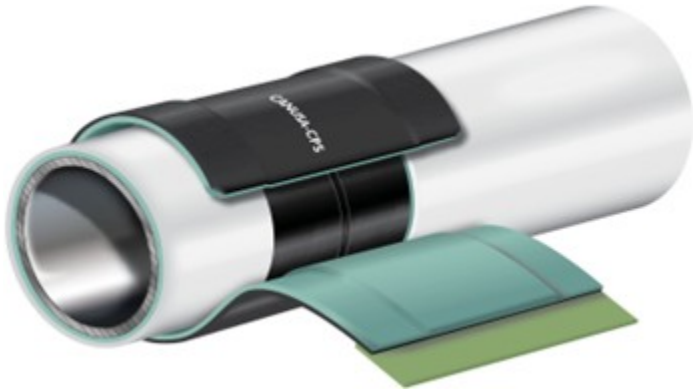


Figure 6 *Transmission sleeve Canusa-CPS (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Freeze Protection

Exposure of piping systems to freezing conditions will cause water and similar low freezing point fluids to freeze. The expansion of the fluid (water) as it freezes can rupture the pipe. When the water thaws the resulting water damage can be extensive.

Several methods can prevent freezing damage, including:

- Installing piping within a heated structure
- Applying insulation or enclosing the pipe (e.g., boxing, tenting, spray foam)
- Installing piping on the heated side of building insulation
- Draining or blowing out the system during cold weather
- Adding antifreeze solution
- Using hot boxes
- Installing heat trace systems
- For buried piping, installing the piping below the frost line or insulating and heat tracing
- Using constant circulation

The easiest way to prevent a piping system from freezing is to install the system within a heated structure. Building standards will often not allow potable water systems to be installed in exterior walls, especially in regions subject to freezing conditions without specific ***freeze protection***. Fire sprinkler systems installed in areas subject to freezing may be designed to be a dry pipe system, for example, parking garages and warehouses. The use of low-point drains are examples of frost-protection measures. Constructing an insulated box around piping or installing the pipe on the warm side of the building ***insulation*** is an acceptable way to insulate piping.

Piping installed in attic spaces, such as the case with residential fire systems, must be protected from freezing. Fire codes have standards on the methods of application of insulation in residential fire sprinkler systems.

Irrigation systems are often designed with compressed air blow out connections and low point drains. Irrigation systems are usually winterized by simply shutting down the systems and draining for the winter season.

Underground piping that can't be installed below the local frost line can't be insulated using materials that would crush under the weight of the compacted fill. Because of this, you might need to install a frost box. A frost box is the term given to one of three accepted assemblies (see the accompanying diagram):

1. An inverted U made of treated wood planks that is installed over the pipe and that maintains an air space between the pipe and planks. Freezing time would be longer due to the absence of physical contact between the pipe and the planks.
2. A pipe installed inside a much larger pipe. The outer pipe reduces contact between the pipe and the frozen earth around it.
3. High-density styrofoam used to separate the pipe and the fill above it. This method requires very high compaction of the fill around the pipe, and the Styrofoam must be of dense construction.

As long as water is moving, it is unlikely to freeze. Leaving a faucet dribbling to a drain can sometimes be effective to prevent freezing, but it wastes a lot of water. This adds cost to owners on a metered system and adds volume to a private septic or a municipal treatment system.

Using a pump to keep water circulating within a closed system, much the same as in a domestic hot water recirculation system, can effectively reduce the threat of freezing and prevent wasting water. Water at the end of the piping run is pumped back to its starting point through a separate pipeline. It is important that these systems are sized correctly to avoid unnecessary erosion of the pipe walls from excessive flow velocities.

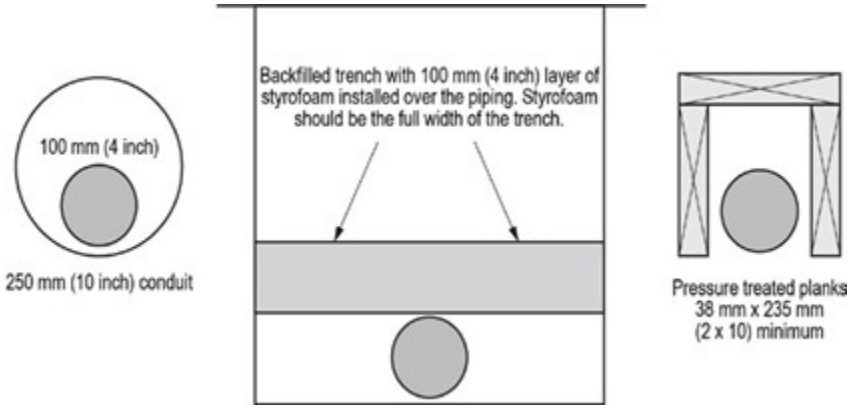


Figure 7 *Frost protection (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Piping Materials and Frost Protection Considerations

Different piping materials respond differently to freezing conditions, which has important implications for system design, installation, and maintenance in cold climates.

Compared to copper piping, PVC plastic pipe generally takes longer to freeze due to its lower thermal conductivity. However, once freezing occurs, PVC is more rigid and brittle, causing it to burst at a lower internal pressure when ice

expands inside the pipe. This makes PVC particularly vulnerable to sudden failure during freeze–thaw cycles, especially in unheated spaces or exterior installations.

Polyethylene (PE) and cross-linked polyethylene (PEX) piping offer greater resistance to freeze-related damage. These materials have a higher degree of flexibility than copper, allowing them to expand slightly as water freezes. This flexibility enables PE and PEX pipes to better absorb the internal pressure caused by ice formation, often preventing the pipe from bursting. In many cases, these pipes can return to their original shape once thawed, provided the freezing was not prolonged or extreme.

Copper pipe, while strong and durable under normal conditions, is relatively rigid and has little ability to expand. When water freezes inside a copper pipe, the expanding ice can generate significant pressure, leading to splitting or rupturing of the pipe, particularly at fittings or soldered joints.

Because of these material characteristics, frost protection measures—such as proper insulation, heat tracing, adequate pipe sizing, and strategic routing away from exterior walls—are critical regardless of the piping material used. However, material selection can play a significant role in reducing the likelihood and severity of freeze damage, especially in residential and light commercial applications.

Applying Freeze Protection

When pipe is installed where it is subject to freezing, the first solution is to apply pipe insulation. The goal is to maintain the temperature of the pipe and contents above the freezing point.

There are many types of insulation pipe wraps available. In many cases, batt fibreglass insulation is simply packed around the pipe in question. Pipe is often boxed in, and insulation is placed in the box surrounding the pipe. Often insulation is not protected from moisture and the environment. Water-soaked insulation does not provide good insulation.

In-ground valve and meter boxes are installed with some method to prevent freezing. Installation of piping below the frost level is a good solution. Where this is not possible, the piping can be covered with light-weight material with insulation qualities. Sawdust and wood chips and shavings can work in dry environments for limited amounts of time before needing to be replaced.

The application of freeze protection requires consideration of the type of insulation and its thickness. It's difficult to know how much insulation is required. How cold will an unheated crawl space, attic, or outside wall get? How long is the ambient temperature going to stay below freezing? Will additional ***heat trace*** cable be required? If the pipe freezes, the resulting damages can be costly. Given this, it's better to be safe than sorry.

Factors affecting heat loss include:

- Thickness of installation
- Ambient temperature
- The size of pipe and the amount of residual heat
- Wind speed (for pipes exposed to wind)

Types of pipe insulation include:

- Flexible closed-cell polyethylene
- Fibreglass
- Mineral wool

- Natural insulation
- Foam

Figure 8 *Fibreglass pipe insulation (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Flexible closed-cell polyethylene or elastomeric insulation are often used for insulating plumbing, both residential and commercial. These lines are found in crawl spaces, walls, attics, parking garages, and unheated warehouses. The closed cell has excellent range of properties, including low thermal conductivity, water vapour permeability, and ease of installation. There is no need for additional water vapour barrier.

Figure 9 *Closed-cell polyethylene foam pipe insulation used for frost protection*

Styrofoam Insulation

Styrofoam insulation is a rigid, closed-cell foam pipe insulation. This insulation has a dense, compact structure ensuring resistance to water, water vapour, and wet freeze-thaw cycling.

Using insulation by itself may be satisfactory in climates where freezing temperatures are rare and for short periods of time only. Where climate temperatures drop below freezing and last for extended periods of time, insulation and heat tracing is recommended.

Heat Trace

Heat tracing protects pipe from freezing by applying a heat-producing source, such as an electrical heat trace cable. The effectiveness of such heat trace or cable depends on correct selection and proper installation.

Heating cable systems can be controlled either manually or by thermostatic control. Self-regulating and all heating cables should be Underwriters Laboratory (UL) Listed, Canadian Standards Approval (CSA) certified, or Factory Mutual

(FM) approved for their use. The most common thickness for heat trace is $\frac{1}{4}$" , and the insulation's inside diameter must be sized properly to fit over both the pipe and the tape. This is done to ensure the insulation seam will close tight and stay tight.

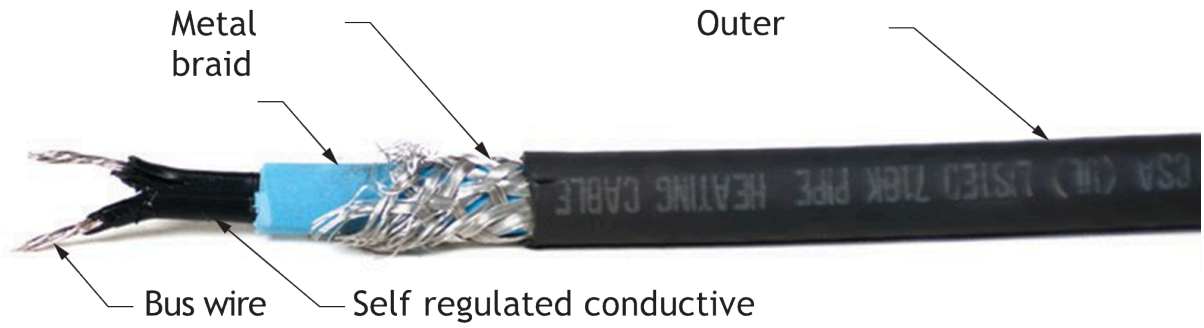


Figure 10 *An example of one type of heat trace cable (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Heat trace frost protection cable is constructed of several layers. The inner layer of the cable contains two conductor wires that supply electrical power to the heat tape. Surrounding the two wires is a special polymer that generates heat when electrical current flows through it.

Some manufacturers supply heat trace cable in coils that may be cut to the exact length needed for a job. Cable connectors and end seals are supplied to terminate the cut ends.

Heat trace cable is also supplied in specific lengths. These pre-cut lengths should not be further cut unless specifically allowed by the manufacturer.

Figure 11 *Coil of heat trace with ground fault plug (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Thermostats

Heat tracing systems may be controlled either manually or through thermostatic control. Manual control requires the

operator to turn the power to the heating cable on or off as needed, relying on judgment and monitoring of ambient conditions.

Thermostatic control uses a temperature-sensing switch to automatically energize or de-energize the heating cable at preset temperatures. This method provides more consistent freeze protection and improved energy efficiency by ensuring the system operates only when required.

Figure 12 *Example of heat trace thermostatic control (©2014 Environmental Technology Inc.) Used with permission*

Aluminum Foil Tape

When required, aluminum foil tape is applied to the pipe under the heat trace. This will provide better conductivity to the pipe, particularly for plastic piping. Aluminum tape can also be used to attach the heat trace tight to the pipe and keep insulation from getting under the heat trace.

Figure 13 *Aluminum tape (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Heat trace cable is available thermostatically controlled or self-regulating. Self-regulating cable consists of a polymer in the cable that has a resistance that changes with the temperature. For example, one manufacturer states that their cable uses about 3.5 watts per foot at 4.4°C (40°F). At –17.7°C (0°F), the power usage increases to about 5 watts per foot. The heat trace cable is simply plugged in or turned on for the winter season and unplugged or turned off at the end of the cold season.

Heat Trace Safety

The following are some considerations for heat trace safety:

- Do not use heat trace cables below ground unless specifically approved for such use.
- Heat trace should be plugged into a grounded electrical receptacle in a dry area.
- Ground fault interruption may be required (consult electrical codes).
- Do not cut or splice heat trace cable unless specifically approved by the manufacturer and electrical codes.
- Heat trace should not be enclosed in walls, ceilings or floors.
- Heat trace must be visible for inspection (under pipe insulation is permitted if specified by the manufacturer's installation instructions).

Heat Trace Selection

Factors to consider when selecting and installing a heat trace cable include:

- Pipe diameter
- Pipe length
- Minimum ambient temperature (worst-case scenario)
- Temperature rating of the fluid being transported
- Manufacturer's sizing tables

> **Note:** A typical maintained temperature of 5°C (40°F) is acceptable. This maintained temperature is used to determine the maximum length of the tracer circuit and the size of the electrical breaker.

Recommended Heat Trace Installation Practices

- The pipe and heat trace cable should extend into the building approximately 300 mm as the pipe enters the building and well below the frost line if the pipe exits or enters the ground.
- For short branches run off a main, you can double-trace (down and back) to eliminate the need for splicing.
- Avoid running heat trace cables through open air from pipe to pipe. Use a conduit extension to protect the cable.
- Select the cable wattage conservatively, allowing a slightly higher wattage output, per foot of cable, than required.

- Insulate all heat sinks in the heat tracing system. Allow sufficient cable to trace additional heat sinks.
- Avoid wrapping heat trace cable around a valve so the valve cannot be easily removed or repaired.
- The better insulation value of the pipe insulation, the less wattage required and the longer the runs.
- Larger pipe may require more than one heat trace cable.
- Place aluminum foil tape over the heat trace cable before applying spray on insulation—this will improve heat transfer to the pipe.
- Avoid contacting heat trace cable with steam from steam cleaning operations—the high temperature can damage the cable.

Electrical Considerations

- Design the heat tracing system using the most commonly expected start-up temperature. Maintaining the higher start-up temperature uses less power and allows longer heat trace circuits and smaller circuit breakers. Breaker tripping may occur if the heating system starts at a lower temperature than it was designed for.
- The maximum lengths and breaker should be in conformance with the manufacturer's specifications and *Electrical Code* requirements.
- All heating cable systems require ground fault protection as required by the *National* and *Canadian Electrical Code*.

For the required wattage given the pipe diameter, the ambient temperature, and the amount of insulation, use the tables provided by the heat trace manufacturer.

Methods Used to Install Heat Trace

Methods used to attach heat trace to pipe include flexible nylon straps and flexible heat trace tape. When attaching heat trace, ensure that the tape or strapping is rated for the temperature of the piping when in use. Do not use metal strapping or tie wire. It's important that the heat trace makes positive continual contact with the pipe surface to provide the best results.

Temporary Attachment

Starting at the end of the circuit and working back towards the power source, attach the heat trace temporarily. Allow extra tracer cable for final attachment to valves, flanges, elbows, and at pipe supports. Also allow extra cable for the power connection and for any splicing that may be required. Pipe supports can act as a heat sink, so on sizes over 2″ in diameter, extra heat trace may be required.

Permanent Attachment of Heat Trace

For instructions applying to large diameter industrial piping or residential application, see the manufacturers' instruction

Ultraviolet Light (Sunlight) Protection

When thinking about UV protection, there are different considerations for different types of pipe and tubing.

ABS Pipe Protection

ABS piping should not be exposed to direct sunlight. An exception is a vent pipe passing through a roof. Vent piping exposed to sunlight must be protected by water-based synthetic latex paints.

Adequate support must be provided where ABS piping is exposed to wind, snow, and ice loading.

Piping passing through wood studs or plates must be protected from puncture by steel nail plates of not less than 18-gauge.

PVC Pipe Protection

PVC does not readily degrade when exposed to sunlight due to natural UV inhibitors present in the material. Short-term exposure of PVC to sunlight during construction is typically not a problem. PVC piping installed outdoors can be painted with a light coloured water-based acrylic or latex paint that is chemically compatible with PVC.

PEX Pipe Protection

PEX tubing is not intended for use outdoors. The tubing must be stored and used in a concealed environment. Some PEX manufacturers produce PEX with varying resistances to ultraviolet light. PEX tubing should not be exposed to ultraviolet light for extended periods of time. PEX tubing can handle ultraviolet light during the installation period; however, you should always consult the manufacturer's specifications.

Note: Plastic piping should be protected from contact with concrete form release oils and foundation emulsions.

Fibreglass Pipe Protection

The effect of ultraviolet light on fibreglass pipe is limited to surface discolouration. Fibreglass pipe degradation is limited to the outer 0.005–0.01″ of the pipe. You may protect fibreglass pipe from the ultraviolet rays by painting with a heavily pigmented industrial coating it or by coating with an ultraviolet absorbing agent.

Pipe Condensation Protection

Pipes that operate below the ambient temperature of the surrounding air are subject to condensation. The moisture in the surrounding air condenses on the cold pipe surface. This accumulation of moisture may contribute to the corrosion

of the pipe and/or its support. Moisture accumulation can contribute to damages to the surrounding building structure. Mould and bacteria growth can cause visual damage or promote rot in wood structures.

Typical examples of piping subject to condensation include:

- Cold water piping
- Storm and rain water drainage piping leading from roof areas and passing through the heated structure
- Piping installed in cold storage facilities or freezers

Damage caused by this condensation may include:

- Staining of building surfaces
- Mildew and bacterial growth
- Decay of structural components
- Promotion of electrolysis causing damage to pipe and supports
- Oxidation of exterior pipe walls

Figure 14 *Condensation on a pipe* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Methods used to prevent condensation include:

- Pipe insulation
- Reduction of moisture content through the use of heat recovery ventilation systems or dehumidifiers
- Use of a vapour barrier to eliminate air infiltration through openings surrounding the pipe

Physical and Mechanical Pipe Damage Protection

There are different sources of damage to pipes, requiring protection.

Steel piping installed parallel to or through wood frame members rarely needs protection from punctures by nails or screws. Plastic and copper tubing, however, is not as robust and therefore needs to be protected from this threat.

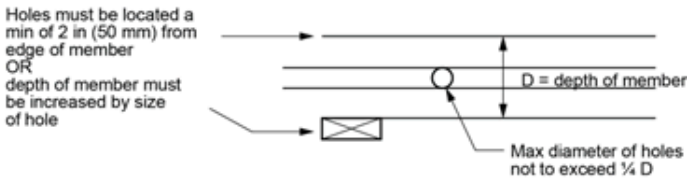
Protective prescriptions for gas piping or tubing are laid out in the CSA B149.1 Code for the installation of natural gas and propane systems, but protection of water lines is not really addressed quite as specifically in the plumbing codes. Following the gas code references for tubing protection should ensure adequate protection for water pipe installations.

When the tube is installed within joist spaces and parallel to the joists, keep the tube face at least 1 $\frac{3}{4}$" (43 mm) above the face of the joist to prevent contact with drywall nails or screws. When run through holes in joists or studs, maintain that same 1 $\frac{3}{4}$" (43 mm) distance between the face of the stud or joist and the edge of the tube. If that minimum separation cannot be maintained, use protective plates or sleeve.

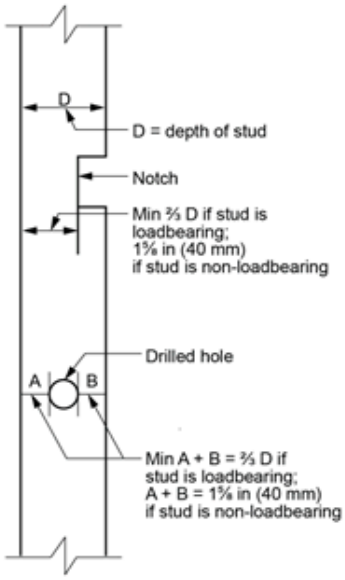
Article 9.23.5 of the National Building Code of Canada specifies the permissible notching and drilling of wood framing members.

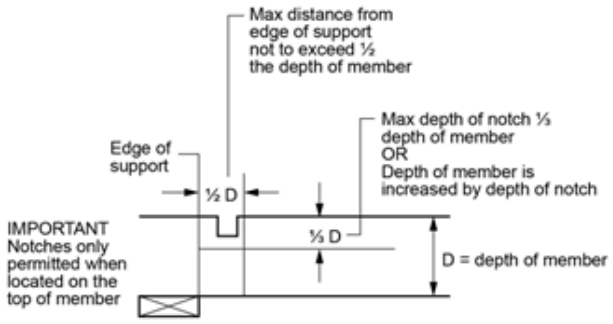
The figures and tables on this page summarize these requirements.

For materials such as concrete and steel, obtain advice from a structural engineer prior to notching or drilling any structural members.



Horizontal Member Size	Maximum Hole Diameter
2 × 4 in (38 × 89 mm)	Not permitted
2 × 6 in (38 × 140 mm)	1⅜ in (35 mm)
2 × 8 in (38 × 184 mm)	1¾ in (46 mm)
2 × 10 in (38 × 235 mm)	2¼ in (58 mm)
2 × 12 in (38 × 286 mm)	2¾ in (71 mm)





Stud	Loadbearing	Non-loadbearing
2 × 4 in (38 × 89 mm)	1⅛ in (30 mm)	1⅞ in (48 mm)
2 × 6 in (38 × 140 mm)	1¾ in (46 mm)	3⅞ in (98 mm)

Member Size	Maximum Distance from Edge of Support	Maximum Depth of Notch
2 × 4 in (38 × 89 mm)	1¾ in (44 mm)	1⅛ in (30 mm)
2 × 6 in (38 × 140 mm)	2¾ in (44 mm)	1¾ in (46 mm)
2 × 8 in (38 × 184 mm)	3⅝ in (92 mm)	2⅜ in (61 mm)
2 × 10 in (38 × 235 mm)	4⅝ in (117 mm)	3 in (78 mm)
2 × 12 in (38 × 286 mm)	5⅝ in (143 mm)	3¾ in (95 mm)

Figure 15 *Example from CSA B149.1 Handbook. Used with permission.*

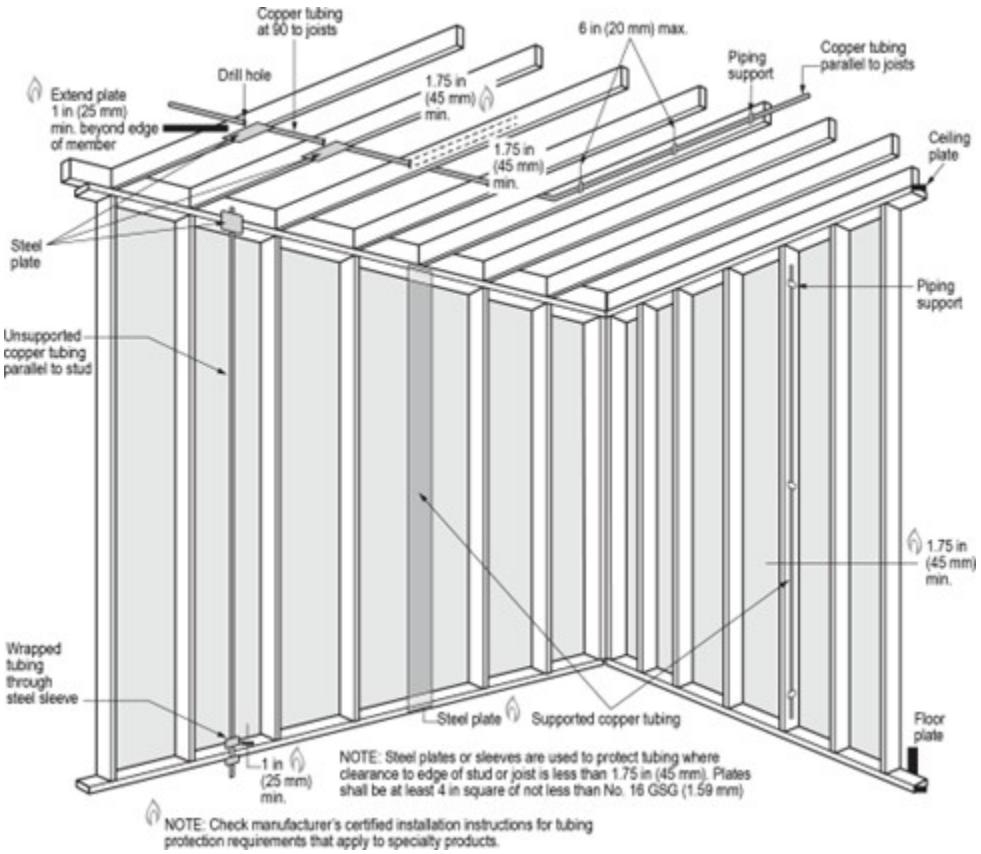


Figure 16 *Example from CSA B149.1 Handbook. Used with permission.*

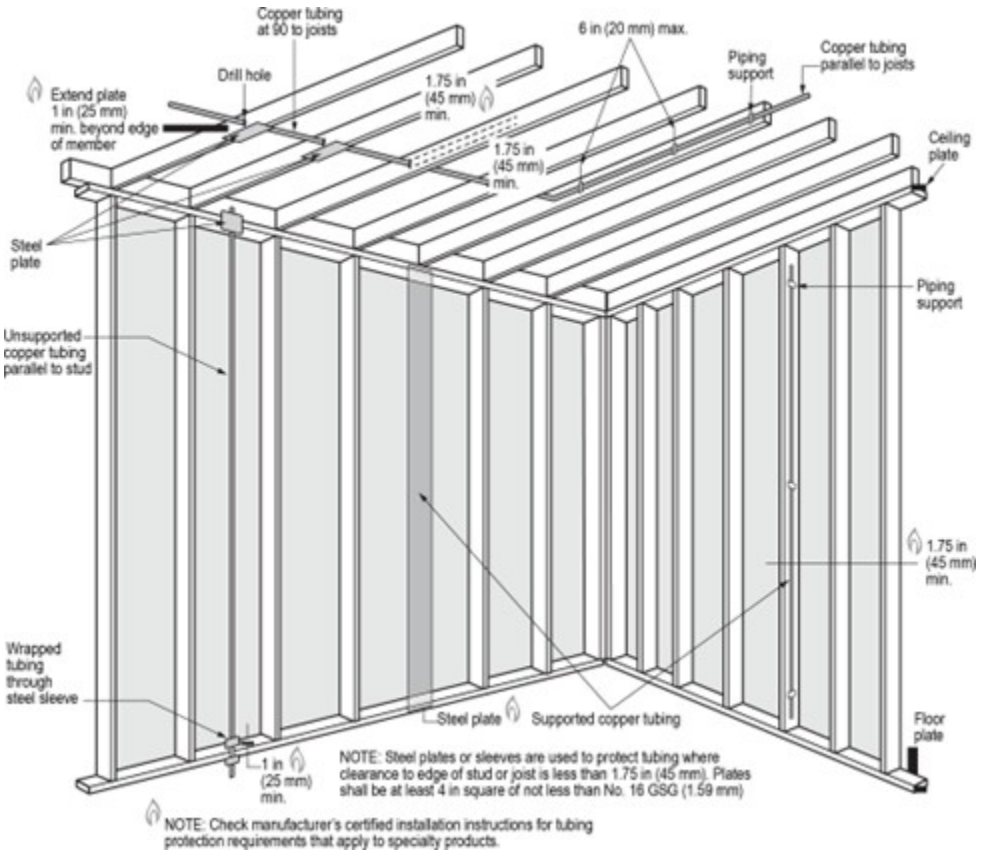


Figure 17 *Tubing protection requirement–Example from CSA B149.1 Handbook. Used with permission.*

A small diameter pipe run through oversized holes drilled through the centre of 2 x 6 studs usually maintains that minimum separation. Oversized holes allow the pipe to deflect if hit. In drilling the holes, however, make sure to not compromise the structural integrity of the stud. If running piping through a 2 x 4 stud wall, the minimum separation usually cannot be met, so it would require that heavy gauge steel protection plates be attached to the stud face. This method usually causes the drywall to bulge outward at that point, so an alternative method would be to run the pipe or tube through short sleeves of electrical metallic tubing (EMT) that are larger than the water line. The sleeves are meant to be fitted tightly into the drilled holes so they can't fall out, and the pipe or tube must be wrapped with a dielectric such as electrician's tape to prevent galvanic corrosion between the pipe and the pipe sleeves. Also make sure to ream the cut ends of the pipe sleeves to prevent abrasion of the tubing running through them.

Expansion and Contraction of Piping

Pipe expansion and contraction occurs when the piping is subject to temperature changes. The temperature changes can be a result of internal fluid temperature or external temperature caused by the surrounding environment. When piping heats up, it will expand. When piping cools down, it will contract. Continued uncontrolled expansion and contraction of piping can result in damage or failure of the pipe or the components of the piping system.

Damage to the building structure can occur when expanded piping has not been controlled. Uncontrolled expansion and contraction stresses applied to connected appliances and equipment can result in damage. It is your responsibility to recognize the expansion and contraction issues and apply installation practices to control it. Providing proper

clearances from building structural components and the use of piping fittings and piping design layout can effectively limit and control the forces of expansion and contraction.

Expansion Control for Metallic Piping

Manufactured Expansion Joints

Manufactured expansion joints are used to protect metallic piping. There are different kinds.

A single bellows expansion joint is simply a bellows element with end connections. It will deflect in any direction—to keep the pipe and bellows in line, the joint is controlled with pipe guides or anchors.

Figure 18 *Bellows-type expansion joint with shipping bars. (Do not remove bars until after installation.) (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Slip-Type Expansion Joints

Slip-type expansion joints are used when the primary problem is large axial movement. The design is basically an inside and outside barrel (sleeve), with a mechanical seal between them that slides back and forth as the pipe expands and contracts.

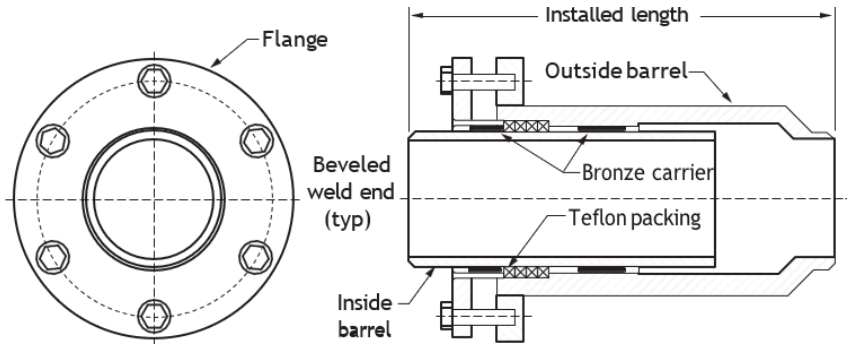


Figure 19 *Cross section of slip-type expansion joint (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Installation Practices for Manufactured Expansion Joints

The following summarizes installation practices for manufactured expansion joints.

- Follow the manufacturer's precautions.
- Inspect for damage during shipment. i.e., dents, broken hardware, water marks on carton, etc.
- Store in clean dry area where it will not be exposed to heavy traffic or damaging environment.
- Use only designated lifting lugs.
- Make the piping systems fit the expansion joint, rather than the other way around.
- Leave one flange loose until the expansion joint has been fitted into position. Make necessary adjustment of loose flange before welding.
- Install joint with arrow pointing in the direction of flow.
- Install single Van Stone liners, pointing in the direction of flow. Be sure to install a gasket between the mating flange and liner.
- With telescoping Van Stone liners, install the smallest ID liner pointing in the direction of flow.
- Remove all shipping devices after the installation is complete and before any pressure test of the fully installed system.
- Remove any foreign material that may have become lodged between the convolutions.
- Refer to appropriate standards for proper guide spacing and anchor recommendations.
- Do not drop or strike the delivery carton.
- Do not remove shipping bars until installation is complete.
- Do not remove any moisture-absorbing desiccant bags or protective coatings until ready for installation.
- Do not use hanger lugs as lifting lugs without approval of manufacturer.
- Do not use chains or any lifting device directly on the bellows or bellows cover.
- Do not allow weld splatter to hit unprotected bellows. Protect with wet chloride-free insulation.
- Do not use cleaning agents that contain chlorides.
- Do not use steel wool or wire brushes on bellows.
- Do not force-rotate one end of an expansion joint for alignment of bolt holes. Ordinary bellows are not capable of absorbing torque.
- Do not hydrostatic pressure-test or evacuate the system before installation of all pipe guides and anchors. Pipe hangers are not adequate guides.
- Do not exceed a pressure test of 1.5 times the rated working pressure of the expansion joint.

Bellows Misalignment

During the installation of the piping systems, the accuracy of the location of equipment, pipe supports, structure, and the piping itself is often not perfect. The expansion joint is usually far more easily deflected than any of these other components. The use of the expansion joint to correct imperfections in piping alignment is not recommended. The expansion joints will arrive from the factory with rigid restraints that maintain their length and ends in the position and dimensions of the specification. Do not remove prior to, or during, installation.

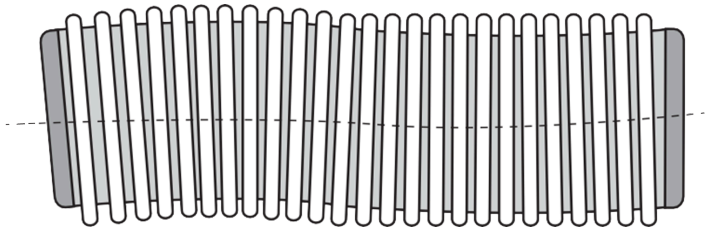


Figure 20 *"Bellows squirm" (damage caused by misalignment) (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Rubber Expansion Joint

A rubber expansion joint, illustrated:

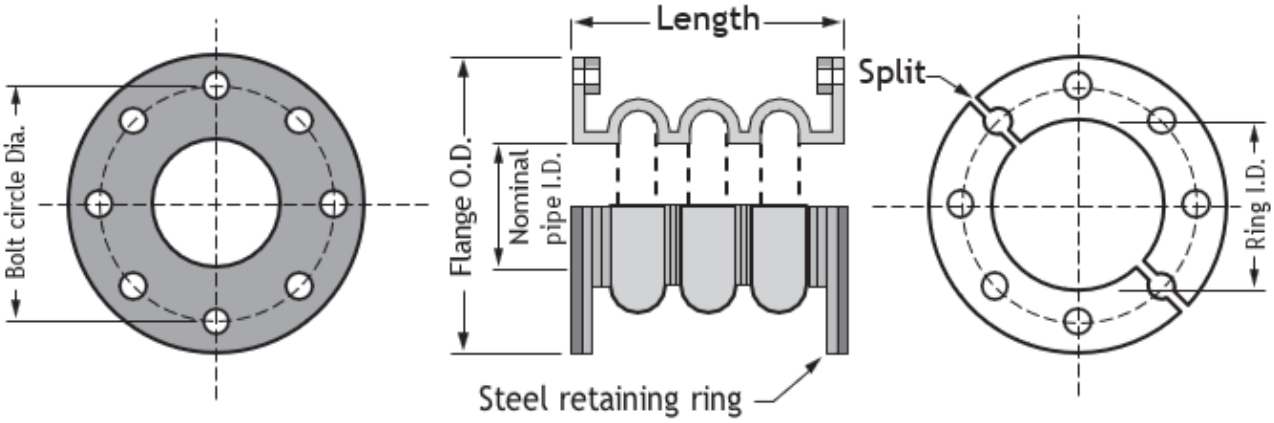


Figure 21 *Rubber expansion joint (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Roller Hangers, Expansion Loops, and Supports

The following illustrations show common roller hangers, expansions loops and supports.

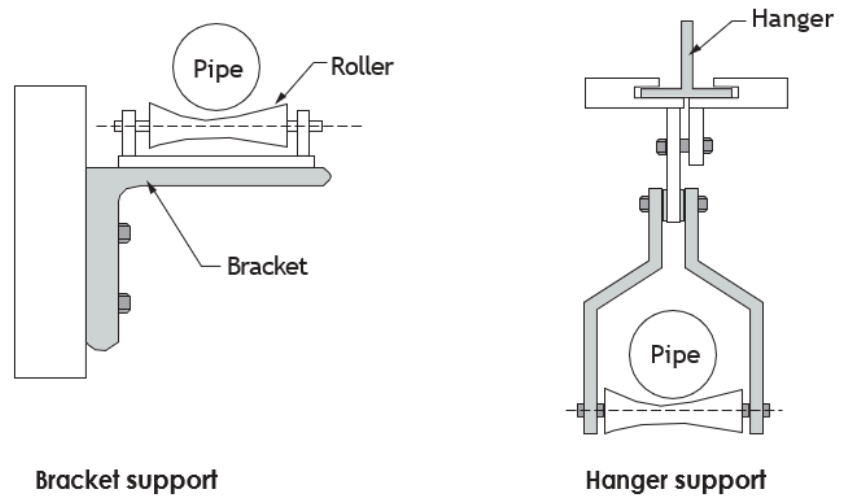


Figure 22 *Roller hanger and brackets (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

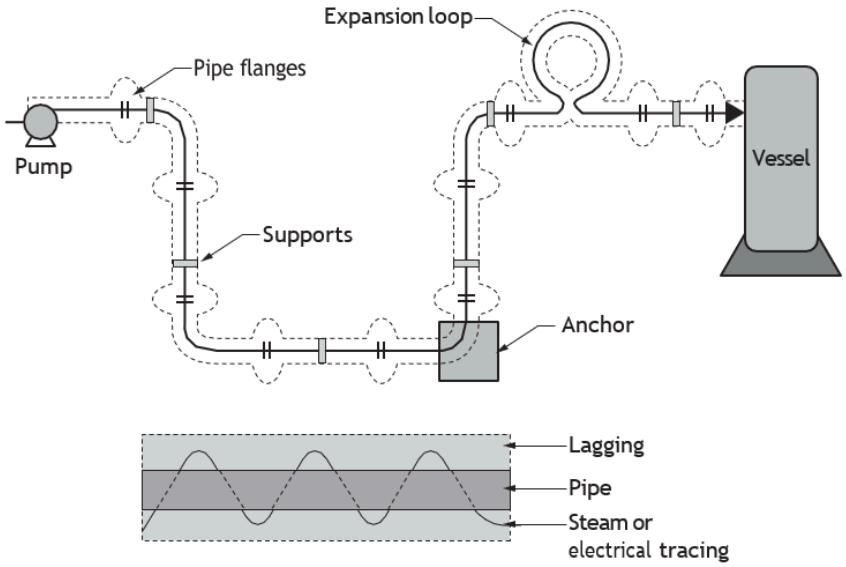


Figure 23 *Expansion loop application (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pipe Guides

Pipe guides ensure that the thermal expansion of the pipeline is properly directed into the expansion joint and to prevent buckling of the line. Additional guides located adjacent to the expansion joint are necessary because of the inherent flexibility of the bellows and the compressive loading on the pipe caused by the pressure thrust of the expansion joint.

The first guide must be located within a distance of four pipe diameters from the expansion joint, and the second

guide within fourteen pipe diameters of the first guide. Additional guides should be located in accordance with the manufacturer's guidelines.

In Figure 21, below, two pipe guides allow pipe to move and are kept in line by the large guide sleeve. Sections bolted to pipe keep the pipe centred in the guide sleeve. The guide sleeves are anchored solidly to the building structure.

Figure 24 *Pipe guides* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

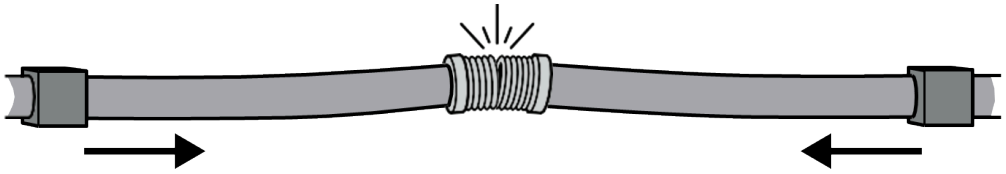
Pipe Guide and Pipe Anchor Placement

Proper pipe guiding is essential to an installation of expansion joints or pipe expansion loops. Properly located pipe guides and anchors keep the pipe in line and reduce or eliminate excessive misaligning forces on the expansion joint.

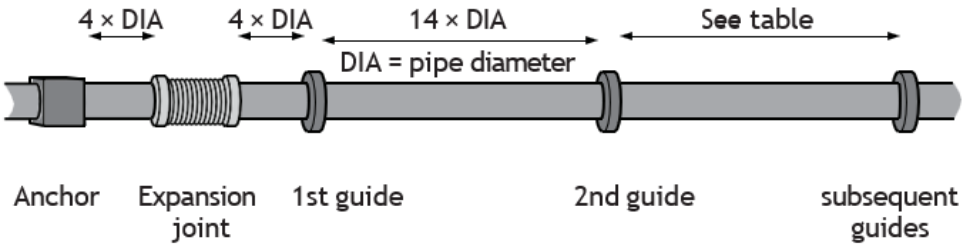
Guides normally permit axial movement of the pipe, while restraining both lateral and angular movement. Pipe guides support the pipe and guide the pipe expansion.

The location and number of pipe guides and anchors is dependent upon:

- Proximity of the expansion joint to an anchor
- Diameter of the pipe
- Length of the pipe run



Effects of Thermal Expansion Without Guides



Typical Pipe Guide Installation

Figure 25 *Location of pipe guides and anchors on straight pipe lengths (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 23 shows the placement of pipe guides and anchors for an expansion loop.

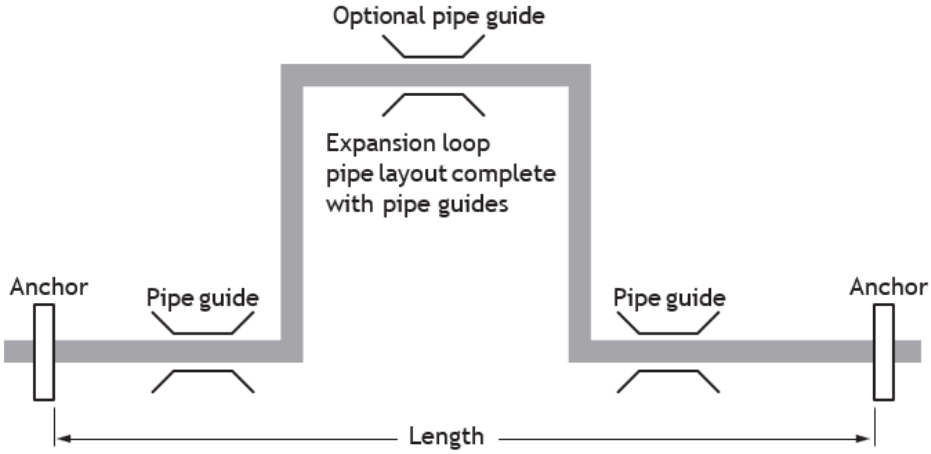


Figure 26 *Expansion loop showing typical pipe guide placement and pipe anchor positions (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Offsets and Changes of Direction to Maintain Piping System Flexibility

Piping flexibility is probably the least understood function of piping design. Although not often thought about in residential applications, it's an important application in larger commercial applications, industrial, and process piping. It's preferable to provide adequate flexibility in piping systems by using elbows to create additional changes of directions in the piping layout. Where space is limited or cost considerations apply, manufactured expansion joints may be used. A good expansion design will provide the maximum flexibility using a minimum number of fittings.

As with any pipe expansion provisions, the use of pipe guides to keep the pipe in line and pipe anchors to direct the expansion is required. An anchor placed near the centre of the run will direct expansion by forcing 50% of the expansion to either side of and away from the anchor point. Remember that pipe guides are used to keep the pipe in alignment.

The design of pipe expansion provisions is normally the work of the design engineer. However, as an installer, it's useful to recognize the basic piping design configurations used to provide for pipe flexibility and expansion movement.

Figures 24–27 illustrate the various piping arrangements used to provide flexibility and accommodate expansion in industrial and process piping applications.

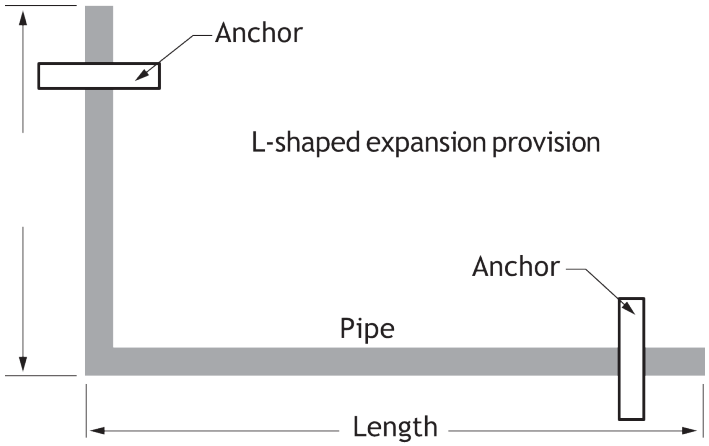


Figure 27 *L-shaped pipe configuration provides flexibility (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Design engineers calculate the flexibility and expansion required. They can then design the piping layout and the required dimensions of L and H to accommodate system flexibility and expansion.

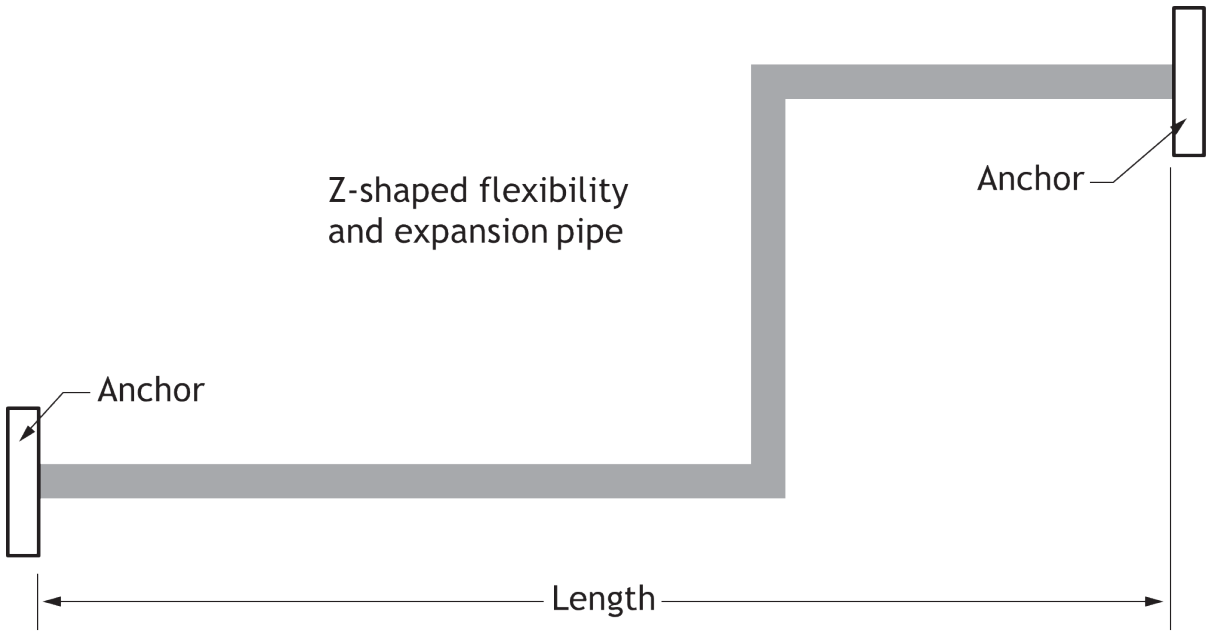


Figure 28 *Z-shaped pipe configuration (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

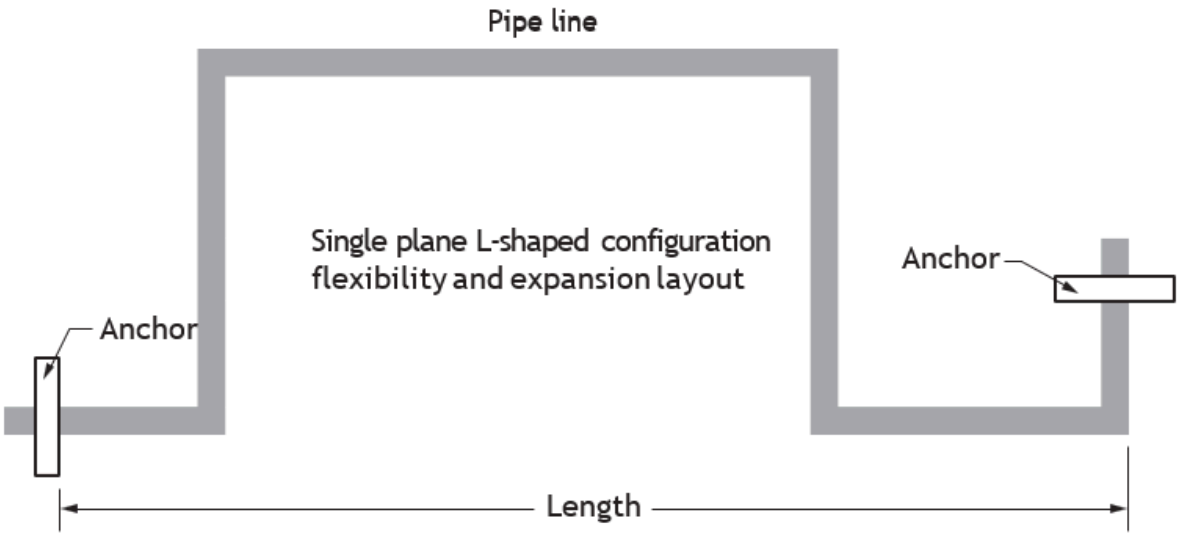


Figure 29 *Single-plane L-shaped configuration (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

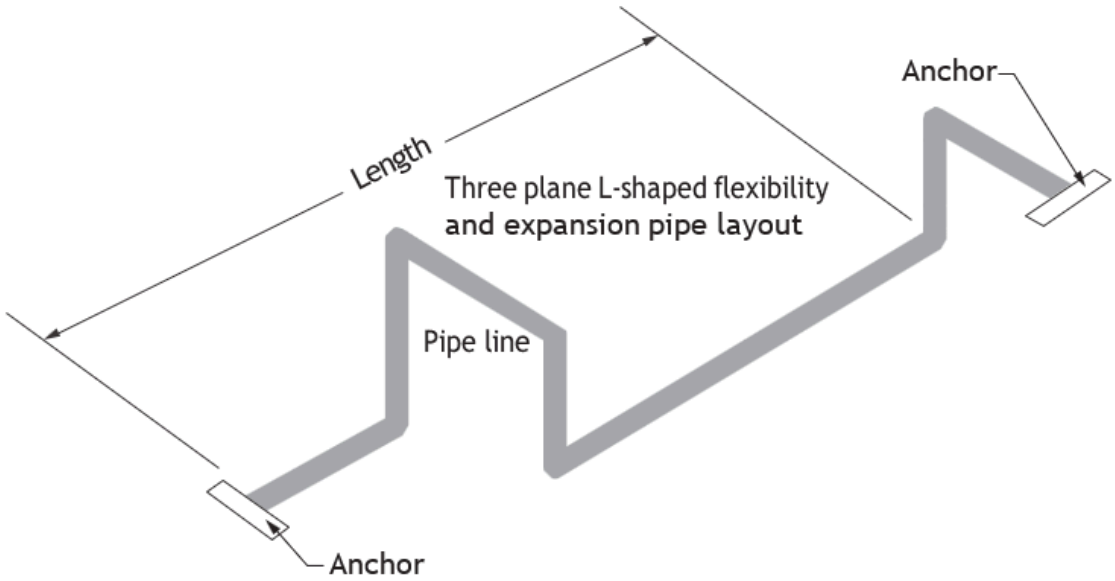


Figure 30 *3-plane L-shaped configuration (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Cold Spring in Piping

Cold spring is the allowance made during installation of the piping to accommodate for the final pipe position after expansion has occurred. Cold spring is applied to piping systems for these basic reasons:

- When required by a design engineer's detailed stress analysis
- To maintain adequate pipe spacing in rack, parallel pipe installations

- To prevent visual misalignment with adjacent piping or structure Figures 28–30 show the theory behind cold spring:

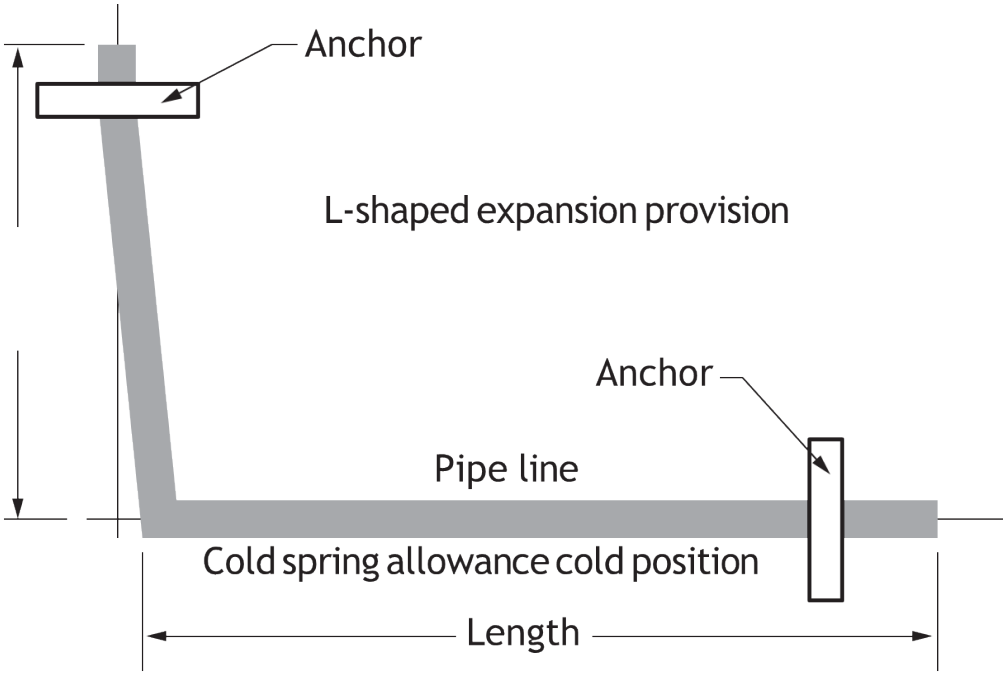


Figure 31 *Pipe configuration before expansion (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

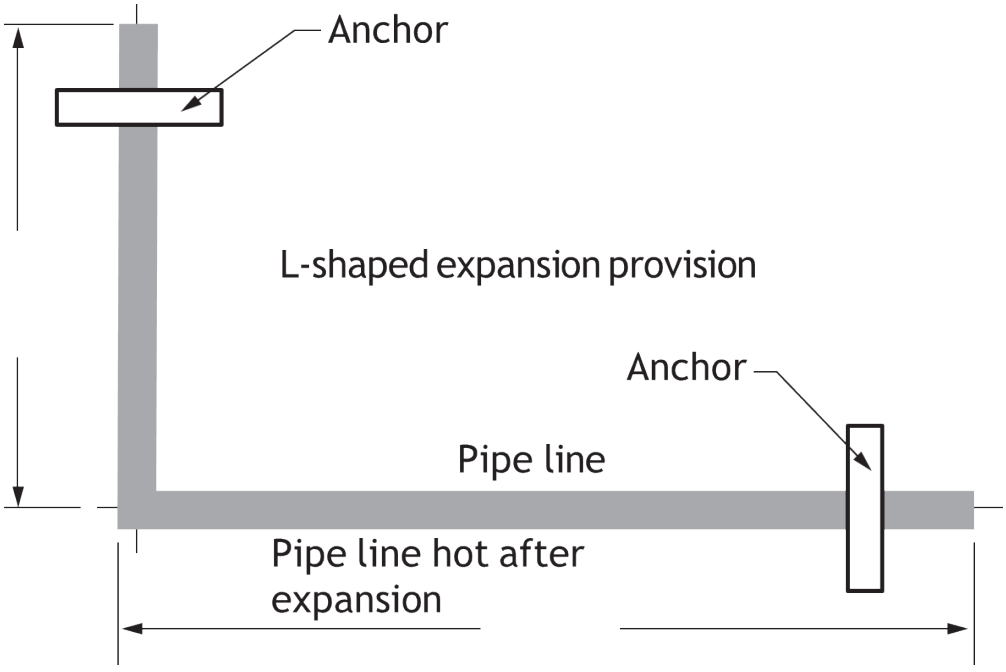


Figure 32 *Pipe configuration after expansion (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

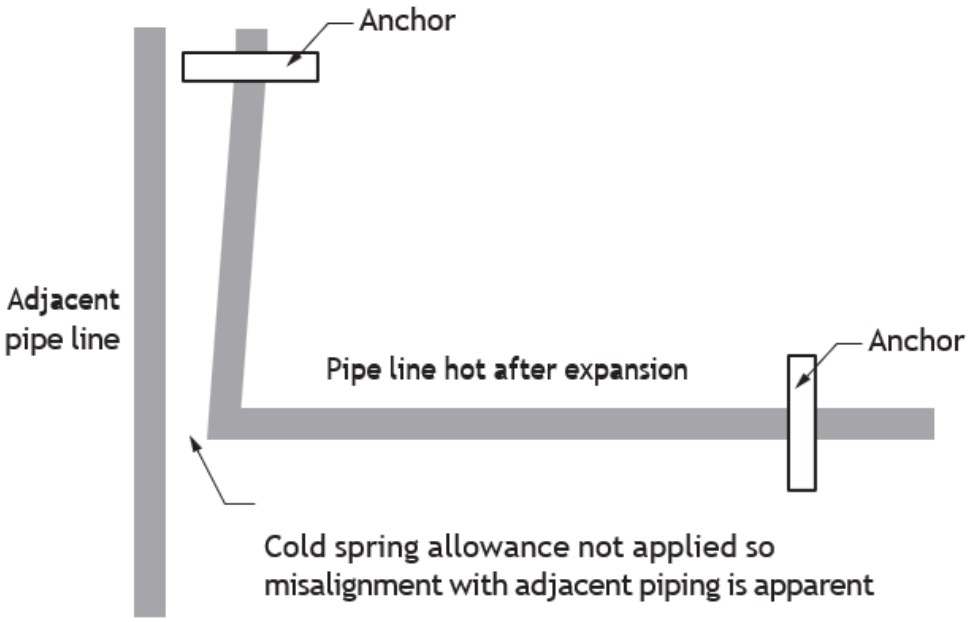


Figure 33 *Pipe configuration after expansion if cold spring allowance is not made (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Piping Fittings that Provide Provisions for Expansion Within Piping Systems

Various types of plumbing and piping fittings that have flexible joints can reduce the stresses of pipe expansion. Fittings designed for joining grooved fittings and pipe use flexible composite rubber seals that, when clamped to the pipe, provide some degree of movement. Typical brand names include Victaulic, Groove Lock, and Press Fit.

Flexible Mechanical and Grooved Type Joints

Flexible mechanical joints can be used in expansion loops without inducing stress in pipes, elbow, or joints. These flexible couplings and fittings have the ability to allow thermal expansion and contraction to be absorbed at elbows and fittings. Pipe configurations can be reduced in size when using these types of fittings (Figure 31).

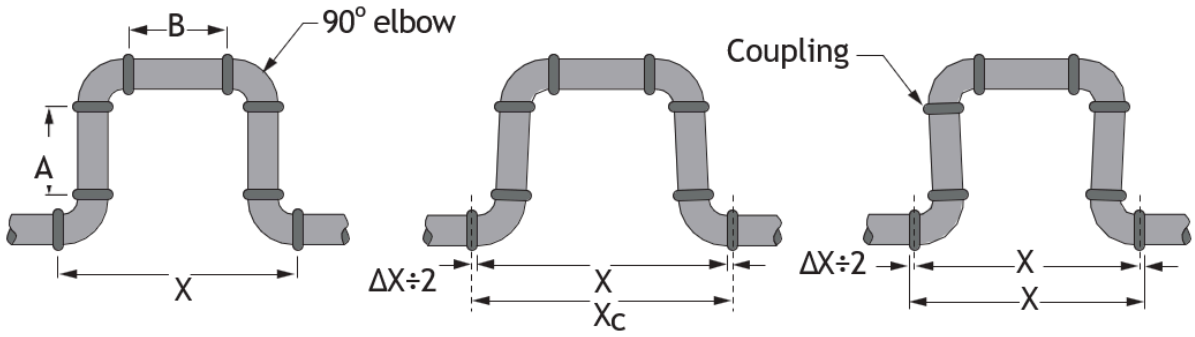


Figure 34 *Pipe configuration using flexible fittings (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 35 *Flexible grooved pipe coupling (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 36 *Limited flexibility grooved pipe coupling (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 37 *Flexible soil pipe coupling (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Swing Joints and Spring Pieces

Swing joints are piping configuration that allow for flexibility, expansion and contraction. The piping configuration for a swing joint includes the use of a minimum of three elbows, as well as a change

in direction and plane. Swing joints are used when connecting equipment such as heat transfer units, gas utility meters, irrigation heads and so on. Swing joints can align piping to the attached equipment and ease the stresses and strains on the equipment connection point.

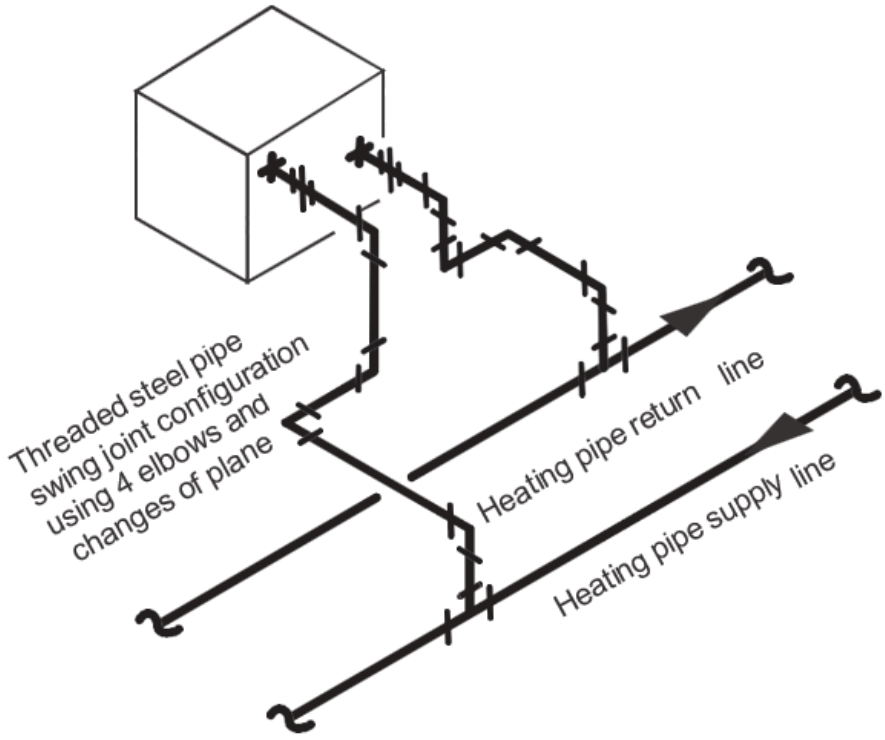


Figure 38 *Swing joint (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Spring Pieces

Spring pieces are section of pipe that, because of their size, length and material, can flex, dispersing any forces and strain along their length. Anchors may be required to reduce stresses on connected equipment. Swing pieces can be applied when fitting joint methods that do not provide flexibility or movement, such as soldered, brazed, or welded fittings.

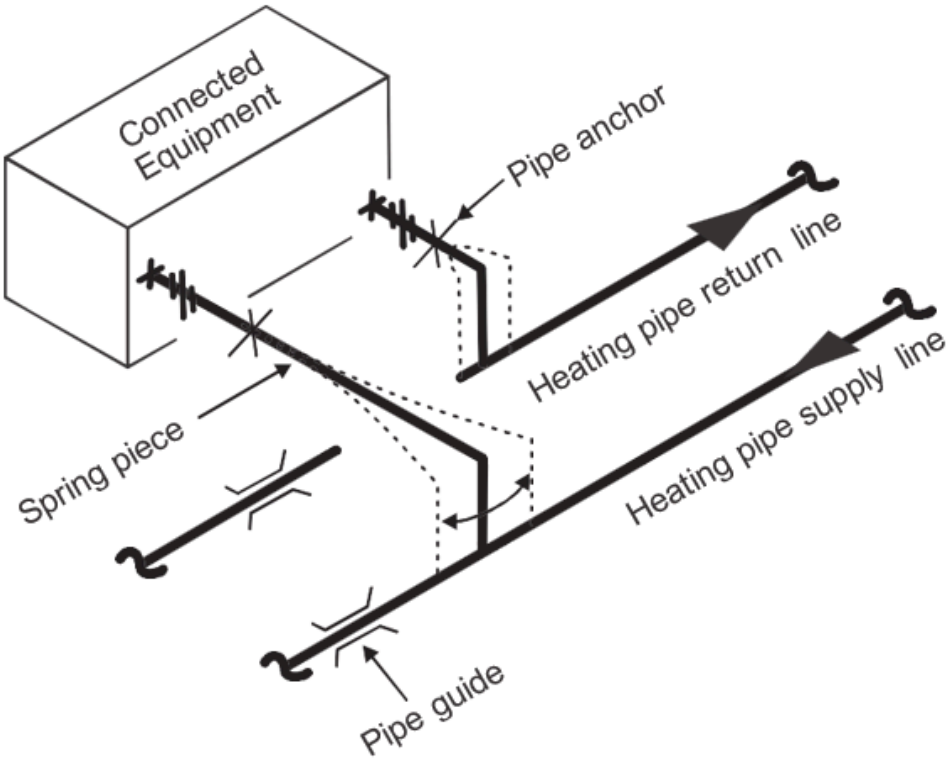


Figure 39 *Spring piece (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

ABS and PVC Plastic Piping Expansion Protection

Expansion within ABS and PVC piping systems is an important issue. Hot and cold wastewater flowing in plastic piping causes the plastic pipe to expand and contract. In residential wood-frame construction, there is often shrinkage of the wood-frame itself. This shrinkage will cause stress on the ABS pipe if it has been rigidly attached to the structure.

Figure 40 *ABS expansion joint (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

ABS DWV and PVC piping has a relatively high rate of expansion when exposed to heat. The linear expansion of ABS is approximately 13 mm ($\frac{1}{2}$„) for each 5°C (10°F) change for each 30 m of pipe (100′). ABS piping is often controlled by the naturally occurring piping offsets and changes of directions in a residential building. ABS expansion joints are typically applied in residential applications when a vertical ABS drainage pipe passes through two floor levels. Vertically installed expansion joints will also provide for naturally occurring shrinkage in wood-frame structures.

Failure to allow for expansion, contraction and shrinkage may result in:

- loss of pipe slope
- pipe bowing
- stress breakage of fittings
- noises caused by plastic piping rubbing against the building structure

Placing ABS drainage piping in walls other than living rooms, dining rooms, studies and video viewing rooms is a good practice.

Guidelines for Installation of ABS Drainage Waste and Vent Piping

Thermal expansion and contraction of plastic drain waste and vent systems must be taken into consideration. Thermal expansion and contraction may be controlled with several methods, including:

- installing expansion joints on vertical ABS drainage pipe
- installing structural penetrations (holes) so they are large enough to provide free movement of the pipe without binding
- providing adequate support without rigidly restraining piping at changes of direction
- designing appropriate changes in piping direction, or offsetting the pipe

PVC Expansion Joint Installation

The travel of expansion joints is typically up to approximately 75 mm (3″). Set the expansion joint approximately mid-point of its full travel. Make sure that the expansion joint is anchored at one end and that the upper piping is guided

to maintain straight alignment with the expansion joint. Failure to guide the pipe straight into the expansion joint can result in leakage of the joint. PVC expansion joints are typically placed close to the base of vertical stacks of drainage systems in residential applications. The seal is maintained by lubricated internal O-rings.

Figure 41 *Installed PVC expansion joint (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Dielectric and Cathodic Corrosion Protection

Electrochemical corrosion occurs when two dissimilar metals are in contact with each other in a moist environment. Although this can happen anywhere, it's especially problematic for buried pipe. One metal becomes a ***cathode***, and the other (usually the pipe) becomes an ***anode*** that corrodes and develops a leak. ***Cathodic protection*** reduces corrosion by forcing the pipe to act as the cathode. It is your responsibility to ensure that ***dielectric (cathodic) protection*** of pipe is used.

Cathodic Protection Applications

Cathodic protection systems are used to protect a wide range of metallic structures in various environments, including:

- Steel water or fuel pipelines
- Storage tanks such as home water heaters
- Steel pier piles, ship and boat hulls

- Offshore oil platforms
- Onshore oil well casings
- Metal reinforcement bars in concrete buildings and structures

Corrosion is the deterioration of metal pipe. Corrosion can be caused by an electrical reaction between the metallic pipe and its surroundings. As a result, the pipe deteriorates and may eventually leak. Although corrosion cannot be eliminated, it can be substantially reduced with cathodic protection.

All metals have a unique voltage stored within them. When two different metals such as copper and steel are connected together, the voltage difference between them will cause a DC electric current (electrons) to flow from the higher voltage to the lower.

Buried Piping Corrosion

Dissimilar soils create an environment that enhances corrosion in buried pipelines. The chemical makeup of the soil and the moisture present allow the soil to become a path for electrons to travel from the negatively charged area of a pipe (anode) to a positively charged area of the pipe (cathode). The movement of electrons away from the anode causes the pipe to corrode.

Definition of Terms

corrosion: The gradual destruction of material, usually metals, by chemical reaction with its environment. Typically, it refers to the electrochemical reaction with an oxidant such as oxygen.

electrochemical reaction: A reaction either caused or accompanied, by the passage of an electric current and involving the transfer of electrons between two substances.

electrode: An electrical conductor used to make contact with a part of a circuit. In an electrochemical cell, the electrode is referred to as either an anode or a cathode. Each electrode can be either the anode or the cathode depending on the current direction.

anode: A metal through which current flows. (In an electrochemical reaction, the anode is the metal that corrodes.)

sacrificial anode: A metallic anode intended to be dissolved to protect other metal components.

cathode: A metal from which current flows.

cathodic protection: A method used to control the corrosion of a metal surface by ensuring that the metal is the cathode in an electrochemical process. Normally, this process requires attaching or connecting the metal to a less-noble metal.

dielectric: A substance with a small amount of electrical conductivity.

disbondment: The separation of a protective coating from a pipe's surface. Disbondment is accelerated when cathodic protection systems are operated with excessively polarized negative potentials, especially in systems operating at high temperatures.

rectifier: An electrical device that changes alternating current (AC) into direct current (DC). This current is then impressed on an underground metallic piping system to protect it against corrosion.

stray current: The portion of a current that flows over a path other than the intended path. There are two types of stray current: direct current (DC) and alternating current (AC). Stray currents found in the ground and in water promote corrosion of piping and metal components.

noble: Possessing outstanding qualities.

galvanic series: A list that indicates the relative stability of different metals and alloys in seawater, based on the measurement of corrosion potentials.

It's important to note the rank of metals and alloys from least to most noble because when pairs of these metals are in contact with each other, the least noble one (i.e., the one highest on the list) will act as the anode, the metal that corrodes in an electrochemical reaction. Since magnesium and zinc are at the top of the list, they make very good sacrificial anodes.

In order for corrosion to occur, there must be four elements present:

- Electrolyte
- Anode
- Cathode
- A complete circuit

Corrosion will occur at the anode.

Methods of Cathodic Corrosion Protection

There are two basic methods of cathodic protection:

- Passive galvanic anode system
- Impressed current system

The simplest method of cathodic protection is to connect the protected metal with a sacrificial metal that acts as the anode in the electrochemical cell. The sacrificial metal corrodes instead of the protected metal.

Passive Galvanic Anode System

Anodes are usually installed near the pipe and connected to the pipe with an insulated conductor. They are sacrificed (corroded) instead of the pipe. Anodes are "sized" to meet the electrical current requirements of the soil. Anodes are made of materials such as magnesium (Mg), zinc (Zn), or aluminum (Al).

Galvanized (zinc) coatings used on pipe are durable in most environments and can provide a small localized degree of electrochemical corrosion protection. The zinc acts as the sacrificial anode, but only in the immediate location.

A proper corrosion protection system requires a sacrificial anode separate from the protected metal but connected by cables. This protects the entire system rather than just a localized section of pipe.

Galvanic Passive Anodes

The sacrificial anode consists of a bag containing either magnesium or zinc ingot and other chemicals and is connected by wire to an underground metal piping system. It functions as a battery that induces a direct current on the piping system to retard corrosion.

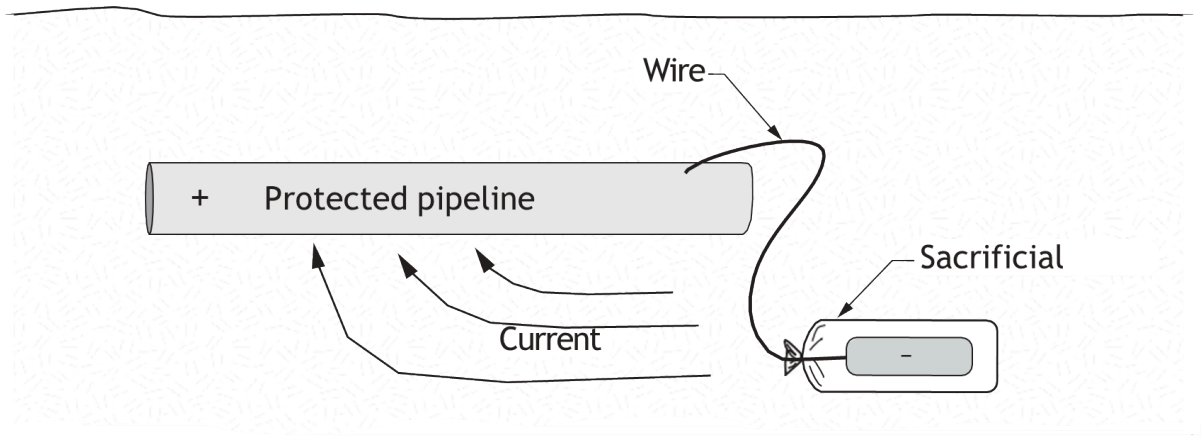


Figure 42 *Sacrificial anode (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Impressed Current Systems

For structures where passive galvanic corrosion protection is inadequate (e.g., long pipelines), an external DC electrical power source is used to provide current. This direct current is induced onto the pipe by means of a rectifier.

These systems are normally used along transmission pipelines where there is less likelihood of interference with other pipelines. Anodes made of corrosion-resistant material such as graphite, high-silicon cast iron, lead-silver alloy, platinum, or scrap steel are used to disperse the electric current. The DC rectifier will typically have a DC output of between 10 and 50 amperes and 50 volts, depending on the system requirements.

Figure 43 *An air-cooled cathode protection rectifier connected to a pipeline (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

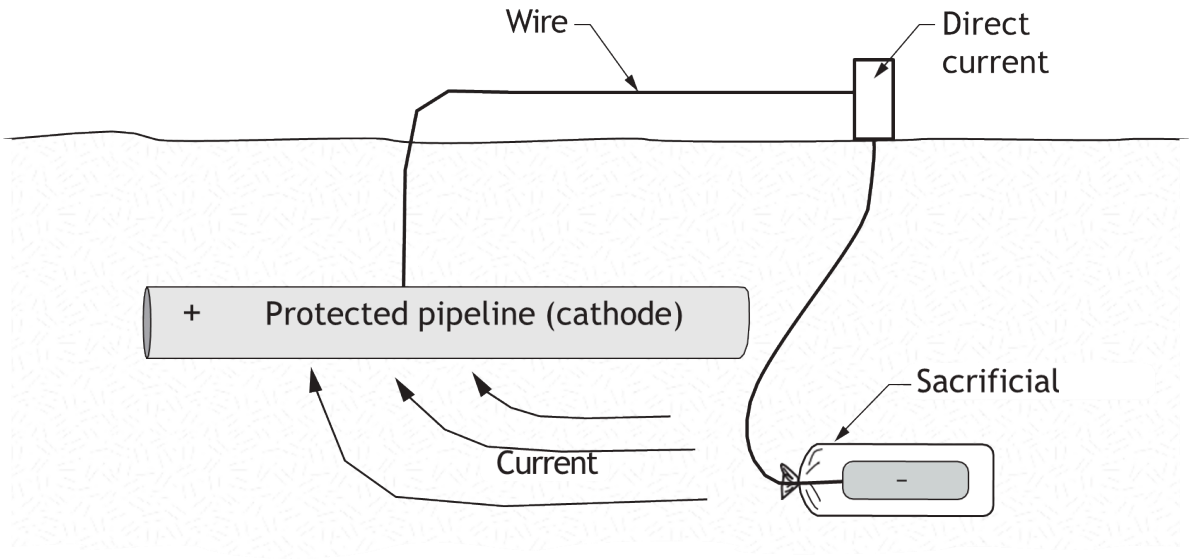


Figure 44 *Impressed current system (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Impressed Corrosion Protection Installation

The rectifier is connected by a cable to the anodes in the system. The other negative cable of the rectifier is connected to the pipeline.

Figure 45 *Thermo weld tool with mold (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Anodes for cathodic protection system are often placed in a vertical hole or trench and then backfilled with conductive materials that improve the performance and life of the anodes. Installation factors also include the location and soil resistivity.

Figure 42 shows the equipment used to attach the anode wire to the pipe using the thermite weld method.

A flint striker gun must be used to ignite the starting powder. This will ignite the copper oxide flakes of the weld powder. The heat from the burning powder fuses the copper wire to the pipe. When the weld has cooled, the mold is removed and any exposed metal is coated with protective mastic.

Rectifier Safety

Rectifier safety is a concern to those who are responsible for rectifier installation, maintenance and repair. Rectifiers should be installed in compliance with appropriate electrical codes and the manufacturer's instructions. Advances in rectifier design include safety features such as touch-safe features, advanced microprocessor technology, electronic fusing, and multiple access doors.

Stopping Galvanic Corrosion with Dielectric Fittings

Dielectric fittings are specialty fittings used to connect two dissimilar metals together. Without them, electrolysis can damage the weaker pipe.

Dielectric fittings are generally installed above ground to provide electrical isolation in piping systems. They can control stray electrical currents and cathodic protection current, and prevent the occurrence of dissimilar metal corrosion. Piping systems with a cathodic protection current should be regulated to follow a specific electrical path. The installation of dielectric unions is a method for electrically isolating cathodically protected piping systems.

Figure 46 *Dielectric union (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

To prevent electrolytic corrosion in dissimilar piping connections, dielectric unions and fittings are used. The dielectric fitting prevents contact between the dissimilar metals interrupting the electric current that would otherwise cause corrosion.

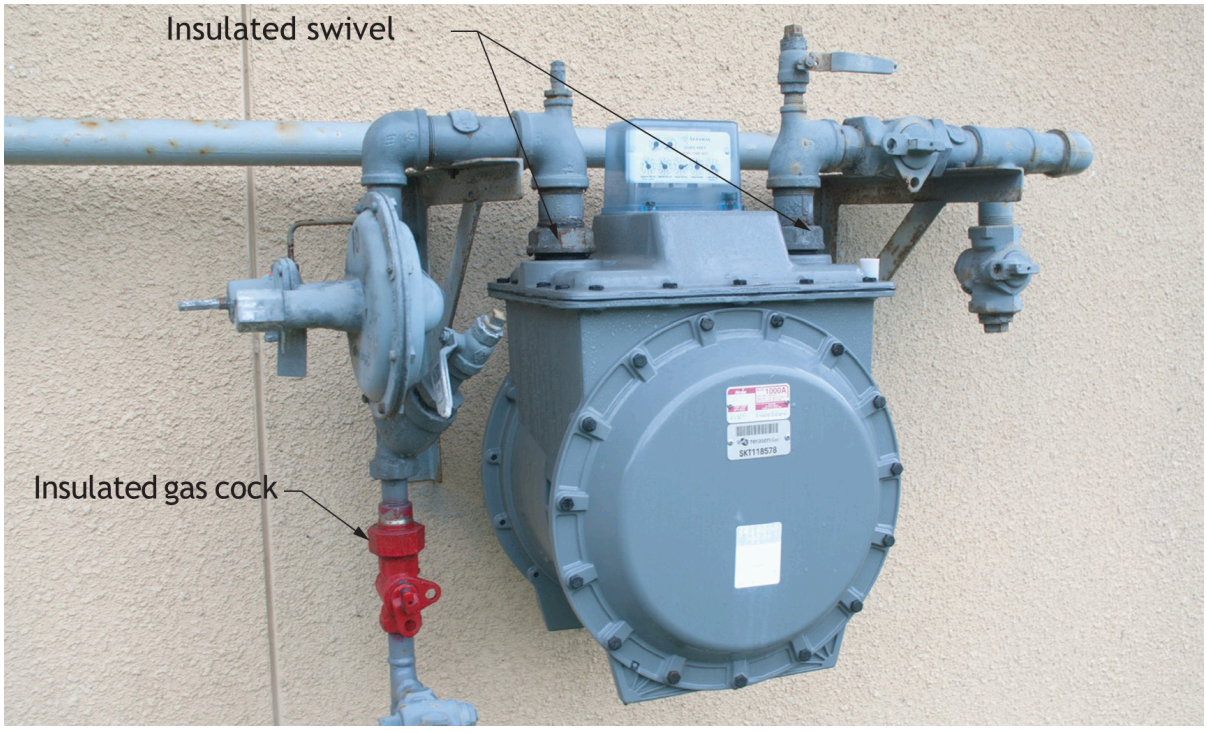


Figure 47 *Gas meter installation showing where dielectric fittings can be installed (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Underground storage tanks and their piping must be electrically isolated from any dissimilar buried metal piping.

Dielectric unions can be made of various metals, such as malleable iron or forged steel, which is either galvanized or black-metal coated.

Dielectric Flange

The ***dielectric flanged pipe fitting*** shown in Figure 45 is installed between pipes of dissimilar metal, in this case copper tube and steel pipe. The flange has an isolative gasket and bolt isolative bushings. It effectively interrupts the electrical current flow that causes corrosion.

Caution: Metal piping in buildings is grounded according to *Electrical Code* requirements.

When a dielectric fitting is installed, it interrupts the grounding safety provided by the grounding connection. This creates a dangerous situation in the remaining piping system downstream of the dielectric fitting.

Additional piping system grounding (bonding) is required, in accordance with the *Electrical Code*.

Figure 48 *Dielectric flange fitting (Image courtesy of Watts). Used with permission.*

Marine and Ship Cathodic Protection

In the marine and ship industry, cathodic protection is applied to shipboard piping systems and also the ship hull itself. Galvanic anodes are attached to ship hulls rather than impressed cathodic protection. Anodes are removed and replaced as regular ship maintenance. Smaller craft boats with non-metallic hulls also use galvanic anodes. However, an electrical conductor connection between the anode and the protected equipment is required.

Water Heater and Water Connections

Figure 49 *Gas water heater tank (https://commons.wikimedia.org/wiki/File:Rheem_home_gas_water_heater_tank_-_newly_installed.jpg) (Tim Evanson/Wikimedia Commons) CC BY-SA 2.0 (https://creativecommons.org/licenses/by-sa/2.0/deed.en)*

Hot water storage heaters come equipped with internal sacrificial anodes, which should be inspected at regular intervals, as recommended by the manufacturer—typically once a year. Hot water storage heaters can also come with plastic-lined connection pipe nipples. These pipe nipples serve as a dielectric connection to the tank. If the hot water storage heater is equipped with a sacrificial anode and dielectric nipples that provide cathodic protection, then dielectric unions aren't needed.

Precaution must be taken to not melt the plastic in the pipe nipple when making a soldered connection to copper piping.

Figure 50 *Dielectric pipe nipple with plastic lining (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Stray Electrical Currents and Pipe Corrosion

The third prong on a standard electric plug is the grounding pin. This grounding pin is a safety component that protects the user from shock in the event of a fault in the tool or equipment. The grounding circuit will dissipate any electrical voltage to an earth-to-ground-rod located in the building's electrical system. This voltage is dissipated into the ground. The electrical system circuitry itself includes a neutral conductor that is connected at the service panel to the earth-to-ground-rod system. Typically, there is always some small current flow in the earth-to-ground-rod

connection. These stray currents can cause in-ground metal piping systems to suffer from accelerated rates of electrolytic corrosion. Any assessment of passive or impressed protection must consider this increased corrosion.

Stray electrical currents and voltages are expected in existing piping systems when the metal piping system is grounded (Figure 51).

Figure 51 *Stray current accelerating corrosion of a copper pipe*

Protective coatings on the buried pipe help reduce corrosion of in-ground piping. Pipe tape insulation, either on the hanger or around the pipe, can eliminate current flow and prevent corrosion.

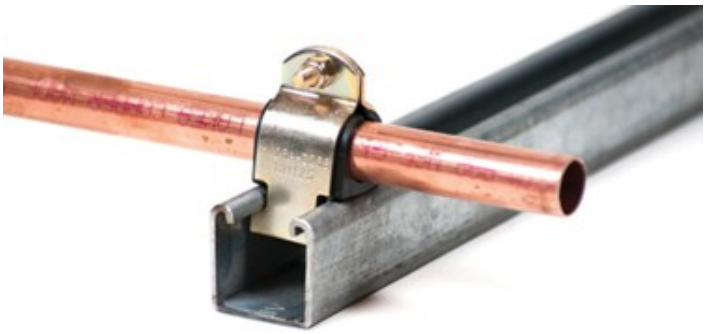


Figure 52 *Pipe support with isolative capability*

Safety Issue with Stray Electrical Currents

Stray current is any voltage or current other than what you are expecting. For example, you would not expect a shock from a pipeline from which you have just removed a valve.

Electrical shocks have been documented when service personnel have removed valves, water meters, and other components. To reduce the possibility of shock from these piping systems, install a jumper cable from the pipe to a

proper earth ground. This is especially important if the piping system is serving as a pathway for stray current back to the building ground rod.

When a grounding system has been removed or improperly installed, the possibility for shock injury is increased. An individual touching an ungrounded metal piping system will become the conductor for any stray currents. The potential for shock is high. The intensity of the shock depends on a number of conditions including the stray current voltage, amperage, conductibility of the individual, and moisture. Always install a temporary jumper ground.

Field Test for Stray Voltage

There are standard test procedures for detecting stray currents and voltages. These tests should be carried out by a qualified electrician and are not part of this competency.

A quick check for you own safety should be completed with a multimeter with milliamp capability. A common ***electrical tester pen*** will also work.

In a properly grounded system, you should not see electrical currents higher than a few milliamps, and the voltage should be less than 10. If you have any doubt, or suspect stray current, contact a qualified electrician.

Water Treatment Pipe Protection

Pipe systems used in hot water heating or steam heating are often treated to avoid pipe corrosion and for greater efficiency.

Pure water (H_20) is tasteless, odourless, and colourless in its pure state. However, pure water is very uncommon—natural waters contain various impurities. If not treated, these impurities can form deposits on heat transfer surfaces in boilers and heating piping.

Untreated boiler water may cause the following:

- Metal corrosion
- Reduced heat transfer rates, leading to overheating and loss of mechanical strength

Typical Impurities Found in Water

pH: This is a measurement of the acidity or alkalinity of a substance. You may need to adjust the pH level of water in a hydronic heating system by adding an acid to stabilize a condition that is too alkaline or by adding a base (alkali) if the solution is too acidic. Hot water boiler manufacturers normally suggest a solution that is very mildly alkaline (pH of approximately 7.8) rather than neutral (pH of 7) to prevent corrosion caused by acidic water.

Dissolved solids: These are substances that will dissolve in water. The principal ones are the carbonates and sulphates of calcium and magnesium, which are scale-forming when heated. There are other dissolved solids, which are non-scale forming. In practice, any salts forming scale within the boiler should be chemically altered so that they produce suspended solids, or sludge, rather than scale.

Suspended solids: These are substances that exist in water as suspended particles. They are usually mineral or organic in origin. These substances are not generally a problem as they can be filtered out.

Dissolved gases: Oxygen and carbon dioxide can be readily dissolved by water. These gases are aggressive instigators of corrosion.

Scum-forming substances: The use of water softeners, iron filters, UV-sterilization and other water treatment devices may be necessary in order to correct any conditions that are undesirable for the water's intended use. Mineral impurities that foam or scum: usually soda in the form of a carbonate, chloride or sulphate.

Corrosion in Fire Sprinkler Systems

Wet and dry fire sprinkler systems are primarily composed of metal pipe, water, and trapped or compressed air. Any environment that has oxygen, metal, and untreated water in prolonged contact with each other is subject to corrosion (i.e., rust). Bacteria and other corrosion mechanisms can accelerate existing corrosion in fire sprinkler systems.

Microbiologically Influenced Corrosion

Microbiologically influenced corrosion (MIC) is an ***electrochemical process*** involving bacteria that can accelerate previously occurring corrosion in both wet and dry fire sprinkler systems. MIC always involves bacteria but does not occur by itself. In recent years, thin-wall piping has been introduced, so the effects of corrosion appear more quickly.

Oxygen corrosion is also common in fire sprinkler systems. Evidence of high corrosion exists especially at the air/water interface at high points in the fire sprinkler system where air accumulates.

The prevention of sprinkler pipe corrosion is becoming a major issue in this trade.

Corrosion Indications in a Fire Sprinkler System

Pinhole leaks can be caused by a variety of corrosion mechanisms but are most often attributed to microbiologically influenced corrosion.

To prevent corrosion in fire sprinkler systems:

- Complete an assessment of the system to determine if a corrosion situation exists
- Treat the system with water treatment chemicals
- Install air vents to remove oxygen

Chemical Treatment

Portable chemical injection systems can be used for injecting corrosion inhibitors into fire sprinkler systems to prevent corrosion caused by MIC.

Figure 53 *Portable injection pump for a fire sprinkler system (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Removing Air (Oxygen)

Air removal means are used to reduce corrosion in a fire sprinkler system.

Figure 54 *Air vent for pressurized fire sprinkler system (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

An ***air vent*** will reduce the amount of air trapped in a pressurized fire sprinkler system. Reducing the amount of air reduces the effects of oxygen corrosion. Air vents should be installed at the collection point for air in the high points in the sprinkler system.

Internal Protection Using Chemical Treatment

Chemicals used in fire sprinkler systems should be environmentally safe. One example of a chemical that is designed specifically for fire protection systems is Potter's Pipe-Shield®, a patented, biostatic, environmentally friendly corrosion inhibitor. This pipe shield protects wet, dry, and pre-action fire sprinkler systems from both microbiologically influenced corrosion and oxygen corrosion, and is completely nonhazardous and biodegradable, with a neutral ***pH***. It does not contain biocides and pesticides commonly used to control or kill bacteria, so it is safe for the environment.

Protection of Buried Pipe Against Flotation Damage

Pipe buoyancy must be considered whenever there is a risk of ***flotation***. When the ***water table*** is above the bottom (invert) of the pipe, the surrounding water creates an upward (buoyant) force. This force is equal to the weight of the water displaced by the pipe. If the upward force is greater than the combined weight of the pipe and its contents, the pipe will float.

Conditions that can lead to a pipe floating out of a trench include the following:

- Pipelines installed in ground with a high water table or where flooding is a possibility
- Pipelines installed under lakes, oceans, etc.
- Flooding of trench before and after backfilling

To avoid flotation buoyancy of pipe, proper installation and/or anchoring of the pipe are critical. The uplift buoyancy of a buried pipeline depends upon the:

- Weight of the pipe material
- Weight of the volume of water displaced by the pipe
- Weight of the liquid load carried by the pipe
- Weight of the backfill material
- Specific gravity of the pipe material and the volume of water displaced

When considering the buoyancy of sanitary and storm lines, you must first determine buoyant force when the pipe is empty, which is when the buoyant force would be the greatest.

To prevent flotation, proper installation and/or anchoring is required. Methods may include:

- Adequate backfill
- Concrete weights or collars
- Ground screw anchors

Flotation Buoyancy Protection Methods

The weight of backfill material is usually sufficient to prevent uplift of piping and hold the pipe in the ground. When backfill alone is not heavy enough, additional methods such as concrete weights or ground screw anchors can be used. Weights such as concrete collars of sufficient size and weight can be positioned on the pipe to prevent flotation. The pipe can also be strapped to concrete pads placed in the trench.

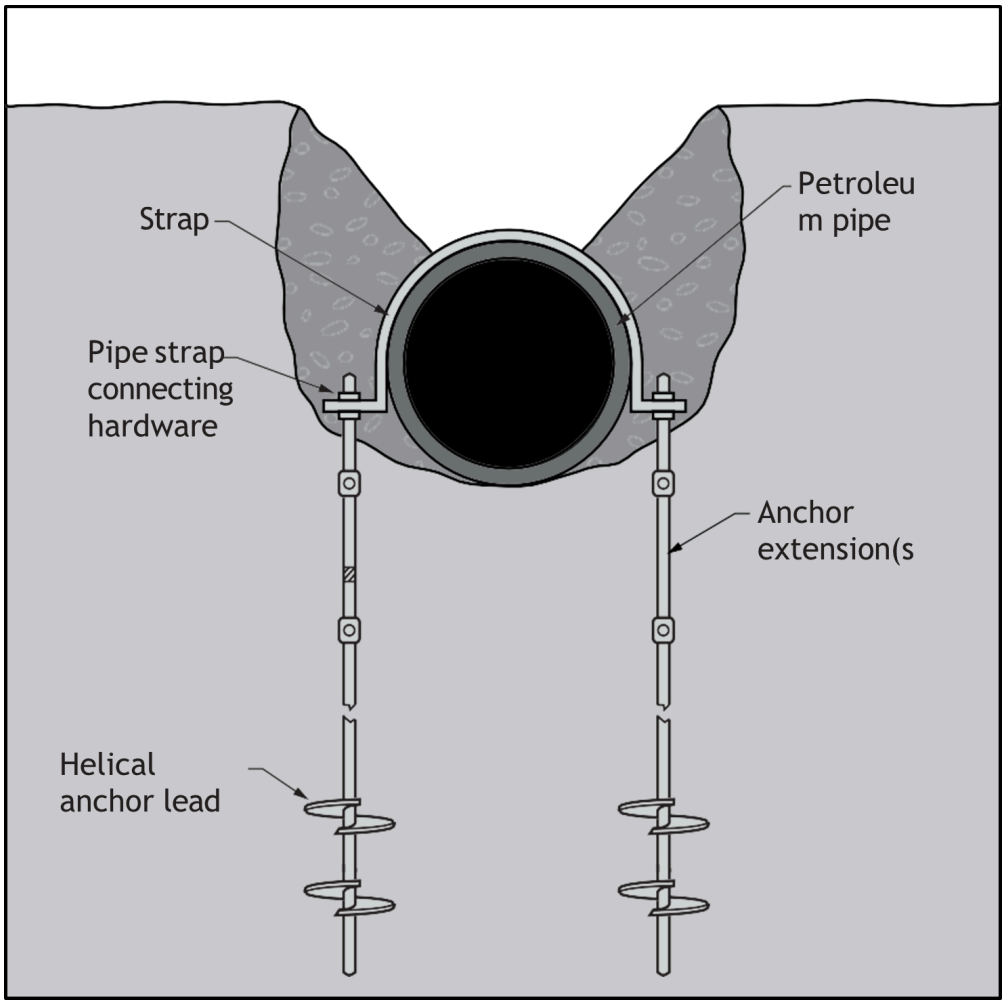


Figure 55 *Buoyancy-restraint screw anchor system on an oil pipeline (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Flotation Protection During Trench Installation

Piping installed in a trench often has to be inspected before backfilling. Proper bedding is required, and the pipe is tested under pressure for leaks. The tests may include pressurizing with air, inert gas and/or water. The pipe cannot be completely backfilled and must be left visible for inspection for a period of time. During this time, the exposed trench might be inundated with groundwater or rainfall runoff. Buoyant upward forces on the pipe may be sufficient to lift the pipe out of the bedding materials. When pipe grades are disturbed, the pipe must be repositioned, which can be costly. Pipe flotation restraint may be accomplished simply with adequate backfill. In cases where adequate cover cannot be achieved, alternate methods for restraining the pipe are available.

To reduce the chances of pipe flotation, it may be acceptable to partially backfill portions of the piping with enough weight to resist flotation before inspections are completed. You should consult with the authority having jurisdiction before backfilling prior to inspection.

Buoyancy of Other Underground Equipment

Buoyancy also applies to storage tanks installed below ground; for example, septic tanks before they are filled with water and underground gasoline and oil storage tanks. Septic tanks should be filled at the time of installation if flotation is a concern. Underground storage tanks are normally braced against flotation buoyancy using in-ground anchor systems such as strapping the tank to a concrete pad.

Figure 56 *A properly restrained tank strapped to a concrete slab (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pipe Expansion from Sunlight

The exposed top of bedded piping can expand when heated by direct sunlight. The expansion may cause the pipe to warp and arch up and lift out of the bedding material. Bedding material such as sand can then fall under the arched portion of the pipe. When the pipe cools, it cannot settle back into its original position, and repositioning is required. To prevent this situation from occurring, lightly cover the pipe with just enough backfill to prevent sunlight exposure. The light cover can be brushed back to expose the pipe markings for the inspection authority and to check that plastic pipe, such as ABS (black surface) and PVC, have high coefficients of expansion and are susceptible to expansion and degradation caused by sunlight exposure. Pipe installed above ground and exposed to direct sunlight may need to be protected by insulation, protective pipe wraps, or shielding.

Refer to *D-4 Penetrate Structures* (#part-d-4-penetrate-structures) for information on pipe wrap and shielding.

Pipe Storage, Shipping, and Handling

Pipes can be distorted and damaged by improper storage, including:

- Improper handling and stacking
- Exposure to sunlight

- Excessive heat or cold

Pipes and fittings stored outdoors for an extended period should be protected according to the manufacturer's instructions.

General Pipe Storage Conditions

The following give guidelines for pipe storage conditions:

- Exposure to excessive heat should be avoided to reduce the risk of pipe distortion.
- If plastic pipes or fittings are to be stored outdoors for extended periods of time, they should be protected as directed by the manufacturer. Plastic pipes may be affected by exposure to sunlight, especially if exposed for extended time periods and outside of protective cover. Bowing of the pipe can also occur.
- Correct stacking of some pipe can result in bowing and distortion (out of round). It can be difficult to attain correct even and continuous grade during installation if the drainage pipe is bowed. You may be able to correct a bow by exposing the opposite side of the pipe to sunlight before installation. However, it is best not to purchase bowed pipe.
- When purchasing pipe, check for damage such as deep scratches, cracked ends, out of round, etc.
- When stacking pipe at the job site, set the pipe on evenly spaced, level runners to prevent sagging. Place wedges or blocking to stop the pipe from rolling off the runners.
- Pipe delivered on pallets is often banded. Be sure that cutting the band does not cause the pipe stack to collapse uncontrolled. If the pipe is not on a supporting cradle, block the stack before cutting the banding.
- When stacking pipe that has hub ends, alternate the hub and spigot ends with the ends protruding so that the pipe barrels will lie flat.
- When unloading alongside a trench, stack the pipe on the opposite side of the trench from the excavated soil pile. Installing large and heavy pipe will be easier from the clean side of the trench.

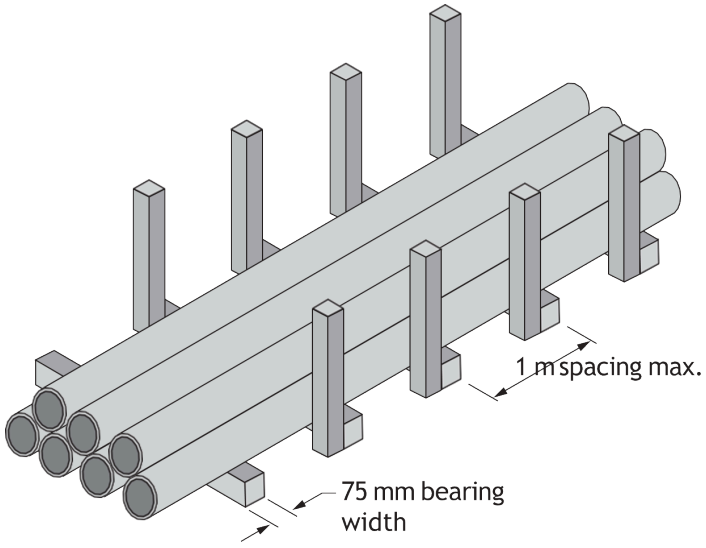


Figure 57 *Storing pipe at job site (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Trench Depths and Pipe Protection

Buried pipes must be able to withstand the forces trying to damage or crush the pipe. Pipe leaks can be serious, especially when combustible liquids and gases, sewage and water supplies are involved. Pipe protection and proper burial are important to prevent pipe damage during installation and regular use.

Factors affecting the depth of a trench and the protection of the installed pipe include the following:

- Type of pipe and schedule (wall thickness strength)
- Job site terrain
- Job specifications
- Code regulations
- Required slope
- Vehicle traffic
- Weight of the fill material
- Proper compaction of the soil below and surrounding the pipe

General Trenching Guidelines

You must consult job specifications and code regulations within the area jurisdiction.

For details on trench depth for plastic pipe, refer to code books and manufacturers' documentation.

Trenching Pipe Protection

Normally, you need to follow the job site excavation engineering specifications, plans and the local code requirement. The following information is non-specific but will give you an idea of the typical requirements for trench construction to protect buried piping.

Typically, a trench would be constructed as follows:

- As narrow as practicable at the pipe depth
- Wide enough to provide space to work on the pipe and proper jointing
- Where soil conditions are unstable, trenches may need to be wider to the depth where the trench is unstable and narrow at the pipe depth where the soil is undisturbed and stable. Trench walls may need to be shored.

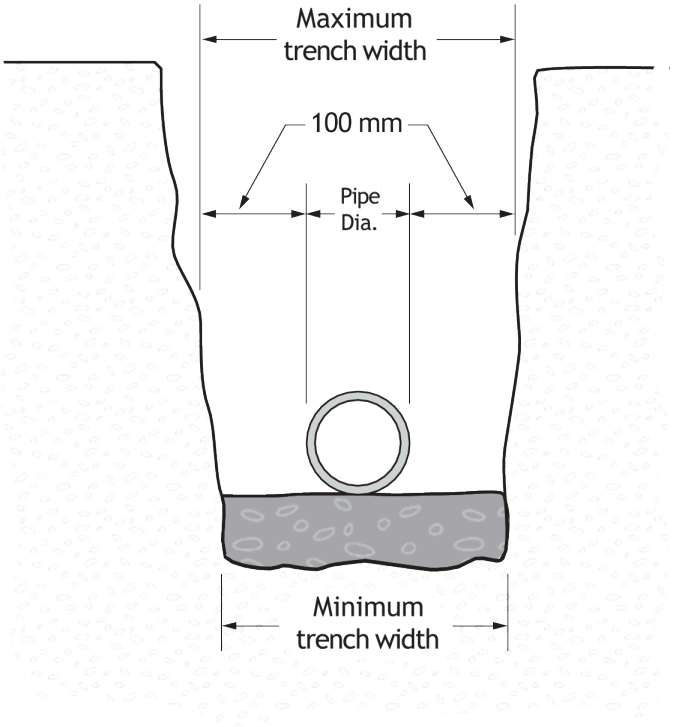


Figure 58 *Trench dimensions in stable soil (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

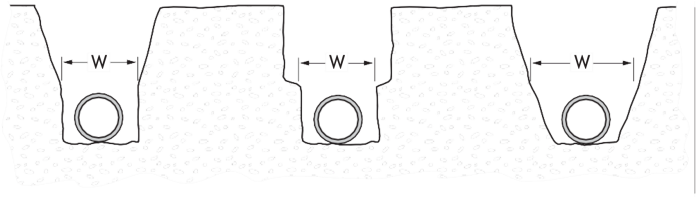


Figure 59 *Trench dimensions in unstable soil (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Table 1 lists examples of trench measurements under stable conditions.

Table 1: Pipe Diameter and Trench Width in Stable Soil

Pipe Diameter	Normal Trench Width
100 mm (4 in.)	400 mm (16 in.)
150–200 mm (6–8 in.)	600 mm (24 in.)
225–300 mm (9–12 in.)	750 mm (30 in.)
375 mm (15 in.)	900 mm (36 in.)

Backfill Material and Compaction of the Soil

Pipe bedding and backfilling material should not:

- Be placed in a ditch where standing water is present
- Include large stones, boulders, cinders, frozen earth or building site debris.

The pipe should:

- Not rest on solid rock without suitable bedding protection
- Be laid on compacted level bedding that supports the full length of the pipe barrel (sand, gravel, crushed rock or good natural sandy soil; no large boulders, etc.)
- Be covered in sand, gravel, crushed rock or good natural soil (no large boulders, etc.) compacted to a minimum of 300 mm (12 in.) above the pipe
- Be covered with natural excavated soil consistent with the surrounding soil for the remaining backfill material

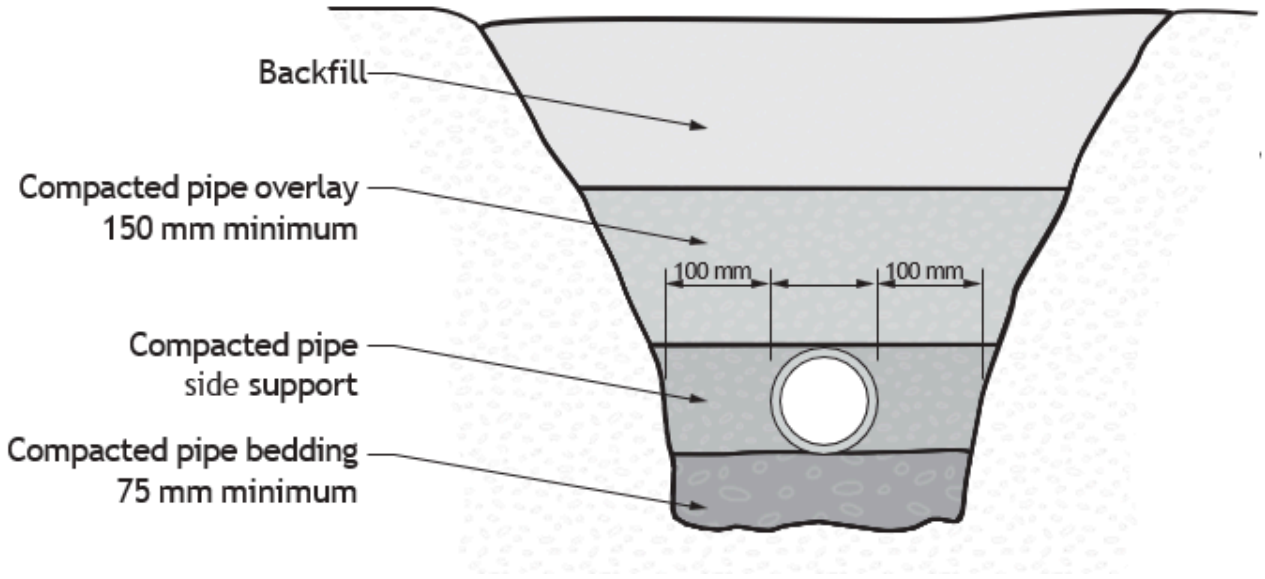


Figure 60 *Example of a manufacturer's trenching requirements for PVC (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Protecting Pipe During Backfilling

- Bedding may not be required in all cases. Soil conditions at the trench bottom may be adequate to support the pipe continuously without additional bedding.
- When bedding is required, the bedding must be compacted before the pipe is laid.
- Pipe overlay backfill is best hand-shovelled around the pipe and continually tamped snugly to the pipe.
- Before covering the pipe, it is tested and inspected as soon as possible.
- Shortly after inspection and approval, overlay backfill is carefully added by shovel or machine. Care must be taken that no heavy rocks are dropped on the pipe.
- Overlay backfill and compacting continues to a depth of approximately 150 to 300 mm (6–12 in.) over the pipe.

Plumbing codes may require a minimum of 300 mm (12 in.) coverage above the pipe.

Compacting provides continuous support for the pipe. Final backfill is complete and compacted. Limited amounts of water can aid compaction.

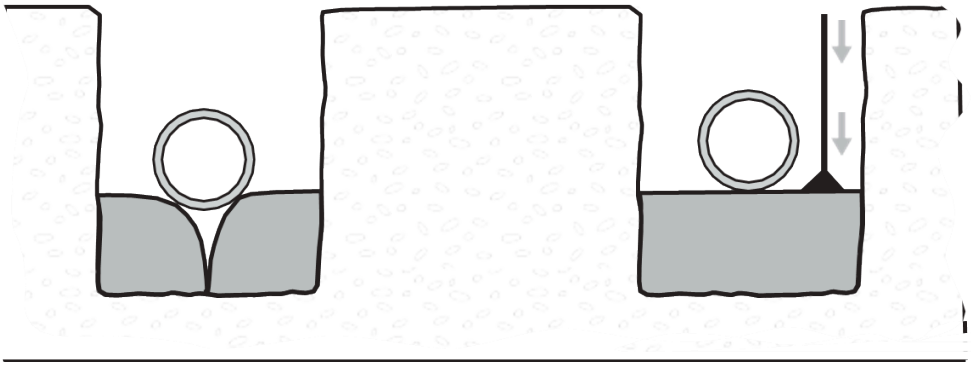


Figure 61 *Correct tamping of bedding (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

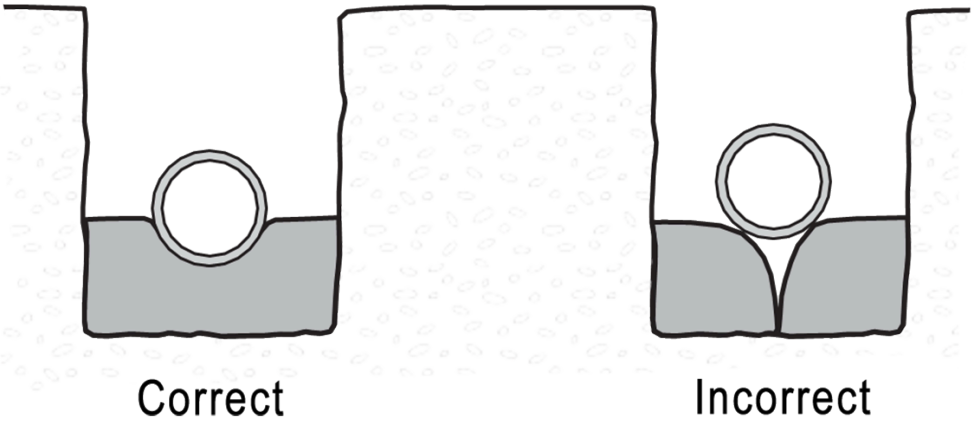


Figure 62 *Left: Correctly placed bedding. Right:* ***Incorrect:*** *Bedding not pushed entirely under the pipe. (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Damage from Vehicles

Damage to piping due to contact with vehicular traffic occurs in locations where services enter a building, such as above-ground gas services. Damage to piping occurs in parking garages or warehouse facilities frequented by vehicular traffic. Protection methods include barriers such as bollards or curbs. These barriers must be constructed to take the force of contact away from the pipe.

The location and design of barriers to protect pipe from vehicular traffic is often done by the design engineers and, in many cases, is addressed in building code regulations.

Figure 63 *Pipe bollards filled with concrete and placed to prevent vehicle damage to the gas service entry and meter located in a driveway. (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Self-Test D-1.4: Describe the Methods of Manufacture of Piping and Tubing

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

If you are using a printed copy, please find Self-Test D-1.4 (#chapter-self-test-d-1-4-describe-the-methods-of-protecting-piping) and Answer Key (#chapter-answer-key-self-test-d-1-4) in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

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References

BC Industry Training Authority. (2019). *Piping trades apprenticeship program: Use Tools and Equipment—Level 1 harmonized* [Binder]. Crown Publications, Queen's Printer for British Columbia. https://www.crownpub.bc.ca/Product/Details/7960000261_S

- Plumber: Competency D-1 Prepare Pipe
- Steamfitter: Competency D-4 Layout and Install Piping and Tubing
- Sprinkler Fitter: Competency D-1 Prepare Pipe and Tubing

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- **Figure 3** Geotextile-GSI (https://commons.wikimedia.org/wiki/File:Geotextile-GSI.JPG) by Marilyn475 from Wikimedia Commons is used under in the publi (https://en.wikipedia.org/wiki/en:public_domain)c (https://en.wikipedia.org/wiki/en:public_domain) domain (https://en.wikipedia.org/wiki/en:public_domain).
- **Figure 4** Steel casing pipe (https://pxhere.com/en/photo/1607653#google_vignette) by annawaldl on Pixabay is used under the Pixabay Content License. (https://pixabay.com/service/license-summary/)
- **Figure 12** Example of heat trace thermostatic control is ©2014 *Environmental Technology Inc. Used with permission*
- **Figures 15-17** are examples from the CSA Handbook and are used with permission.
- **Figure 48** Dielectric flange fitting is courtesy of Watts and is used with permission.
- **Figure 49** Gas water heater tank (https://commons.wikimedia.org/wiki/File:Rheem_home_gas_water_heater_tank_-_newly_installed.jpg) by Tim Evanson from Wikimedia Commons and is used under a CC BY-SA 2.0 (https://creativecommons.org/licenses/by-sa/2.0/deed.en) license.

D-1.5 Describe the Inspection of Pipes and Tube Before Installation

Before installing a piping system, you need to be aware that new piping materials can have ***defects***. Defects can occur during manufacturing, and most manufacturers have strict procedures for inspecting and testing the pipe before it leaves the factory. Freight damage can occur during shipping and transit to the wholesale distributor. Cast iron pipe can crack or break when handled roughly. Plastic piping can be damaged if not stored properly or if exposed to direct sunlight for extended periods. Soft metal tubing can be bent or pushed out of round, making installation difficult. Rough handling of pipe at the job site can also result in damage. Open ends of pipe can collect debris during shipping and before or during installation. You need to inspect for and identify these types of damage before you install pipe and tubing.

Inspect Pipe for Defects

Despite quality assurances, piping can arrive at the job site with damage. It is important that you take the time to inspect each pipe or fitting carefully before you install it. Discovering a defect after the pipe has been installed and is under test is costly and time-consuming or, at best, irritating. Time is wasted by removing test pressure, draining the system, repairing the defect, reassembling, and finally, retesting.

Once the pipe has been cut and ***reamed***, inspect the pipe ends for signs of deformity or damage. Any splitting, ***out-of-round*** shape, or excessive burring on either the inside or the outside of the pipe should be corrected or replaced before attempting to join the piping. ***Deburring*** is referenced in most pipe assembly instructions and cannot be over-emphasized. Once the pipe end has been formed, it is extremely difficult, if not impossible, to ream it without damaging it beyond further use. Besides causing possible leaks, failure to ream piping and tubing will result in ***cavitation***, ***friction loss***, ***noise,*** and ***erosion***.

Detecting Defects

When a defect is found, you can either reject the product or cut out the defect (damaged section) and use the undamaged section of the pipe. You would expect to pay less for a damaged product. Accepting a damaged pipe means you have chosen to accept defective materials. Before doing this, you must consider pride in your workmanship and the reliability and safety of the product for as long as the system is in use. Equally important is that using defective piping might invalidate manufacturer warranties.

When the pipe has been received, visually inspect each pipe for the following:

- Is the pipe straight? Look along the length of the pipe. Is it is curved or bent? You will need to decide whether you can use the pipe. A bent drainage pipe will present issues when you try to lay the pipe at a specific even and continuous slope.
- Are the pipe ends damaged or out of round? If the end is damaged, it will have to be removed before you can make a good connection.
- Inspect the circumference of coiled copper tubing to see if it has been pinched or flattened.
- Inspect cast iron drainage pipe for cracked ends or pinholes in the casting. Tap the end of the pipe with something

solid or on the ground. Listen closely for a rattling sound, which indicates a crack of some kind.

- Cast iron pipe can also have ridges and depressions caused by uneven casting that won't be evident by "sounding." Ideally you can detect these irregularities by feel before the pipe is installed by running a hand along the outside of the pipe. But most often, these irregularities are discovered through failed pressure testing caused by being out-of-round or otherwise defective and should be removed and replaced upon discovery.
- When receiving steel pipe with bevelled, grooved, or threaded ends, inspect the grooved and threaded end sealing surfaces for scratches, gouges, nicks, or other damage.
- If piping is coated for permanent ***corrosion*** protection and not just for not shipping, check to see if the coatings have been damaged. You may have to repair or cut out the damaged sections. Refer to the manufacturer's specific instructions on repair of damaged products.
- Inspect the pipe ***bore*** for blockages or debris on receiving and immediately before installation. Tilting the pipe toward the vertical will allow any lose debris to fall out of the pipe. Debris in a pipe can cause no end of problems when the system is put into service.
- Plastic piping can be seriously damaged by extended exposure to the ***ultraviolet rays*** in sunlight, especially if the pipe does not have ultraviolet protection.
- Check PVC plastic for cracks, discoloration, gouges, and scratches.
- Check PE and PEX for discoloration, gouges, and scratches.

Determine Environmental Effects

Both environmental conditions and faulty, defective materials can contribute to piping installation problems. Here are some environmental factors to consider before installing piping.

- Will the constituents contained in the soil have a detrimental effect on the pipe? High salt content necessitates the installation of pipe materials with better resistance to corrosion.
- Is the ground boggy? If so, there might be too much settlement for a normal installation, and piping may have to be supported using hangers imbedded in the slab-on-grade or suspended from the edge of the footing. Also, cast iron pipe installed underground in these conditions could crack, so plastic pipe may be a more acceptable choice.
- Is the atmosphere around the piping likely to be corrosive? If so, plastic rather than metal piping may be better.
- If the finished installation will be subjected to a lot of moisture, the pipe and the hardware used to support it may need to have a higher corrosion-resistance rating than normal. Outdoor exposed piping is an example of this.
- Check to see if there is going to be excessively high or low temperatures surrounding the pipe. Wide swings in ambient temperatures can necessitate alternative pipe types.
- If piping is installed in areas where there is a lot of paint and coatings being applied close to the pipe, it may be a good idea to check the pipe's compatibility with the coatings.
- If the installed piping is going to be in direct sunlight, the effects of expansion/contraction and of UV rays will be an issue. ABS pipe installed in direct sunlight will undergo a lot of expansion and warping, which can cause problems with grade in drainage systems. PEX tubing should never be exposed to direct sunlight for extended periods, either before or after installation, and pipe failure could result if not protected.
- Has the plastic pipe been stored in direct sunlight? If so, check with the manufacturer to ensure that the pipe can still be installed without threat of failure or of voiding warranties.

Inspect Pipe for Proper Markings

The various codes that pipe installations must conform to will typically specify pipe or tube according to the standard that it was manufactured to. For instance, the National Plumbing Code of Canada (https://nrc-publications.canada.ca/eng/view/object/?id=c97ac796-01fc-4383-9c68-b271db2802cf) specifies both in the body of the Code (2.2.6.1 (1); 2-8 Division B) and in Table A-2.2.5., 2.2.6. and 2.2.7 "Summary of Pipe and Fitting Applications" (2-80 Division B) that cast iron soil pipe used in a drainage or a venting system must conform to the CSA B70:19 (R2024) – Cast iron soil pipe, fittings, and means of joining (https://www.csagroup.org/store/product/CSA%20B70%3A19/) standard. Because there is enough space on the pipe itself, a reference to that standard is painted or indelibly marked onto the pipe, and inspectors will look for that marking for acceptance. If it's not evident, they may not accept the installation. Cast iron pipe is fairly easily recognizable, so is rarely, if ever, mistaken for anything else.

Where copper tube is concerned, there are at least five different grades available on the market that could be installed, and the pipe/tube marking becomes more of an issue. The various codes may say that the markings have to be visible after installation so that an inspector can readily determine if the grade of copper used is correct for the application. Besides having the relevant standard applied in ink to the pipe or tube, the colour of the ink is also used to differentiate between the grades. Further to that, copper tube is embossed (etched), indicating the grade at specific points along its length, in case the inking isn't identifiable.

Installers may be required to access codes and manufacturers' literature to determine that the proposed pipe type is in fact correct for the application. In some instances, the type of pipe chosen may not be acceptable to the building specifications, even though it conforms to the plumbing code. Remember that building specifications can be and sometimes are more stringent than the codes involved. Always consult local codes, as well as building specifications and manufacturers' literature, before installing any pipe or tube.

Self-Test D-1.5: Describe the Methods of Manufacture of Piping and Tubing

Complete Self-Test 1.5 and check your answers.

If you are using a printed copy, please find Self-Test D-1.5 (#chapter-self-test-d-1-5-describe-the-methods-of-manufacture-of-piping-and-tubing) and Answer Key (#chapter-answer-key-self-test-d-1-5) in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

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References

BC Industry Training Authority. (2019). *Piping trades apprenticeship program: Use Tools and Equipment—Level 1 harmonized* [Binder]. Crown Publications, Queen's Printer for British Columbia. https://www.crownpub.bc.ca/Product/Details/7960000261_S

- Plumber: Competency D-1 Prepare Pipe
- Steamfitter: Competency D-4 Layout and Install Piping and Tubing
- Sprinkler Fitter: Competency D-1 Prepare Pipe and Tubing

CSA Group. (2019). *CSA B70:19 (R2024): Cast iron soil pipe, fittings, and means of joining*. https://www.csagroup.org/store/product/CSA%20B70%3A19/

National Research Council Canada. (2025). *National plumbing code of Canada: 2025*. Government of Canada. https://nrc-publications.canada.ca/eng/view/object/?id=c97ac796-01fc-4383-9c68-b271db2802cf

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D-1.6 Install Tubing and Pipe

As a qualified pipe trade worker, you will be expected to install various types of piping systems, including different types of piping and tubing. The methods used to assemble and install piping systems depend largely on the manufacturer's installation instructions and the design engineer's specifications. Codes such as those for plumbing, gas, fire sprinkler systems, etc., also contain selection, installation, and ***jointing*** (commonly referred to as *joining*) requirements for piping and tubing. The study of detailed code requirements is not part of this section.

In this section, the focus is on jointing methods for the installation of various types of pipe. Detailed installation requirements for the piping system as a whole are covered in other sections and training levels.

Piping Installation Layout

No matter what type of piping system is being planned, it will be installed within some form of a structure. Laying out the piping route involves reading drawings and relating the information to actual site conditions.

The procedures to follow when laying out a carbon steel piping system are similar to those used when planning a drainage and venting system for plumbing fixtures. Critical information that is key to any installation will be found in the "Book of Specifications" for the project (assuming the project is large enough to warrant this literature). In it you will find information on the appliances and equipment that you will be connecting to, as well as the types of hangers and supports to use along with all other aspects of the materials mandated for the job. Once those key pieces of information are collected and considered, the next step will be the actual layout of the piping routes.

There is a logical order to the events required in order to lay out the proposed piping system. The order of steps can change, but they are all important to the successful completion of the installation.

1. **Review the architectural drawing:** On it you will find the location of fixtures and equipment relative to the building. Make a note of the finish planned for walls and floors in order to estimate finished thicknesses. Check ceiling heights and finishes, and check the architectural plan that shows an upside-down view of the finished ceiling (known as a "reflected ceiling plan"). Make sure your piping won't conflict with light fixtures, air grilles and sprinkler heads. Look for the number of appliances/equipment/fixtures planned and their approximate locations. Check the model and manufacturer of each item and familiarize yourself with any key pieces of information that might affect your pipe installation.
2. **Review the mechanical drawing:** Check for pipe sizes and look for the path of travel for your piping as well as that for any other such as sprinkler or gas. Check the equipment literature and mark on it the connections required. Also check the mechanical drawing for HVAC ductwork. The location of sheet metal ductwork is the most difficult aspect of the entire mechanical system to alter, due to its physical size, so the ductwork location usually takes precedence. Altering the paths of pipes and electrical wiring are much easier to accomplish when there are interferences to consider, and it is always better to identify conflicts with other trades' work on paper before they actually occur. As a matter of fact, most building plans will state that it is the responsibility of the contractor or installer to identify and deal with any interference prior to installation.
3. **Review the electrical and structural drawing:** Make sure the planned piping connections will not interfere with electrical lines or outlets or require you to compromise or weaken supporting structural members. Check for necessary penetrations in suspended slabs and floors and identify any holes that may need to be cored or sawn through them. Remember that penetrations through structural slabs may have to be X-rayed in order to avoid

embedded conduits or cables.

4. **Locate manufacturers' rough-in literature or suppliers' rough-in sheets:** These are known as "shop drawings" for the equipment identified in the architect's information. Check the important dimensions for pipe connections and supports. Measure at the intended installation location to confirm actual points of connections and that clearances are adequate. With accurate measurements, changing piping routes can be avoided.
5. **Refer to relevant code requirements for your work:** Check that your planned piping connections and equipment supports will not conflict with any regulations. Also check the elevations that your piping will be installed at. Any liquid system, such as a hydronic heating system, will need high point vents and low point drains. Try to avoid too many changes in elevation, as these drains and vents may be difficult to locate in a finished ceiling space without the added expense of access doors to conceal them.
6. **Check with your local Authority Having Jurisdiction (AHJ:.** Check for any special requirements regarding inspections. Also check if there are any local bylaws that may affect the installation.
7. **Prepare a piping isometric drawing for either the entire installation (if it is small) or for sections of piping (if a large installation):.** They assist in visualizing just how the piping is expected to be installed. From these drawings, items such as number and type of fittings, pipe lengths and material lists can be formulated and ordered. The creation of isometric drawings is normally the responsibility of either the installer or their supervisor if there are particulars to the installation that are atypical.

Once these items listed above have been considered, the piping installation can proceed.

Pipe Installation Guideline

When installing pipe:

- Make sure piping is not distorted, so you can bring it into alignment for joint assembly.
- Don't use wedges to laterally contain or position pipe for closure ***fit-ups***.
- Ensure the amount and direction of ***cold spring*** (the intentional deformation of piping during assembly to produce a desired initial displacement and stress) matches the design values.
- Confirm support locations, type, and restraint direction are as specified in the design drawing.
- Ensure pipe slope has been maintained in the direction specified by the slope arrow and/or work point elevation indicated on the design drawing.
- Ensure changes in piping elevation have not impacted slope requirements, high-point vents, or low-point drains.
- Upon completion of installation, record the as-installed piping geometry on the design documents. Typical tolerances for ***erection (field installation)*** are the larger of 152 mm (6 in) or D/2 for safety-related piping or 300 mm (12 in) or D/2 for non-safety-related piping, while maintaining code, design, and vendor alignment and slope requirements. Tolerance must not affect the sequential location of components and fittings or the centreline lengths.
- Ensure valves and other components are oriented as shown in design documents or manufacturer's requirements.
- Check that insulation is installed as specified.
- Ensure there are no visible defects, or missing or damaged parts in piping, components, or piping.

Specialized Pipe and Tubing Joint and Assembly

Certain types of pipe or tube may have joining methods that will require you to receive specialized training and

certification from the product manufacturer. In such cases, you must follow the manufacturer's joining, assembly, and installation procedures. If these procedures conflict with code regulation, resolve the differences with the **AHJ** before you start the job. As the installer, you may be responsible for any damages and liabilities caused by joint failure.

Identify Safety Hazards

Apply the appropriate safety practices when joining pipe and fittings.

Calculations

Pipe or tube is almost always installed between fittings or valves. When cutting pipe to length, you need to calculate for cut lengths by using fittings at hand or by consulting fitting catalogues. Either way, terms such as ***pipe or thread engagements***, ***centre-to-face***, ***centre-to-centre,*** and ***fitting allowance*** will need to be understood and applied.

Measurements for ***makeup-type joints*** that require *fitting allowance (takeoff) calculations* are those involving soldered or brazed connections, compression joints, socket weld, solvent-cemented plastic fittings, threaded connections, pressed connections, and insert/push fittings for PEX and polyethylene piping. ***Non-makeup type joints***, which butt together and would therefore not need fitting allowance calculations are those such as hubless mechanical joint cast iron, butt weld steel, groove-and-shoulder and butt fusion of plastics.

Centre-to-centre measurements of fittings that use a 90-degree change of direction can be calculated quite easily using simple subtraction and conversion of fractions. Centre-to-centre measurements using ***wyes*** and 45-degree fittings tend to be a little more challenging in that the offset multiplier of 1.414 must be factored into the calculations before a length of pipe can be cut. Always remember to measure/calculate twice to ensure that you only cut once.

Common Pipe and Tubing Joining Methods

There are several methods of joining piping. These have been established to suit the material being joined, with the goal of creating a joint that has the same integrity as the pipe itself. Different pipe and tubing materials are better suited for a particular joining method.

Basic types of piping joints include the following:

- Soldered and brazed
- Extracted tees
- Flared
- Compression
- Flanged
- Clamped
- Slip-on
- Threaded
- Solvent welded
- Welded

- Fusion welded
- Other

Design features of a piping or tubing joint may include the following:

- Type of material: copper, steel, cast iron, plastic, etc.
- Strength
- Tightness against leakage
- Ease of assembly
- Rigidity or flexibility

Methods for Joining Copper and Copper Alloys

Plastic has become the material of choice for piping and tubing in many residential applications. However, it is still important to be able to solder and braze high-quality joints. Copper tubing and fittings are still used extensively in commercial and industrial applications.

Copper tube and fittings may be joined in a number of ways, depending on the purpose of the system. Methods used for joining copper tube include:

- Soldering and brazing fittings
- Extracted tee connections
- Flare joints
- Compression joints
- Press-fit joints
- Grooved joints
- Push-on joints
- Flared joints

The following images will help you visually identify the methods of joining copper tube.

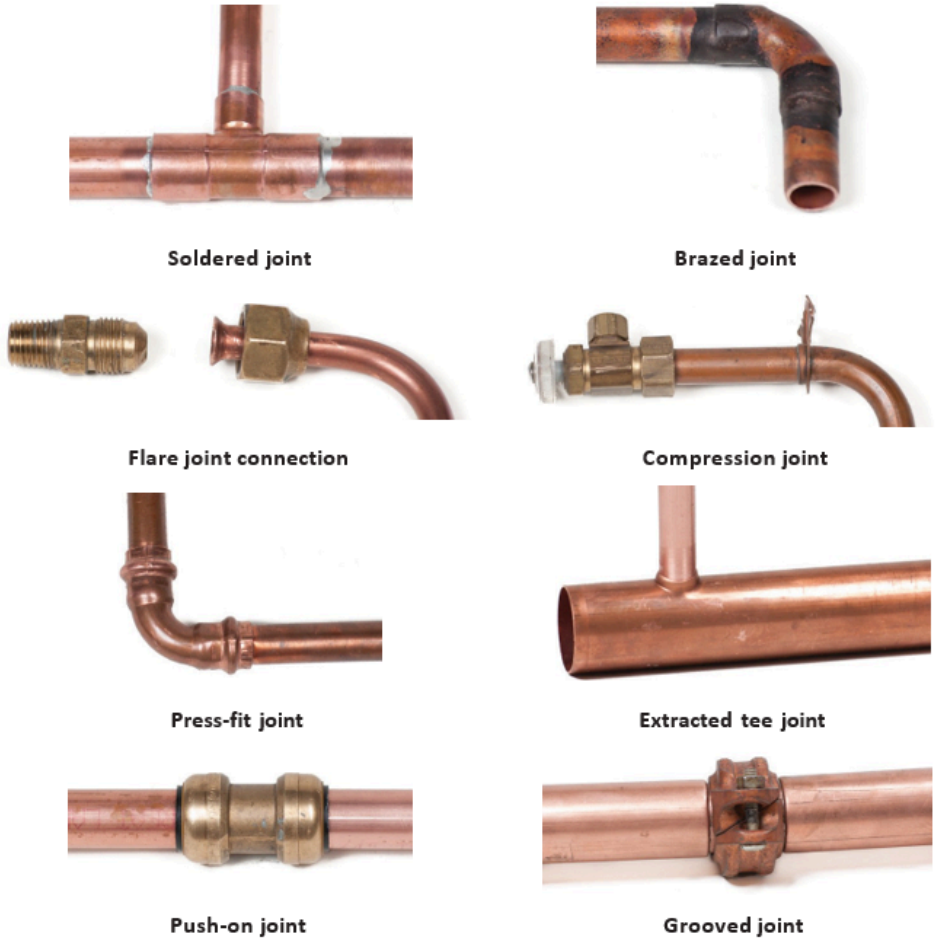

Figure 1 *Copper tube joining (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Soldering and Brazing Copper Jointing

The ability to make complete soldered or brazed jointing in copper tubing systems is essential for the tradesperson.

Soldering and brazing jointing is used in the following:

- Potable water systems (residential, commercial and industrial)
- Refrigeration tubing (silver brazing only; no soft soldering)
- Extracted tee joints in fire sprinkler systems
- Drainage, waste, and venting (DWV) systems
- Medical gas systems (brazing only; no soft soldering)

Soldering and Brazing Definitions

capillary action: The action by which liquid solder is drawn into the annular space between the inside fitting wall and

the tubing outside wall due to attraction between the copper and the liquid solder molecules. This attraction is a result of the forces of adhesion, cohesion, and surface tension.

Capillary action is most effective when the space between surfaces to be joined is between 0.05 mm and 0.013 mm (0.002 in and 0.005 in). A certain amount of looseness of fit can be tolerated, but too loose a fit can cause difficulties with larger size fittings.

Solder joints depend on capillary action to draw free-flowing molten solder into the narrow clearance between the fitting and the tube. This occurs regardless of whether the solder flow is upward, downward, or horizontal.

soft soldering: Soldering at temperatures below 450°C (840°F).

hard soldering (brazing): Brazing at temperatures above 450°C (840°F).

solidus: The temperature at which 100% of the alloy is in a solid, crystalline form but starts to melt when additional heat is applied. Soldering begins upon reaching the solidus.

liquidus: The temperature at which 100% of the alloy is in a fluid, non-crystalline form. The liquidus temperature is the minimum temperature at which soldering or brazing will take place.

plastic range: The temperature range between the solidus and liquidus, where some portion of the alloy is solid but the majority is liquid. Also called the melting (pasty) range. It may be of importance when selecting a filler metal. It indicates the width of the working range for the filler metal and the speed with which the filler metal will become fully solid after brazing. Filler metals with narrow ranges, with or without silver, solidify more quickly and therefore require careful application of heat.

eutectic: A mixture having the lowest liquefaction point possible with a tin/lead mix. Alloys are eutectic when the solidus and liquidus are the same.

Soldering and Brazing Abbreviations

- Sn: tin
- Pb: lead
- Ag: silver
- Ni: nickel
- Cu: copper
- Sb: antimony
- Cd: cadmium
- Zn: zinc

Soldering and Brazing Materials

The following describes soldering and brazing materials.

Soft-Solder Filler Metals

Soft-solder filler metals belong to a group of filler metals with melting temperatures below 427°C (800°F). They are available in 1-pound spools in diameters of $\frac{3}{64}$", $\frac{1}{16}$", $\frac{3}{32}$" and $\frac{1}{8}$". Other diameters and spool sizes are available on request.

Tin/Lead 50/50, 40/60, 60/40 Soft Solders

With some exceptions, the tin/lead solders can be used to solder copper and most copper alloys, lead, nickel alloys, and steel.

Tin/lead solders are not recommended in the cooling industry for joints subject to high stress or vibration due to their lack of sufficient elongation properties. It is illegal to use lead alloys in connection with potable water systems. (Refer to lead-free solder information.) These solders (40/60, 60/40, 50/50 – numbers referring to the percentage mix of metals) are available with rosin or acid cores.

Tin/Antimony 95/5

Tin/antimony 95/5 lead-free solder is useful for applications where moderately elevated temperatures are present. With higher electrical conductivity and high fluidity, 95/5 is recommended for lead-free installation of small-diameter, tight-fitting connections. Tin/ antimony solders are not recommended for use on brass.

Lead-free Solders

Lead-free solders were developed to conform to regulations banning the use of solders containing over 0.2% lead in potable water systems. These solders may contain some or all of the following metals: specific amounts of silver (Ag), antimony (Sb), copper (Cu), nickel (Ni) and/or tin (Sn). The strength of a lead-free solder joint normally exceeds the pressure at which copper tubing will burst.

Silver Brazing Filler Metal (Hard Soldering)

There are two general categories of silver brazing alloys:

- BAg—containing varying amounts of mainly silver and copper, with lesser amounts of other elements
- BCuP—similar to BAg, but with added phosphorus that acts as a flux

Selecting Solders or Brazing Alloys

The choice between soldering or brazing depends on operating conditions. Solder joints are generally used where the service temperature does not exceed 121°C (250°F), while brazed joints are used where greater ***tensile strength*** is required to resist vibration, pressure, or temperature cycling, or where system temperatures reach as high as 177°C (350°F).

Tube and Fittings Made for Soldering and Brazing

Copper tube and solder-type pressure fittings are accurately manufactured for compatibility. The tolerances permitted for each ensure the capillary space remains within the limits required for a strong enough joint.

Brazing Silver Copper Filler Alloys (BAg)

B (Brazing) and Ag (Silver) Element 47

These alloys are usually available in diameters of $\frac{1}{32}$", $\frac{3}{64}$", $\frac{1}{16}$", $\frac{3}{32}$" and $\frac{1}{8}$" as wire, bare rod, or flux-coated rod, in straight lengths, coils, strips, rings, and other forms.

Sil-56

This high silver content (56%) alloy makes first-quality brazes. It is free-flowing with unequalled capillary attraction and deep penetration. ***Ductility*** is high, and corrosion resistance is suitable for most applications, except strong chemical environments. Sil-56 offers the highest elongation of silver brazing alloys, and is suitable for use in the food-processing industry. The silver colour is an excellent match for stainless steel and silverware applications.

Sil-45

This is an excellent general-purpose non-toxic brazing alloy. It has good ductility and capillary flow, and is often specified for government use. Its colour ranges from silver to light yellow, similar to polished brass.

Sil-25

This is a lower-cost brazing filler metal with good flow properties at relatively low brazing temperatures.

Brazing Copper Phosphorous Alloys (BCuP)

Phosphorous-copper and silver-phosphorous-copper alloys are used to braze copper-to-copper and copper-to-brass joints. The phosphorus content in these alloys makes them self-fluxing on copper. When brazing brass or copper to brass, use brazing flux. These alloys are not recommended for brazing steel or other ferrous metals.

Typical examples and usage of BCuP include medical gas systems, refrigeration systems, and other systems where flux is not permitted into the system. Available in stick form approximately 610 mm (24 in) long.

Fluxes

Soldering fluxes are classified as corrosive, intermediate, or non-corrosive. The selection depends on the metals being joined, the melting range of the solder, and whether residues will be removed after soldering.

Fluxes are either petroleum-based or water-based. Soft-solder joints require a flux to be applied to the metal surfaces prior to heating.

The purpose of a flux is to:

- Remove mild oxides
- Prevent oxides from forming (oxidation) while heating
- Wet the metal to permit the solder to flow smoothly over the surfaces and aid in capillary action

Different fluxes perform these duties differently at different temperatures. Therefore, the choice of flux depends on the metal being used and the temperature of the flow point of the solder.

Petroleum-Based Soft-Soldering Paste Flux

Petroleum-based paste fluxes are made of organic chlorides, zinc, bromides, fluorides, and ammonium chlorides mixed in a petroleum grease base. They are slightly corrosive, which helps clean the surface during soldering. Therefore, you must limit the amount of flux entering the joint and thoroughly clean the exterior after soldering to avoid visible discoloration and a poor, “shabby” appearance.

Water-Based Soft-Soldering Paste Flux

Water-based fluxes are a newer development. Experimenting with these new fluxes on the job may require changes to work practices. Many of these new fluxes are more sensitive to heat within the temperature ranges typically used for petroleum-based fluxes. Water-based fluxes may burn away, leaving residue and oxidation that can result in leaks once the system is activated (in service). Some begin reacting immediately upon application and do not allow for delays between fluxing and soldering. They contain chlorides and have an active soldering temperature range of 93 to 315°C (200 to 600°F).

Water-Based Brazing Fluxes

White brazing paste flux is good for use with silver-brazing most ferrous and non-ferrous metals, except aluminum, magnesium, and titanium. Recommended filler metals for use with white brazing flux include those in the BAg and BCuP classifications. White brazing paste flux contains water, boric acid, and potassium fluorides, and has an active temperature range of 566 to 871°C (1050 to 1600°F).

The shelf life of these types of fluxes is approximately one year from the time of manufacture.

Solder Joints and Brazed Joints

Methods of forming joints include soldering, brazing, and electric resistance soldering.

- Soldered joints, using capillary fittings, are used in plumbing for water lines and sanitary drainage.
- Brazed joints, using capillary fittings, are used where greater joint strength is required or where service temperatures may reach 177°C (350°F).
- Electric resistance soldering can be used for most soldering applications and is especially helpful when you need to bring the intended joint to temperature rapidly to avoid thermal damage to surrounding components.

Soldering and brazing can be defined as a group of joining processes that join materials together by heating them to a required soldering or brazing temperature and using a filler metal (solder).

Solder generally has a liquidus temperature not exceeding 450°C (840°F) and below the solidus of the base metals. In actual practice, most soldering is done at temperatures from about 177 to 315°C (350 to 600°F). Brazing temperatures range from approximately 566 to 871°C (1050 to 1600°F).

Soldering and Brazing Specifications

Selection of Soldering Filler Metal

The selection of a solder depends primarily on the pressure and temperature at which the system will operate. Consideration should also be given to stresses on joints caused by thermal expansion and contraction. However, this may not be necessary when a tube length is short or when an expansion loop is used in a long tube run. In such cases, the stresses caused by a temperature change are usually insignificant.

When joining copper tube to soldered valves, follow the manufacturer's instructions. The valve should be partially open before applying heat, and heat should be applied primarily to the tube. Commercially available heat-sink materials can also be used to protect temperature-sensitive components during the joining operation.

Copper tube and solder-type fittings are accurately manufactured to work together. The tolerances permitted for each ensure the capillary space will be within the limits necessary for a joint of satisfactory strength. Soldered joints rely on capillary action to draw free-flowing molten solder into the gap between the fitting and the tube. Flux acts as a wetting agent and, when properly applied, permits uniform spreading of the molten solder over the surfaces to be joined.

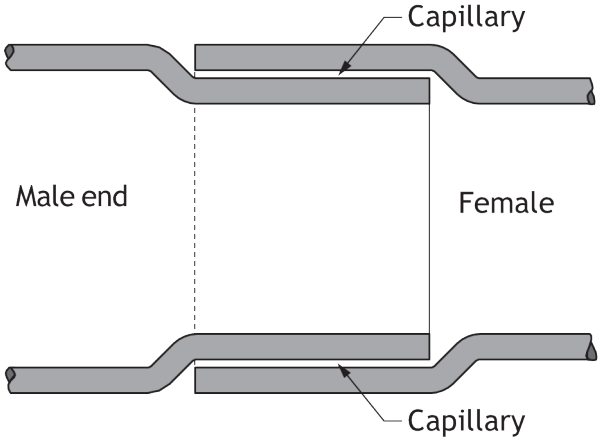

Figure 2 *Capillary space (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The 50/50 tin-lead solder is suitable for moderate pressures and temperatures. For higher pressures or where greater joint strength is required, 95/5 tin-antimony solder can be used. For continuous operation at temperatures exceeding 121°C (250°F) or where the highest joint strength is required, brazing filler metals should be used.

Solder alloys that meet ASTM B32, *Standard Specification for Solder Metal* (a standard that defines requirements for solder materials), can be used to join copper tube and fittings in potable water systems. Solders containing lead at concentrations of greater than 0.2% are banned for potable water systems. Some jurisdictions may allow the use of 50/50 tin-lead solder in some HVAC, drainage, and other piping system applications.

Always refer to manufacturers' documentation and applicable code regulations.

Soldering and Brazing Procedures

To consistently make satisfactory joints, the following sequence of joint preparation and operations, based on ASTM Standard Practice B 828, should be followed.

First Preparation Procedures: Measuring and Cutting

Soldering and brazing to produce a solid, leak-proof joint begin with accurately measuring the length of each tube segment (Figure 3). Inaccurate measurements can compromise joint quality. If the tube is too short, it will not fully enter the fitting cup, and a proper joint cannot be made. If the tube segment is too long, system strain may be introduced, which can affect service life.

Figure 3 *Measure carefully (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Cut the tube to the measured length. There are a number of different methods to produce a satisfactory squared end. The tube can be cut with a disk-type tube cutter, a hacksaw, an abrasive wheel, or a stationary or portable bandsaw. Care must be taken that the tube is not deformed during cutting. Regardless of the method used, the cut must be square to the ***run of the tube*** (the straight direction or alignment of the pipe) so that it seats properly in the fitting cup.

Figure 4 *Using a tube cutter (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Reaming

Ream all cut tube ends to the full inside diameter of the tube to remove burrs created during cutting. If this rough inside edge is not removed by reaming, erosion-corrosion may occur due to local turbulence and increased local flow velocity in the tube. A properly reamed piece of tube provides a smooth internal surface for better flow.

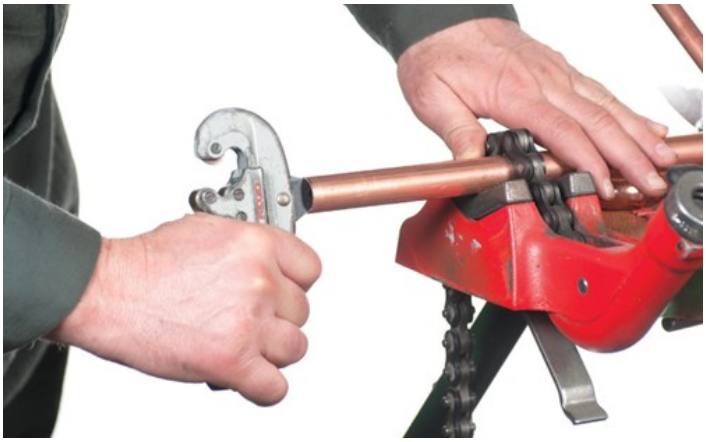

Figure 5 *Ream file (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Remove any burrs on the outside of the tube ends that were created during the cutting operation, to ensure proper insertion of the tube into the fitting cup.

Tools used to ream tube ends include the reaming blade on the tube cutter, half-round or round files, and suitable de-burring tools. With soft tubing, care must be taken to avoid deforming the tube end by applying too much pressure.

Soft temper tube, if deformed, can be brought back to roundness with a sizing tool. This tool consists of a plug and sizing ring.

Figure 6 *De-burring tool (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Cleaning

The removal of all oxides and surface soil and contaminants from the tube ends and fitting cups is crucial for proper solder flow into the joint. If not removed, they can interfere with capillary action, lessening the strength of the joint and causing failure.

Lightly abrade (clean) the tube ends using sand cloth or nylon abrasive pads to a distance slightly greater than the depth of the fitting cup.

Clean the fitting cups using abrasive cloth, abrasive pads, or a properly sized fitting brush.

Figure 7 *Clean tube end with sand cloth (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 8 *Wipe off tube end (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 9 *Clean inside fitting with fitting brush (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Do not touch the cleaned surface with bare hands or oily gloves. Skin oils, lubricating oils, and grease can impair the soldering process.

Copper is a relatively soft metal. If too much material is removed from the tube end or fitting cup, a loose fit may result, leading to a poor joint. The capillary space between tube and fitting is approximately 0.1 mm (0.004 in). This spacing is critical for the solder metal to flow into the gap and form a strong joint.

Applying Flux

Use care in applying flux. Careless workmanship can cause problems long after the system has been installed. First, apply a thin, even coating of flux to the tube using a brush, then apply a smaller amount to the inside of the fitting hub. Flux the fitting as soon as possible after cleaning. If you apply too much flux inside the hub, the excess will get pushed into the pipe. Excessive flux can leave residue that may cause corrosion. In extreme cases, this corrosion could perforate the wall of the tube, fitting, or both.

Figure 10 *Flux pipe end (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 11 *Flux the fitting (do not overload the fitting with flux)* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Assembly and Support

Insert the tube end into the fitting cup, making sure that the tube is seated against the base of the fitting. A slight twisting motion helps distribute the flux evenly. Remove excess flux from the exterior of the joint with a clean cotton rag.

Figure 12 *Insert and twist fitting fully* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Figure 13 *Remove excess flux (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Support the tube and fitting assembly to maintain a uniform capillary space around the entire circumference of the joint. Uniformity of capillary space will ensure good capillary flow of the molten-solder metal. Excessive joint clearance may lead to solder metal cracking under conditions of stress or vibration. The joint is now ready for soldering.

Joints should be soldered the same day they are prepared and not left overnight.

Heating

Begin heating with the flame at right angles to the tube (Figure 14). The copper tube conducts the initial heat into the fitting cup to produce even distribution of heat in the joint area. The extent of this preheating depends upon the size of the joint. Preheating of the assembly should include the entire circumference of the tube in order to bring the entire assembly up to a suitable preheat condition. For horizontal joints, avoid directly preheating the top of the joint to avoid burning the soldering flux. The natural tendency for heat to rise will ensure adequate preheat of the top of the assembly. Practice and experience will indicate the amount of heat and the time needed.

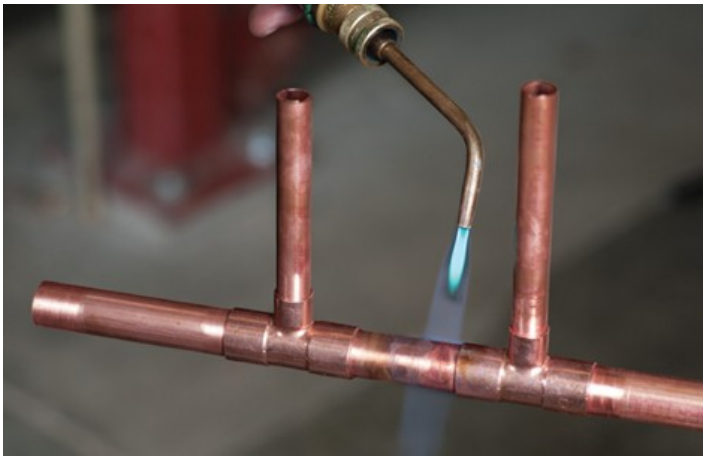

Figure 14 *Preheat the tube (position 1 in Figure 15, right). (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

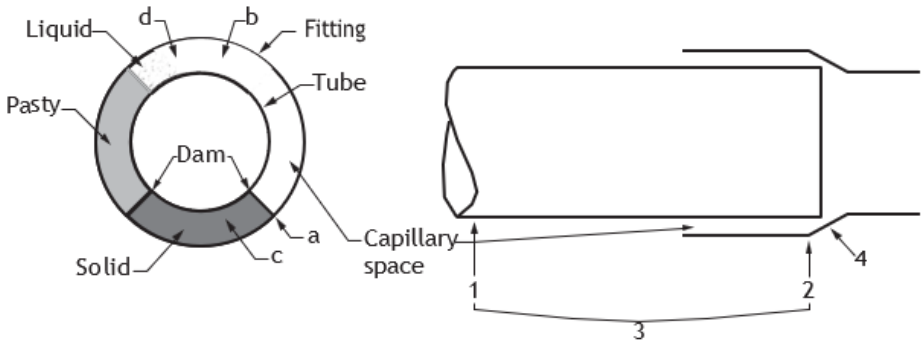

Figure 15 *Heating positions (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Next, move the flame onto the fitting cup (Figure 16, position 2). Sweep the flame alternately between the fitting cup and the tube approximately a distance equal to the depth of the fitting cup (Figure 15, right, position 3). Again, preheat the circumference of the assembly as described above, with the torch at the base of the fitting cup (Figure 15, right, position 4). Touch the solder to the joint. If the solder does not melt, remove it and continue heating.

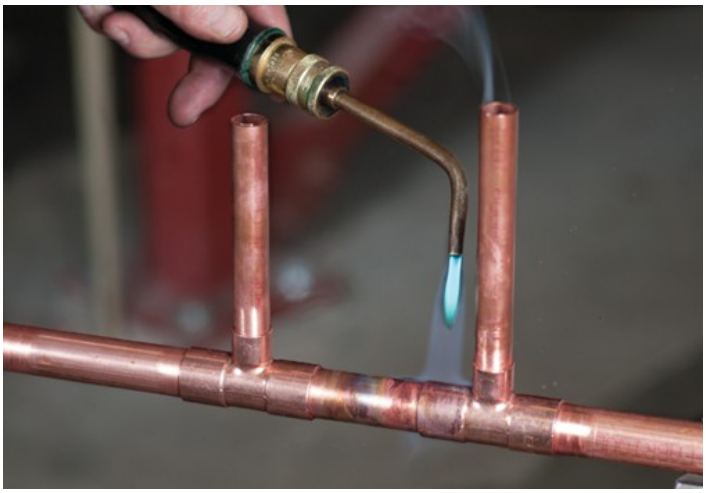

Figure 16 *Preheat the fitting cup (position 2) (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

CAUTION: Do not overheat the joint or direct the flame into the face of the fitting cup. Overheating could burn the flux, which will destroy its effectiveness, and the solder will not enter the joint properly.

Applying Solder

Continue heating while touching the solder to the joint. When the solder melts, apply heat to the base of the fitting cup to aid capillary action in drawing the molten solder into the cup toward the heat source. For joints in the horizontal position, start applying the solder metal slightly off-centre at the bottom of the joint (Figure 15, left, position a, and Figure 17). When the solder begins to melt from the heat of the tube and fitting, push the solder straight into the joint while keeping the torch at the base of the fitting and slightly ahead of the point of application of the solder. Continue this technique across the bottom of the fitting and up one side to the top of the fitting (Figure 15, left, position b).

Figure 17 *Applying solder (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Return to the point of beginning, overlapping slightly (Figure 15, left, position c), and proceed up the uncompleted side to the top, again overlapping slightly (position d). While soldering, small drops may appear behind the point of solder application. These indicate that the joint is full to that point and will take no more solder. During this process, solder transitions through solid, pasty, and liquid states.

The now-solidified solder at the bottom of the joint has created an effective dam or barrier that will prevent the molten solder from running out of the joint as the side and top of the joint are being filled.

For joints in the vertical position, make a similar sequence of overlapping passes, starting wherever is convenient.

Cooling and Cleaning

Allow the completed joint to cool naturally. Shock cooling with water may stress the joint. When cool, clean off any remaining flux residue with a wet rag (Figure 18). Whenever possible, based on end use, flush the system to remove excess or residual flux and debris.

Figure 18 *Clean off flux residue (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Testing

Test all completed assemblies for joint integrity. Follow the testing procedure prescribed by applicable codes governing the intended service.

Visual Examination

The finished joint shall be visually inspected. The following conditions shall be considered unacceptable:

- Excess solder drips on the outside of the tube and/or fitting
- Cracks in the tube or fitting
- Cracks in the solder filler metal

Brazed Joints

Brazing Filler Metal Alloys

Brazing filler metals are used in plumbing, HVAC, refrigeration, and fire sprinkler systems. For joining copper tube, any of these filler metals will provide the necessary strength when used with standard solder-type fittings or commercially available short-cup brazing fittings. Brazing filler metals are sometimes referred to as “hard solders” or “silver solders.” These confusing terms should be avoided.

There are two classes of brazing filler metals suitable for joining copper tube:

- BCuP series alloys containing phosphorus: brazing (B), copper (Cu) phosphorous (P)
- BAg series alloys containing a high silver content: brazing (B), silver (Ag)

The two classes of brazing metals differ in their melting, fluxing, and flowing characteristics, and this should be considered when you are selecting a filler metal.

Each class of filler metal comes in variations for specific uses:

- BCuP-2: used for close tolerances
- BCuP-3, BCuP-4and BCuP-5: used where close tolerances cannot be held
- BAg-1, BAg-5 and BAg-7: used when the specific characteristics of the BAg alloy are required

Brazing alloy key characteristics:

- BAg filler metals are used for joining dissimilar metals.
- The BCuP series filler metals are less expensive than the BAg series.
- BCuP alloys are better suited for general piping applications.
- The strength of the brazed joint will meet or exceed that of the tube and fitting being joined.
- Depending on the composition of either BAg or BCuP alloys, they melt at temperatures between 590 and 815°C (1100 to 1500°F).
- Brazing filler metals can form strong, leak-tight brazed connections for copper tube.
- The temperature at which a filler metal starts to melt on heating is the solidus temperature; the liquidus temperature is the higher temperature at which the filler metal is completely melted. The liquidus temperature is the minimum temperature at which brazing will take place.
- The difference between solidus and liquidus is the melting (pasty) range and may be of importance when selecting a filler metal. It indicates the width of the working range for the filler metal and the speed with which the filler metal will become fully solid after brazing. Filler metals with narrow ranges, with or without silver, solidify more quickly and therefore require careful application of heat.

For details about brazing filler metal composition, use the manufacturers' documentation.

Strength of Brazed Joint

The strength of a brazed copper tube joint does not vary much with the different filler metals. The joint strength depends mainly on maintaining the proper clearance between the outside of the tube and the cup of the fitting.

Brazing Flux

The fluxes used for brazing copper joints are different in composition from soldering fluxes. The two types must not be used interchangeably.

Unlike soldering fluxes, brazing fluxes are water-based. However, brazing fluxes perform the same functions as soldering fluxes:

- Dissolve and remove residual oxides from the metal surface
- Protect the metal from re-oxidation during heating
- Promote wetting of the surfaces to be joined by the brazing filler metal

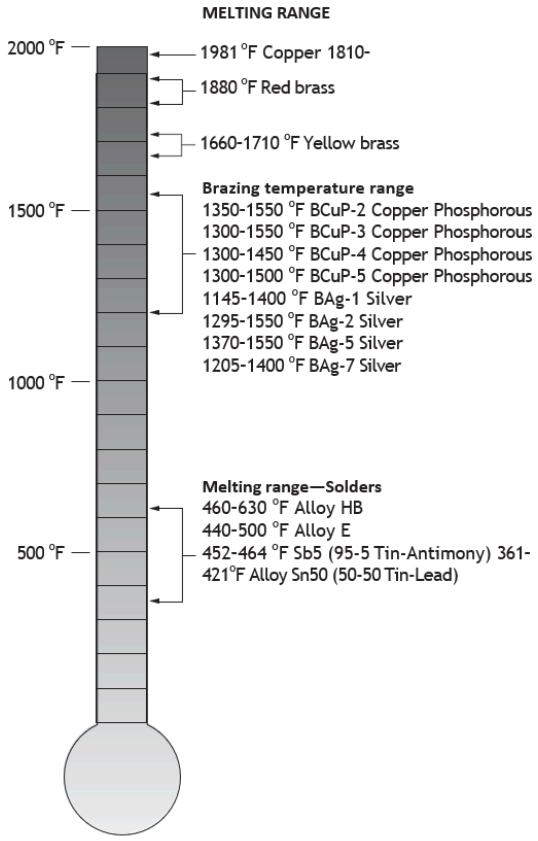

Figure 19 *Melting ranges of solders, brazing filler metals, and base metals (°F) (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Brazing fluxes also provide an indication of temperature (Figure 20).

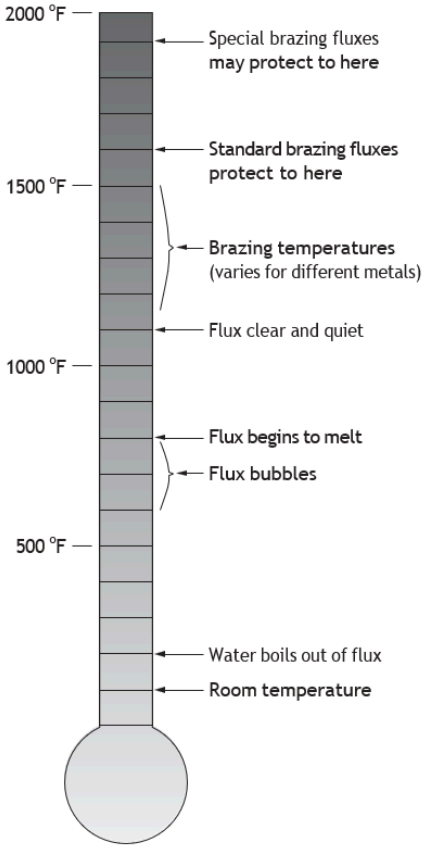

Figure 20 *Temperature behaviour of flux during brazing* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

The flux can be used as a guide as to how long to heat the tube.

By observing the flux reaction during soldering or brazing, you can judge the temperature and avoid overheating. Excessive oxidation will be minimized, and the appearance of the joint will be greatly improved.

For information about flux requirements based on tube, filler metal, and fitting type, refer to manufacturer documentation.

Brazing Procedures

The procedures for measuring, cutting, de-burring, cleaning, fluxing, and assembly are the same as for soldering. The following brazing procedures start once heat is applied to the joint being brazed.

When brazing, selecting the right size of tip and torch is important. A torch tip that is too small will produce insufficient heat and take longer to reach and maintain the brazing temperature. Normally, a single B-size acetylene tank will be adequate for smaller diameter copper tubing. On larger joints over 2.5 cm (1 in), an oxy-acetylene system may be required. Experience will guide the selection of heat source and tip size.

When brazing larger diameters, a B tank will work with a larger tip, or multiple B tanks could be used. However, an oxy-acetylene fuel torch with a neutral to slightly ***carburizing flame*** is preferred.

Apply Heat

Heat the tube first, beginning about 2.5 cm (1 in) from the edge of the fitting and sweeping the flame around the tube in short strokes at right angles to the axis of the tube (Figure 21, right, position 1).

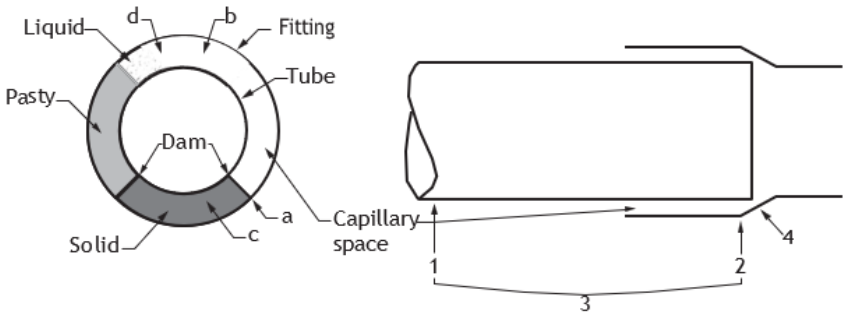

Figure 21 *Heating positions of a brazed joint (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

It is very important that the flame remain in motion and not stay in one spot long enough to damage the tube.

Switch the flame to the fitting at the base of the cup (Figure 21, right, position 2). Heat uniformly, sweeping the flame from the fitting to the tube until the flux on the fitting becomes quiet (stops bubbling and becomes smooth). Avoid excessive heating of cast fittings, as this may cause cracking.

When the flux appears liquid and transparent, start sweeping the flame back and forth along the axis of the joint to maintain heat on the parts to be joined, especially toward the base of the cup of the fitting (Figure 21, right, position 3). The flame must be kept moving to avoid melting the tube or fitting.

For tube sizes 2.5 cm (1 in) or larger, it may be difficult to bring the whole joint up to temperature at one time. It frequently will be found desirable to use an oxy-fuel, multiple-orifice heating tip to maintain a more uniform temperature over a large area. A mild preheating of the entire fitting is recommended for larger sizes, and the use of a

second torch to retain a uniform preheating of the entire fitting assembly may be necessary in larger diameters. Heating can then proceed as outlined in the steps above.

Applying the Brazing Filler Metal

Apply the brazing filler metal at a point where the tube enters the fitting socket. When the correct temperature is reached, the filler metal will flow readily into the space between the tube and fitting socket, drawn in by the natural force of capillary action.

Keep the flame away from the filler metal itself as it is fed into the joint. The temperature of the tube and fitting at the joint should be hot enough to melt the filler metal.

Keep both the fitting and tube heated by moving the flame back and forth from one to the other as the filler metal is drawn into the joint. When the joint is properly made, filler metal will be drawn into the fitting socket by capillary action, and a continuous ***fillet*** of filler metal will be visible completely around the joint. To aid in the development of this fillet during brazing, the flame should be kept slightly ahead of the point of filler metal application.

Horizontal and Vertical Joints

When brazing horizontal joints, it is preferable to first apply the filler metal slightly off-centre at the bottom of the joint, proceeding across the bottom of the joint, and continuing up the side to the top of the joint. Return to the beginning point, overlapping slightly, and proceed up the uncompleted side to the top, again, overlapping slightly. This procedure is identical to that used for soldering.

Also, similar to the soldering process, make sure the operations overlap. On vertical joints, it is immaterial where the start is made. If the opening of the socket is pointing down, avoid overheating the tube, as this may cause the brazing filler metal to run down the outside of the tube.

Removing Residue

After the brazed joint has cooled, remove flux residue using a clean cloth, brush, or swab with warm water. Remove all flux residue to avoid the risk of the hardened flux temporarily retaining pressure and masking an imperfectly brazed joint. Wrought fittings cool faster than cast fittings, but all fittings should be allowed to cool naturally before wetting and cleaning.

Techniques for troubleshooting brazing include:

- If the filler metal fails to flow or has a tendency to ball up or ***bead***, it indicates oxidation on the metal surfaces or insufficient heat on the parts to be joined.
- If the tube or fitting starts to oxidize during heating, insufficient flux has been used.
- If the filler metal does not enter the joint and tends to flow over the outside of either member of the joint, it indicates one part is overheated or the other underheated.

Testing

Test all completed assemblies for joint integrity. Follow the testing procedure prescribed by applicable codes governing the intended service.

Purging

Some installations (such as medical gas, high-purity gas, and ACR systems), require the use of an inert gas during the brazing process. The***purge gas*** (usually nitrogen) displaces oxygen from the interior of the pipe system while it is being subjected to the high temperatures of brazing and therefore eliminates the possibility of oxide formation (oxidation) on the interior tube surface during heating.

Purge gas flow rates and methods of application should be included in the *Brazing Procedure Specifications* of these applications.

Visual Examination

The finished joint should be visually inspected. The following conditions shall be considered unacceptable:

- Excess filler metal on the outside of the tube and/or fitting
- Cracks in the tube or fitting
- Cracks in the filler metal

Copper Swaging

The Canadian Oxford Dictionary (2004) defines the term "**swage**" as "A tool, die, or stamp for bending and shaping wrought iron, etc., by hammering or pressure." A pipe swage for copper is a tool that expands the end of an annealed piece of copper tube to form a ***coupling***.

One type of swaging tool uses a hand-held steel pin or mandrel that is driven into the tube end by repeated hammer blows, thereby expanding the inside diameter of the tube. Each size of tube requires a different size of swage.

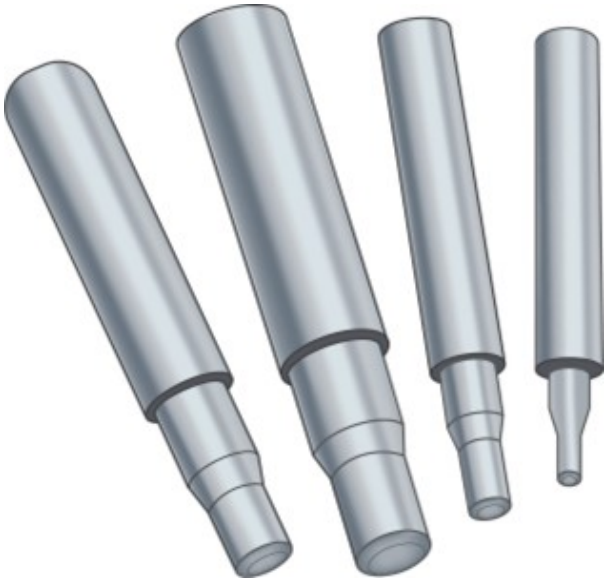

Figure 22 *Swaging tool kit (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Another type of swage uses handles that are pumped to expand a die. The die is placed into the pipe end and, when the handles are opened and closed repeatedly, the die expands and forms the coupling. Like the hand swage, each pipe size requires a different die head.

Figure 23 *Tube expander kit (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

This variety of swage is more commonly known as a tube expander, and can also be found using an electric motor to power the swaging movement.

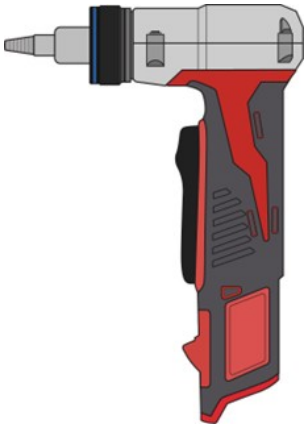

Figure 24 *Milwaukee expander kit (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

To be an acceptable joint, pipe swage manufacturers usually specify that the newly formed expanded connection should be brazed rather than soldered.

Extracted Tee Joints

Extracted tee joints are a tested and effective method for joining copper tubes. In this method, the tool forms a raised collar on the pipe to which another tube is brazed. Soldering is not permitted, because the joint would not be strong enough.

Power or hand tools quickly form an extracted tee connection in a run of copper tube, reducing the number of soldered or brazed joints. The process is faster than individual tees piped together (because there are fewer joints) and can reduce installation costs. This method may be used for general plumbing, HVAC, refrigeration, fire sprinkler, and service projects.

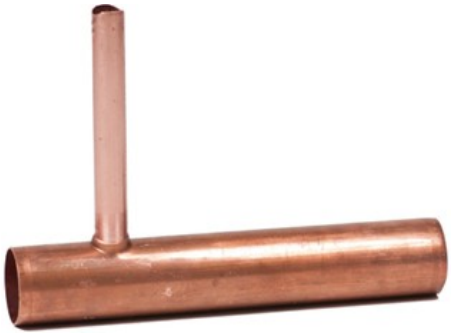

Figure 25 *Extracted tee joint (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Typical Code Regulations

Extracted tees can be formed from Type K and Type L copper used in water distribution systems, provided the following requirements are met:

- A tool specifically designed to form the joint is used.
- The branch line size is at least one size smaller than the tube in which the tee is formed (the main tube).
- The end of the branch incorporates a means to prevent the branch from penetrating into the run of the tube and obstructing the flow.
- The joint is brazed using filler metal with a melting temperature of at least 540°C (1004°F).

Although manufacturers may suggest that extracted tees can be formed with Type M copper, code regulations may not permit it. Refer to manufacturer instructions and authorities having jurisdiction for these applications.

Figure 26 shows a tube end preparation tool that forms the end of a branch pipe to match the inner curve of the tube. The tool simultaneously presses two dimples in the end of the branch tube. One acts as a depth stop, and the other is used to inspect branch alignment after brazing.

Figure 26 *End prep tool (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

On larger tube sizes and/or heavier wall thicknesses, the area for forming the tee outlet must be annealed before preparing an extracted tee joint. Refer to manufacturer instructions when working with these sizes.

Installation Steps

The following procedure is typical for forming and brazing 12.5 to 31.75 mm ($\frac{1}{2}$ to 1 $\frac{1}{4}$ in) outlets using power-operated equipment. Although there are specific steps to follow, the tee-forming and brazing process takes little time and is quickly repeatable. Follow the manufacturer's operating instructions for all tube sizes.

1. Select and adjust the drill head and forming pins according to the manufacturer's instructions. The drill bit and pins are quite sharp, so be careful when handling them.
2. Insert the drill head into the chuck (Figure 27) and extend the forming pins (Figure 28).

Figure 27 *Insert drill head* (BC Industry Training Authority, 2019). *CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 28 *Extend forming pins* (BC Industry Training Authority, 2019). *CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

3. Lubricate the drill head and forming pins (Figure 29).

Figure 29 *Lubricate drill head (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

4. Pull out the support legs (Figure 30).

Figure 30 *Pull out the support legs (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

5. Press in the conical cover and rotate counter-clockwise to retract the forming pins (Figure 31).

Figure 31 *Retract the pins (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

6. Place the tube support firmly at the point where the tee is to be formed on the tube. Then twist the machine counter-clockwise using the handle to centre the drill head on the tube. The support legs will centre and stabilize the drill while absorbing rotational torque (Figure 32).

Figure 32 *Position the drill tip and ensure a snug fit of the support legs (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

7. Start the tool by squeezing the trigger and drill until the bit has fully penetrated into the tube. Then release the trigger to stop the drill. **Do not extend the forming pins while the motor is running.**
8. Extend the forming pins on the drill head by pressing the cover toward the tool and rotating it counter-clockwise until the head locks in the tee-forming position (Figure 33).

Figure 33 *Stop drill and extend the forming pins (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

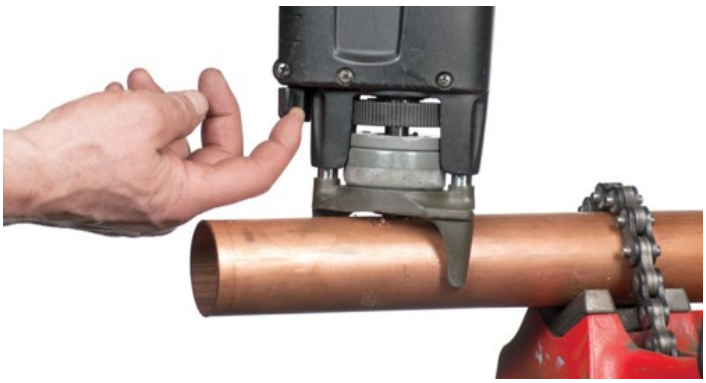

Figure 34 *Engage support legs (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

9. Turn the speed selector control to the slowest position (typical) and engage the feed mechanism. You may need to rotate the motor by giving a nudge on the trigger to engage it.
10. Squeeze the trigger to start forming the outlet and continue until the drill head exits completely out of the tube (Figure 35). Maintain a slight downward pressure on the drill to ensure a firm contact with the tube. The rotation of the forming pins causes a backflow and thickening of the metal around the lower circumference of the outlet. It is important to release the drill trigger as soon as the drill head clears the rim of the outlet. **Note:** Removing the drill head from the tube before it emerges will result in an oval or imperfect outlet.

Figure 35 *Form the outlet (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

11. Select the appropriate branch-size die on the tube-end notcher to notch and dimple the sides of the branch tube end. Proper notching and dimpling must be performed to meet code requirements and to ensure that the branch does not protrude into the tube and obstruct flow.

Figure 36 *Using the notching and dimpling tool (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

12. Ream or de-burr the branch tube end.

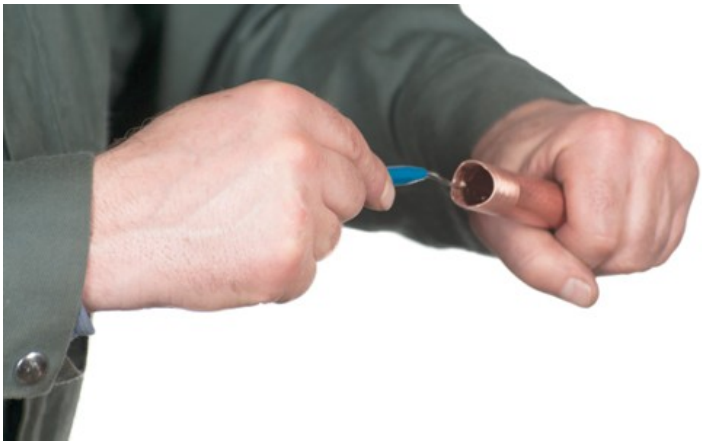

Figure 37 *Ream the branch tube end (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 38 *Proper notching (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

13. Remove any excess lubricant from inside the outlet and use a sand cloth to clean the inside of the outlet rim.

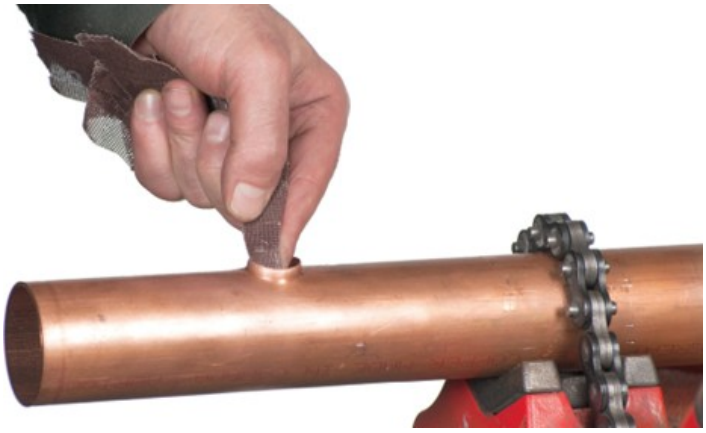

Figure 39 *Clean the inside rim surface (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

14. Insert the branch tube into the outlet up to the first dimple and align the dimples with the run of the tube.

Figure 40 *Align the dimples with the run of the tube (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

15. Align the joint for brazing and complete the brazing process using the specified filler metal and following the normal joint procedures.

Figure 41 *Align the joint ready for brazing (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Testing the Extracted Tee Joint System

All drilling residue and debris must be flushed out before the system is placed in service.

Final pressure testing of the completed piping system is accomplished by using pressurized air or water as required by local codes or project specifications. Test pressures should never exceed the maximum operating pressure specified by the manufacturer of the fitting system.

Push-Connect Joints

Push-connect joints use an integral ***elastomeric gasket*** or seal (such as **EPDM**) and a stainless-steel grab ring to produce a strong, leak-free joint connection. This push-on method of joining of copper and copper alloy tube is fast and may be economical in specific applications.

There are two common types of ***push-connect*** fitting: removable and permanent. Both create strong, permanent joints. However, one allows easy removal after installation (Figure 42) to permit equipment service, while the second type cannot be easily removed once the fitting is installed.

Figure 42 *Removable push-connect fitting (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Examine the tube to ensure that it has no dents, deep scratches, dirt, oils, paint, grease, or other surface imperfections.

Figure 43 *Examine pipe ends for damage (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Push-On Fitting Installation Procedure

1. Measure and cut the tube square, perpendicular to the run of tube, using an appropriate tubing cutter.
2. Remove burrs from the inside diameter (ID) and the outside diameter (OD) of the cut tube end by reaming the ID and ***chamfering*** the OD using the appropriate tools.

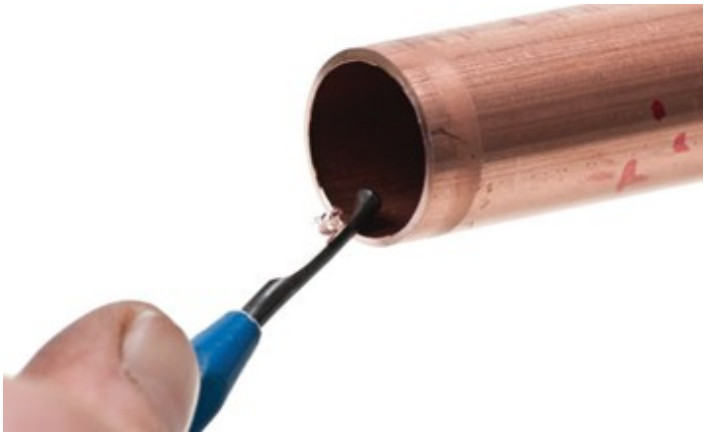

Figure 44 *Deburring tube (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

3. The cut tube end must be chamfered to reduce the possibility of gasket damage when the tube is being inserted. Cleaning the chamfered tube end with emery paper, abrasive nylon cloth, or plumber's cloth will ensure that there are no sharp edges or nicks that might damage the sealing gasket when the tube is inserted into the fitting.

Figure 45 *Chamfered OD of tube (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

4. Examine the fitting to ensure that the sealing gasket and gripper ring are properly positioned and not damaged.

Figure 46 *Examine gasket and gripper (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

5. Mark the depth of insertion on the tube before inserting it into the fitting to ensure that it will socket to the back of the fitting cup.

Figure 47 *Mark the insert depth (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Note: Lubrication of the tube end may or may not be required. Follow the manufacturer's installation recommendations related to pre-lubrication of the tube end.

6. Align the tube so that it is straight and in line with the fitting. Using a firm pushing and twisting motion, insert the tube into the fitting and push the tube and fitting together until the tube is seated at the back of the fitting cup, as evidenced by the pre-marked tube insertion depth line.

Figure 48 *Align tube and fitting, push and twist together (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

7. Test the completed piping system using pressurized air or water as required by local codes or project specifications. Test pressures should never exceed the maximum operating pressure specified by the manufacturer of the fitting system. Refer to manufacturers' instructions.

Press-Fit Joints

The ***press-connect*** joining method and associated fittings and tools were introduced in North America in the late 1990s. Also known as *press-fit*, this method has been used successfully in Europe since it was patented there in the late 1950s.

Press-fit joints rely on the sealing capability of a special fitting that contains an elastomeric gasket or seal (such as EPDM) (Figure 49).

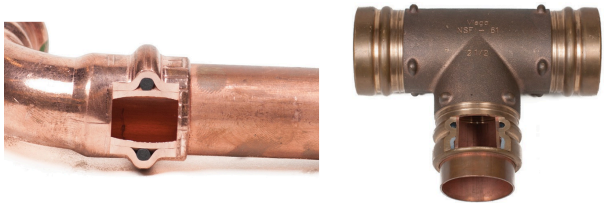

Figure 49 *Cutaway of press-connect fitting with elastomeric gasket (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The joint is formed using an approved pressing tool and jaws (Figure 50). Typical ranges of pressure-temperature ratings for these no-flame joints can be found in the manufacturers' documentation.

Figure 50 *Press tools and jaws (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Several manufacturers offer full product lines of press-connect fittings, valves, and specialty items (Figure 51). Tubing is available with an integrally formed press-connect end.

Figure 51 *Samples of available fittings (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Examine the tube to ensure there are no dents, deep scratches, dirt, oils, grease, or other surface imperfections.

Press-connect Fitting Installation Procedure

1. Measure tubing accurately to ensure it sockets completely to the base of the fitting cup.

Figure 52 *Measure (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

2. Cut the tubing square, perpendicular to the run of tube, using an appropriate tube cutter.

Figure 53 *Cut the tube square (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

3. Deburr the tubing. Burrs must be removed from the ID and OD of the cut tube end.
4. Chamfer the cut tube end to reduce the possibility of gasket damage when inserting the tube. Clean the chamfered tube end with emery paper, nylon abrasive cloth, or plumber's cloth to ensure there are no sharp edges or nicks that might damage the sealing gasket when the tube is inserted into the fitting.
5. Examine the fitting to be used to ensure the sealing gasket is properly positioned and is not damaged.
6. Mark the depth of insertion on the tube before inserting the tube into the fitting.
7. Select the proper size of the appropriate pressing jaw and insert it into the pressing tool.
8. Ensure that the tube is completely inserted to the fitting stop (appropriate depth) and squared with the fitting before applying the pressing jaws onto the fitting.
9. Place the pressing jaw over the bead on the fitting and ensure the tool and jaws are at a 90° angle (perpendicular) to the centreline of the tube.

10. Depress the pressing tool trigger to begin the pressing cycle.
11. When the pressing cycle is complete, release the pressing jaw and visually inspect the joint.

Figure 54 *Fitting prepared for pressing* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

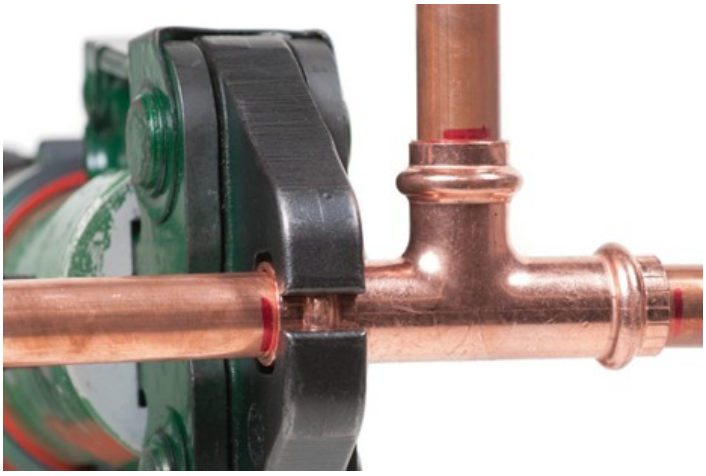

Figure 55 *Properly positioned press tool* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Figure 56 *Completed installation of a press-connect joint* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Testing the System Joints

Test the completed piping system using pressurized air or water. When the test pressure is relatively high, use

hydro-pneumatic testing. The test pressures should never exceed the maximum operating pressure specified by the manufacturer of the fitting system. Check the documentation they provide and always follow manufacturer specifications and applicable codes.

Roll Groove Joints

Since 1925, the ***grooved-end piping*** method has been used reliably to join steel and iron pipe in HVAC, fire protection, process piping, and related applications.

This method of mechanical joining is also available in a system for copper tube in sizes from 5 to 20 cm (2 to 8 in). Included are couplings, gaskets, and a myriad of fitting configurations. The system offers a practical alternative to soldering and brazing larger-diameter copper tube—and most importantly, it requires no heat or open flame.

Copper ***roll groove joining*** takes advantage of copper's excellent ***malleability*** and its increased strength when ***cold-worked***. The joints rely on the sealing capability of a special clamping system that contains an EPDM gasket and a specially designed clamp. Several manufacturers offer roll groove tools, gaskets, clamps, and fittings (Figure 57).

Figure 57 *Copper roll groove fittings and clamps (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Roll Groove Copper Tube Joining Procedures

Proper selection of the correct roll grooving tool and heads for each type of tube to be prepared is essential. Manufacturers' recommendations must be followed to ensure safe, trouble-free tube preparation.

1. Examine the tube to ensure there are no dents, deep scratches, dirt, oils, grease or other surface imperfections.
2. Measure the tube length accurately.
3. Cut the tube end square (perpendicular to the run of the tube).
4. Remove burrs (de-burr) from the ID and the OD of the tube end by reaming the ID and chamfering the OD.
5. Roll groove the tubing to the proper dimensions, as required by the fitting manufacturer.

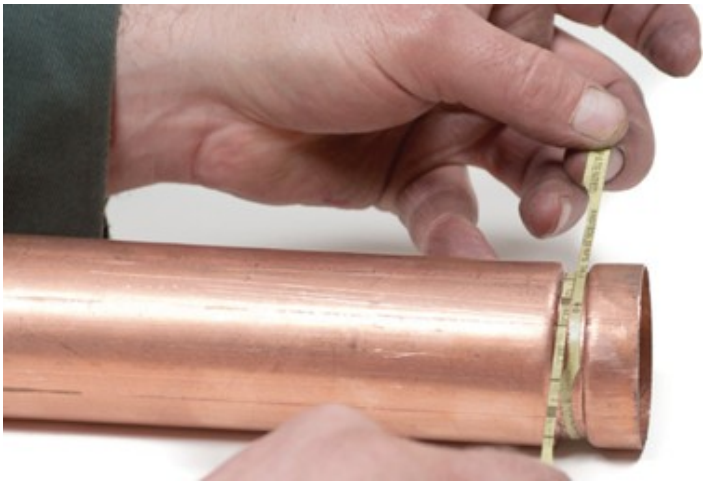

Figure 58 *Check the dimensions (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

6. Examine the fittings, gaskets, and clamps to ensure the proper gasket is inserted into the clamp and the fitting end is not damaged.
7. Inspect the clamping surfaces to ensure they are clean and free from construction debris.
8. Lubricate the gasket according to the manufacturers' recommendations.

Figure 59 *Apply lubrication (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

9. Assemble the clamp and pipe, ensuring that the gasket and groove and sealing surfaces align and seal correctly.

Figure 60 *Assembled joint (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

10. Tighten the clamp evenly.

Figure 61 *Tighten the clamp (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

11. Visually inspect the completed joint alignment, etc.

Figure 62 *Inspect clamping surfaces (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

12. Test the completed piping system using pressurized air or water. When the test pressure is relatively high, hydro-pneumatic testing may be used. Test pressures should never exceed the maximum operating pressure specified by the manufacturer of the fitting system. Test pressures are determined by the job specifications and regulations standards such as the plumbing code, fire sprinkler code, or other applicable codes.

Bending of Pipe and Tubing

Most pipe and tube can be bent. There are several benefits to bending, including:

- Reduced or eliminated unnecessary joints and connections, resulting in fewer leaks
- Greater flexibility of pipe when bends rather than fittings are used
- The ability to create offsets at angles not available with manufactured fittings

This basic bending information section focuses on tube bending only.

Tube bending is used in refrigeration and other piping systems, including, but not limited to, gas fitting applications, residential fuel oil systems, pneumatic control piping, and small-diameter water lines to plumbing fixtures.

When copper tube is properly bent, it will not collapse on the outside nor buckle the inside of the bend. Because copper is readily formed, expansion loops and other bends necessary in an assembly can be made quickly and efficiently. A well-constructed system of exposed tubing will also present a more professional appearance when bends are used instead of fittings.

Both ***annealed*** and ***hard-drawn tube*** can be bent using the appropriate hand benders. Use the proper size of bender for each tube size. Refer to manufacturers' guides for a list of each tool's typical bend radii.

Aside from brittle pipe materials, such as cast and ductile iron, both ferrous and non-ferrous pipe can be bent using machines. Machine bending methods include ***draw bending***, ***compression bending***, ***roll bending***, ***ram bending***, and ***stretch bending***. The use of dies and rolls helps prevent the pipe from distortion that could cause pipe failure or difficulty connecting to other pipes or fittings. *Cold* and *hot bending*, *bend radius*, *bend angle*, *throat-of-bend*, *back-of-bend*, *bend arc*, *inner curvature*, *outer curvature*, *thinning*, *stretching* and *shortening* are some of the terminology that will be used in pipe bending theory for steel pipe, which will be covered in detail in future levels of your apprenticeship training.

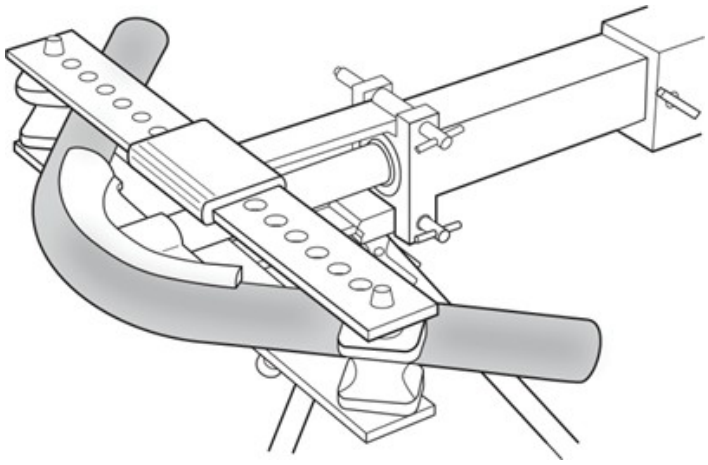

Figure 63 *Rothenberge pipe bender* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Plastic Fusion Welding Jointing Methods

Thermoplastic pipe is increasingly used in many industries, such as gas, water, and mining. The advantages over traditional materials (e.g., steel and cast iro) include lower cost, resistance to corrosion, lighter weight, and ease of joining. Ease of joining is only applicable if installation is done by qualified personnel following correct procedures and pipe and fitting tolerances.

The information, procedures, and equipment described here are generic and do not represent any specific manufacturer. Fusion welding of plastic pipe may require specific training and certification by a particular manufacturer to conform to the product they are providing.

Fusion welding is a type of welding that uses hot air or heating plates to fuse certain types of plastic piping. For example:

- Plain-end pipe: joined by ***butt fusion***
- ***Hub-to-spigot*** pipe: joined by socket fusion
- Branch connections (tees): often formed by saddle fusion

Polyethylene piping can be heat welded by socket fusion.

Heat fusion welding of ***high-density polyethylene pipe (HDPE)*** employs specially designed heating elements along with appropriate forming blocks, cutting tools, and clamping devices to fusion weld the pipe joint.

The heating element heats the pipe and fitting components to a temperature at which the HDPE material begins to soften and melt. At a specified temperature, the heating element is removed, the opposing joint surfaces are brought together, and a specific force is held on the joint, forcing the two heated surfaces to mix and become one. As they cool, the joint forms a single continuous material with strength comparable to the original pipe.

General Safety Specific to Fusion Welding and Machines

Follow all safety requirements.

Before adjusting or attempting maintenance, disconnect the machine from the power source. The heater is hot and will burn clothing and skin. Keep the heater in its insulated heater stand or blanket when not in use and use care when heating the pipe.

Use only a clean, natural-fibre cloth (such as a cotton) to clean heater plates.

Basic Fusion Welding Equipment

The subtopics describe some basic fusion welding equipment to be familiar with.

Heating Irons

Specially shaped ***heating irons (also called heaters)*** are used to:

- Heat pipe ends for butt fusion
- Heat the inside of fittings and the outer surface of the end of a pipe for socket fusion
- Heat the exterior wall of a pipe and its mating surface on a fitting for saddle fusion

With all types of joining with heating irons, the heating iron is applied to the surface of the mating components until each surface melts but does not burn.

The length of time required to heat a joint is determined from the manufacturer's specifications and used for heating the joints systematically.

When irons have seen a lot of use, the protective non-stick coating can be damaged. At some point, this will allow the melted plastic to stick and interfere with the actual joint. Replacement adapters would need to be purchased. Some irons have temperature gauge and temperature adjustment screws. Check the fitting manufacturer's instructions for appropriate temperature settings.

Coated heater adapters are available for all fusion applications. Heater adapters are installed with stainless steel cap screws. Ensure that the heater adapters are seated on the heater body and that there is no foreign matter trapped between these surfaces. Do not over-tighten the bolts. The surface of the heater adapters are coated with an anti-stick coating. Only install heater adapters when the heater is cool. Check manufacturer's tightening instructions.

Figure 64 *A regular plastic pipe cutter with a plastic cutter wheel can be used to cut the pipe* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

The following figure shows an example of a large-diameter poly pipe fusion machine.

Figure 65 *Large portable fusion machine (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Other Fusion Welding Equipment

Pyrometer

Incorrect heating temperature can result in poor fusion joints. Periodically check heater plate surface temperature with a properly calibrated ***pyrometer*** and make necessary adjustments. The thermometer on fusion heaters indicates internal temperature and should be used as a reference only.

Figure 66 *Pyrometer (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

You can use a ***Tempilstik*** to check the heating element surface temperature. Simply apply the end of the stick to the surface of the heater. Never touch the stick to the surface being melted, as you could contaminate the joint.

Figure 67 *Tempilstik (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Fusion-Welding Assembly

Figure 68 shows a small-diameter fusion assembly used for fusion-welding poly pipe.

This assembly holds the pipe tight with built-in cold-clamping rings (A). The cold clamps are tightened around the pipe using a handle (C).

The system can be used for butt fusion or saddle connections. For pipe saddles, the chains wrap around the pipe and hook into the latches (B).

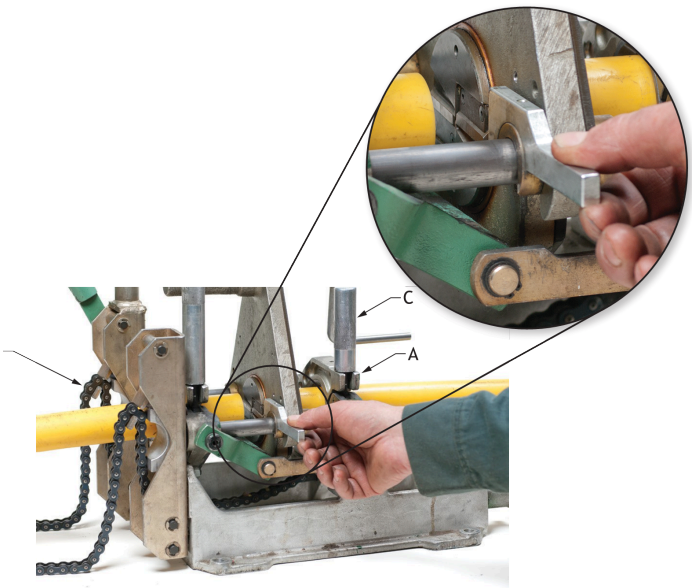

Figure 68 *Facer not locked onto the rail (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 68 shows the pipe facer mounted on the fusion machine. The pipe ends have been lined up for a butt fusion weld. The facer/trimmer has been lowered into place to trim the ends of each pipe. The operator is holding the locking lever ready to swing it up to the locked position.

Figure 69 *Vice-grip cold-clamping ring (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pipe Facer

A ***pipe facer (trimmer)*** fits onto the fusion assembly and is used to trim the ends of the poly pipe square for butt fusion welding. Before using the facer, also known as a trimmer, make sure the pipe ends are aligned with each other by checking the outside diameters for perfect circumference alignment. The figures below show the facer being installed.

Figure 70 *Pipe facer (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

In Figure 71, the facer/trimmer locking lever has been swung up and locked into position. The facer is now ready to trim the ends of the pipe perfectly square and smooth. The cold-clamp handles have been tightened on both pipes on both sides of the facer/trimmer.

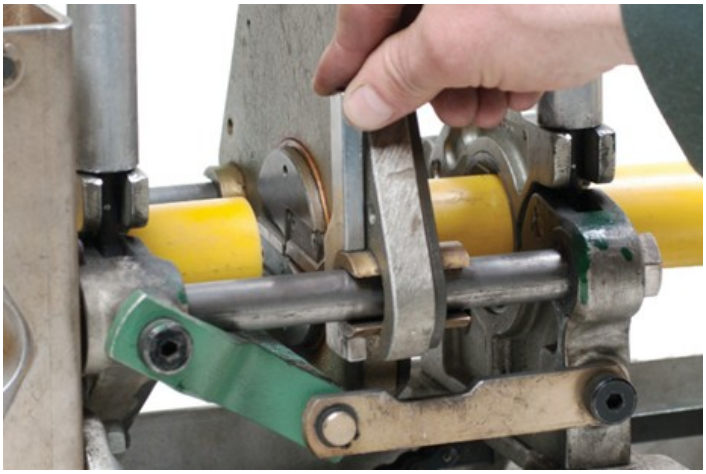

Figure 71 *Facer locked onto the rail (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Trimming for Butt Fusion

The facing cutter is used to square up the ends of the poly pipe after first aligning and clamping the pipe. The pipe ends must be aligned perfectly over the entire circumference of each end. After facing, recheck for proper alignment and resurface if necessary.

To face the pipe end, rotate the facer trimmer handle, applying just enough pressure to cause the cutter to cut into the pipe (Figure 72). Continue to rotate the handle until a continuous ribbon is produced from each end of the pipes being faced. As you finish up the trimming, ease off the pressure so as not to leave nicks in the ends of the pipe.

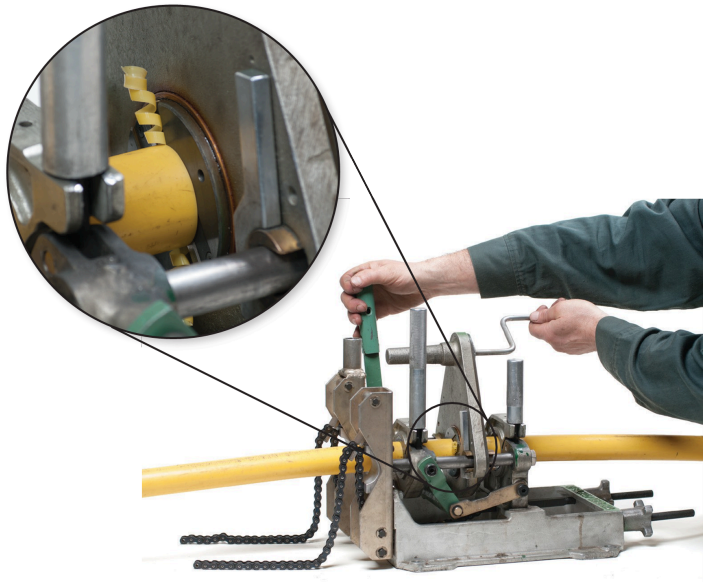

Figure 72 *Facing the pipe end (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 73 shows the operator checking the final alignment of the pipe ends after facing. Alignment is critical and should be perfect, with no gap between the pipe ends.

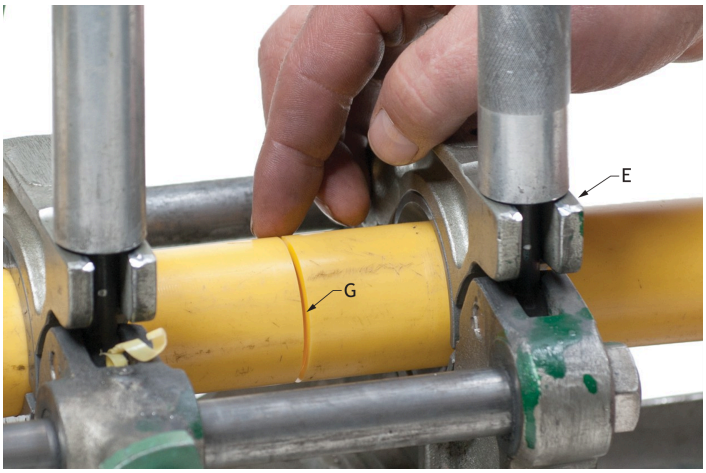

Figure 73 *Pipe ends in alignment* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

- Note the following in the above figure: the clamps (E) are positioned close to the joint.
- The pipe ends are aligned and ready for the heating iron (G).

Fusion Welding Procedure

Before proceeding with the weld, do the following:

- Make sure you have cleaned the ends of the pipe with a clean, non-synthetic cloth or paper towel. Remove burrs and debris from inside the pipe ends.
- Recheck the alignment. There should be no gaps, nicks, etc.
- Check the tightness of the cold clamps. Do not overtighten.
- Make one last check for proper alignment.
- You are now ready to install the fusion heater.

The fitting and pipe must be clean and dry. Use a clean cloth to wipe the mating surfaces. Do not touch the surfaces with your hands.

Figure 74 *Cold-clamping ring being used in preparation for fusion welding hands-free without the fusion assembly (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The procedures shown here are for education purposes only. Always follow manufacturer specifications, standards, and procedures. Fusion welding procedures are found in the manufacturer's specification or in recognized approved and accepted standards. Follow the procedure carefully and adhere to all specified parameters. Failure to follow the pipe manufacturer's procedure could result in a defective joint.

Basic Procedures

Following are general, non-specific fusion welding procedures:

1. **Clamping:** The pipe and fitting must be held firmly to allow all subsequent operations to take place.
2. **Cleaning:** The area of pipe that the fitting will contact must be cleaned.
3. **Aligning:** The fitting must be properly seated on the pipe for proper alignment.
4. **Heating:** A melt pattern must be formed that penetrates into the pipe and into the fitting.
5. **Joining:** The pipe and fitting must be joined and the pipe fully seated within the fitting.
6. **Holding:** The molten joint must be held immobile until adequately cooled.
7. **Inspecting:** Visually examine the entire circumference of the joint for compliance with standards established by your company, customer, industry or local regulations.

Procedures for Butt Joint Fusion Welding

1. Plug in the heater and confirm that it reaches the correct temperature according to the manufacturer's specifications. This is normally 260°C ±4°C (500°F ±7°F). Also check the surface temperature using a Tempilstik.

Figure 75 *Temperature at 260°C (500°F) (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

2. Place the heater into the assembly and bring both pipe ends into contact with the heater surface. Do not apply any pressure.

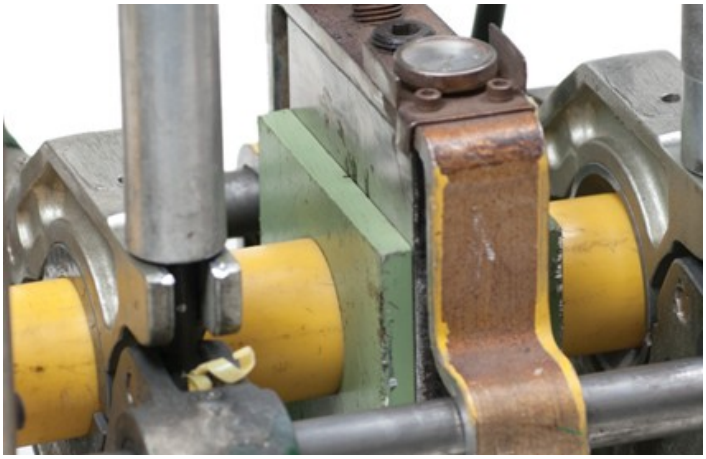

Figure 76 *Pipe contacting heater (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

3. Allow the pipe ends to form a bead (melt pattern), approximately 3 to 4 mm (0.12 to 0.16 in) in size.

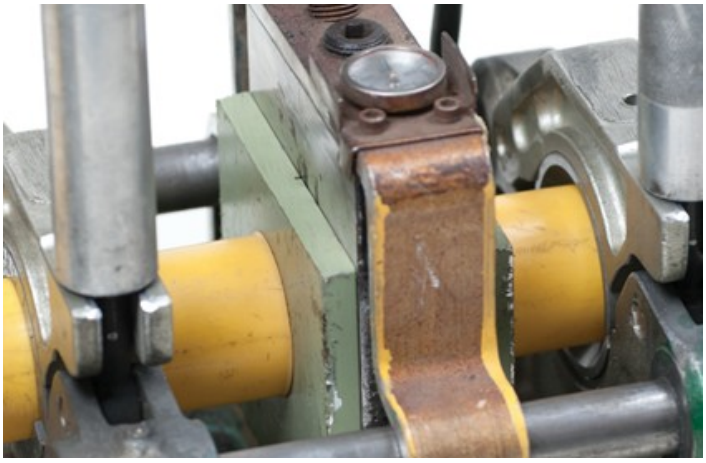

Figure 77 *Melt pattern on pipe end (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

4. Move the ends of the pipe away from the heater and remove the heating plate quickly. Bring the ends of the pipe together rapidly without slamming. Use just enough force to form a ***double roll-back bead***. Too much force will push melt away from the bead, resulting in a poor fusion. Hold in position until you can touch with your finger comfortably. Wait for approximately 10 minutes before applying any stress to the joint.

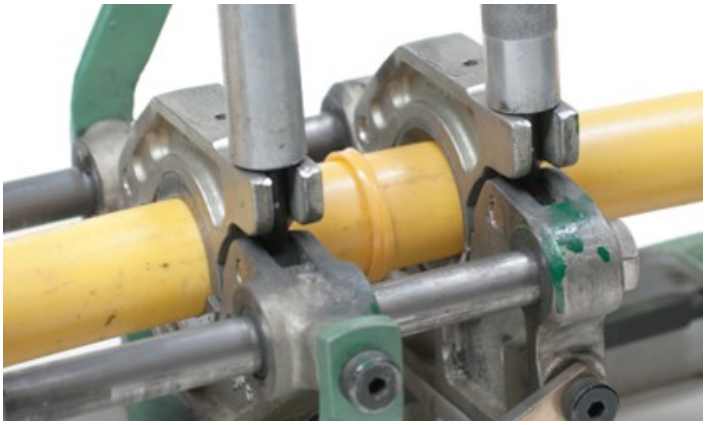

Figure 78 *Double bead (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Temperature, applied pressure, and melt and cooling times are critical factors in creating a good fusion joint. With practice, you will learn when and how much pressure to apply to complete a fusion joint.

Safety Precautions for Butt Joint Fusion Welding

The heater is not explosion-proof. Take safety precautions when operating the heater in hazardous environments to prevent explosion, injury, or death. Bring the heater up to temperature in a safe environment, then unplug it before entering the hazardous environment to perform the weld. Use a clean, natural-fibre cloth to clean the heater adapter surfaces.

Clearly mark all hot surfaces to indicate they are hot. Store the heated iron in the appropriate holder to stay hot when in use or to cool off when not in use.

Precautions for Cold Weather Butt Fusion Welding

Follow these precautions when butt fusing pipe in cold weather:

1. Avoid hitting the pipe ends on hard surfaces. Cold temperatures make plastic more brittle and susceptible to damage from mechanical abuse, such as impact.
2. Carefully remove, by light tapping and scraping, any snow, ice, or frost from inside and outside the open ends and the areas to be clamped in the joiner. Failure to remove ice and snow could lead to incomplete fusion at the joint and slippage of the jaws.
3. Use tape or paper ***shims*** if needed to prevent clamps from slipping during cold weather. Clamping inserts are usually more than adequate to prevent pipe slippage, but slippage can still occur when pipes contract in low temperatures.
4. Follow the standard butt fusion steps, giving particular emphasis to the fusion steps. The time required for an initial melt bead to form will be longer than usual. Do not apply greater than normal pressure to the pipe ends.
5. Bring the pipe ends together quickly after removing the heater plate from between them. Do not slam the pipe ends together.
6. Protect and shelter the heating and fusion tools from high winds or rain to prevent excessive heat loss and to keep the heating tool dry at all times. The melt area should also be sheltered to reduce heat loss from the melted ends and to prevent rain or moisture from contaminating the fusion area.

Saddle Fitting with a Built-in Hole Cutter

Some saddle fittings have a built-in cutter. After fusion, the cutter can be advanced to cut the hole in the pipe. The removed cut-out section from the hole is held in the cutter, and the cutter is then repositioned at the top of the saddle. The cap is then reinstalled. The fitting may also function as a shut-off valve.

Figure 79 *Saddle fitting with built-in cutter (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 80 *Cap removed to show cutter head (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Saddle Fusion Procedure

Saddle fusion (also called *sidewall fusion*), is used when installing polyethylene service saddles onto compatible polyethylene pipe mains.

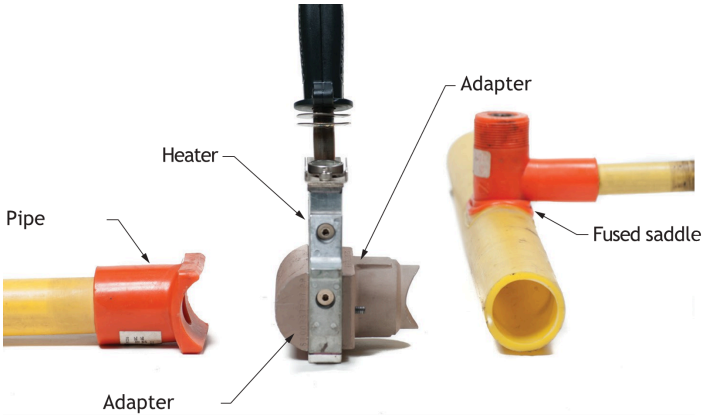

Figure 81 *Saddle fusion components (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 82 *Installed saddle (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Follow this procedure when saddle fusing pipe:

1. Clean the pipe surface so that it is free of dirt, oil, and water. Remove any printed ink lettering with a clean cloth.
2. Install the fusion machine on the main. Ensure that the machine is adequately supported in the desired position and that it is firmly attached to the pipe.
3. Prepare the surface of the pipe and fitting by first roughing with coarse emery cloth then brushing away any loose material.
4. Align the fitting on the main, then tighten the fitting while applying slight pressure on the movable clamp handle.
5. Check the saddle base for square alignment on the main.
6. Use a Tempilstik to check the heating iron temperature, which should be 260°C ±4°C (500°F±7°F). Take care not to contaminate the actual fusion surface with Tempilstik residue.
7. Quickly place the heater onto the main and remove it. Check for evidence that the heater has contacted all areas of the main. Two to three seconds of heating time should indicate this. If the main is not contacting the heater properly, the most probable reason is that the pipe is out of roundness. This can sometimes be corrected by either tightening or loosening the clamp knobs. The heater must be proven to make full contact with the main before fusion can be started.
8. Place the heater between the fitting and the main. Apply firm (but not excessive) pressure while heating. Ensure that the heater is centred under the fitting. Continue to heat until a bead has formed on the pipe and on the fitting all the way around the heater. The last place that the bead should form is on the pipe, in the middle of the heating

iron face

9. Once the bead is at least 1.6 mm ($\frac{1}{16}$ in) all the way around, snap the fitting and main apart and snap the heater free. Be careful not to damage the pipe or the fitting while removing the heater. Care must be taken not to over-melt the main, as there is a risk of a blowout if the main is under pressure. The recommended maximum time for the heater to contact the main is 30 seconds.
10. Bring the melted surfaces together quickly, but do not slam the surfaces together. Apply continuous progressive pressure until a proper fusion bead is formed. Maintain pressure until the joint has cooled sufficiently to allow your finger to remain comfortably on the bead.
11. Remove the saddle fusion unit and inspect the fusion. The joint should have a uniform, well-aligned appearance all around. There should appear to be three beads at the fusion joint. Inspect the joint for gaps or voids or other evidence of incomplete fusion.
12. Do not subject the fitting to any abnormal stresses until the fusion is sufficiently cooled, which should be in approximately 10 minutes.
13. Do not drill or tap through the main until the pipe is sufficiently cool.

Precautions for Cold Weather Saddle Fusion

Follow these precautions when saddle fusing pipe in cold temperatures:

- The length of time necessary to obtain a complete melt pattern will depend not only on the outdoor (pipe) temperature, but also on wind conditions, pipe tolerances, and operator variation.
- If possible, store the fittings at room temperature before use. This will make it easier to place the fittings on the heating iron, because fittings shrink when subjected to low temperature.

After observing the above precautions, follow normal saddle fusion procedures.

Socket Fusion Welding Procedure

Follow this procedure when ***socket fusing*** pipe:

1. Cut the pipe square using shear-type cutters or pipe cutters fitted with special plastic pipe cutting wheels.
2. Chamfer pipe sizes 31.75 and 50.8 mm (1- $\frac{1}{4}$ and 2 in). Smaller sizes do not require chamfering.

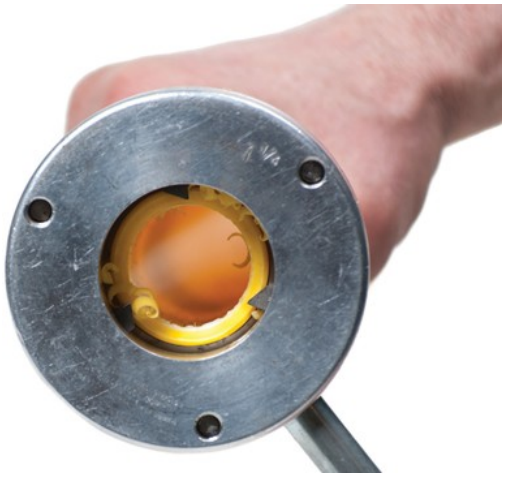

Figure 83 *Chamfering tool (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

3. Remove any oil or dirt from the surfaces to be joined. Sand pipe ends with emery cloth and then remove any loose material with a clean dry cloth or paper towel.
4. Place the depth gauge on the end of the pipe to allow for correct positioning of the cold ring. Position the cold ring on the pipe and remove the depth gauge.

Figure 84 *Setting cold ring depth (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

5. Use a Tempilstik to check the heating iron temperature, which should be 260°C ±4°C (500°F±7°F). Take care not to contaminate the actual fusion surface with Tempilstik residue.
6. Push the socket fitting into the heating iron until it bottoms out, and then place the heating iron on the pipe until it bottoms against the cold ring. Hold it there until the surfaces melt, about 5 to 40 seconds, depending upon the diameter and the temperature of the heating iron.
7. Quickly remove the fitting and the pipe from the heating iron. Immediately push the fitting squarely onto the pipe until it bottoms against the cold ring. Do not twist or rotate the pipe in the socket. Hold the fitting onto the pipe for the duration of the cooling cycle (see manufacturers' documentation).

Figure 85 *Socket fusion weld (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Additional Considerations

- Do not subject the joint to any externally applied stresses (pulling or bending) until it is completely cool, generally in about 10 minutes.
- Inspect the joint for evidence of complete fusion. This is shown by a flat melt bead pattern on the fitting that completely encircles the pipe.
- Clean the heating iron of any residue after use.

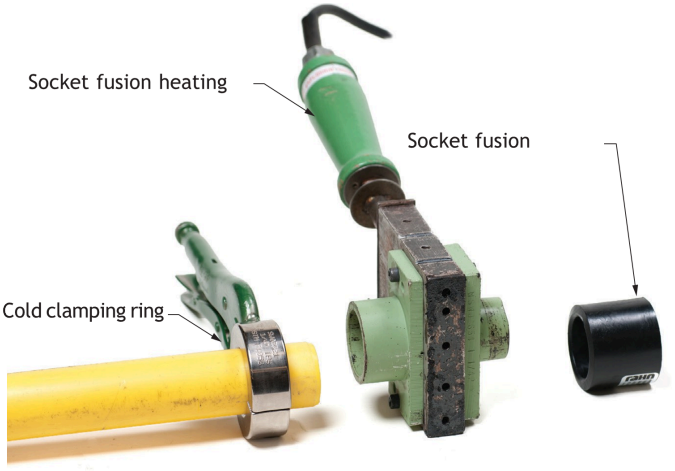

Figure 86 *Socket fusion components (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Precautions for Cold Weather Socket Fusion

Follow these precautions when socket fusing pipe in cold weather:

1. Remember that the length of time necessary to obtain a complete melt pattern will depend on the outdoor (pipe) temperature, wind conditions, pipe tolerances, and operator variation.
2. If possible, store fittings at room temperature before use. This makes it easier to place fittings on the heating iron because fittings shrink when subjected to low temperatures.
3. The pipe also contracts in cold conditions, which may result in loose or slipping cold-clamp rings. For best results, clamp one cold-clamp ring in its normal position directly below the depth gauge, then place ***shim*** material (a piece of paper or tape) around the inside diameter of a second cold-clamp ring and clamp it directly behind the first cold-clamp ring to prevent slippage. The first cold-clamp ring will allow the fused portion of pipe to expand to its normal diameter during heating.
4. Under abnormal or extreme weather conditions, use the following method to determine melt times for socket fusion:
    a. Place the heater onto a pipe test piece and begin timing when the cold-clamp ring bottoms out.
    b. After a chosen heating time, quickly remove the pipe from the heater and gouge the outer pipe wall with a screwdriver or other sharp object. The correct heating time is achieved when half of the wall thickness can be gouged out in this manner. If less than half of the wall thickness can be gouged out, increase the heating time; if more than half can be gouged out, decrease the heating time.
    c. Discard all gouged test pieces.
5. After observing the above precautions, follow normal socket fusion procedures.

Solvent Welding Plastic Piping

Figure 87 *Glueing lengths of pipes (https://commons.wikimedia.org/wiki/File:David_Caldwell_glueing_lengths_of_pipe_(12366938823).jpg) (USFWS/Southeast/Wikimedia Commons) CC BY 2.0 (https://creativecommons.org/licenses/by/2.0/deed.en)*

Solvent cementing is the process of fusing plastic pipe and fittings by the use of an adhesive containing a suitable active solvent system and an appropriate resin. This process is referred to as ***solvent welding***.

Plastic piping systems are easy to install, but larger sizes (more than 50 mm or 2 in) require a degree of expertise to produce a leak-free joint.

Most plastics are joined by inserting ***plain-ended piping*** into fittings and solvent welding them together. PVC and chlorinated poly-vinyl chlorine (CPVC) piping and fittings are joined with a different type of solvent cement than acrylonitrile butadiene styrene (ABS).

Consult the manufacturer's detailed directions on the solvent cement container. Environmental conditions, such as temperature and moisture, will affect the time required for the joint to set.

Safety Precautions for Solvent Cements

Ensure there are no ignition sources in the area you are working, as solvent cements are flammable.

- Ensure that the work area has adequate ventilation, or wear a respirator.
- Wear protective eyewear and avoid contact of solvent cement or cleaner with your skin.
- Read the manufacturer's Material Safety Data Sheet (MSDS) before using the solvent cement.

Solvent Cementing Joining Procedures

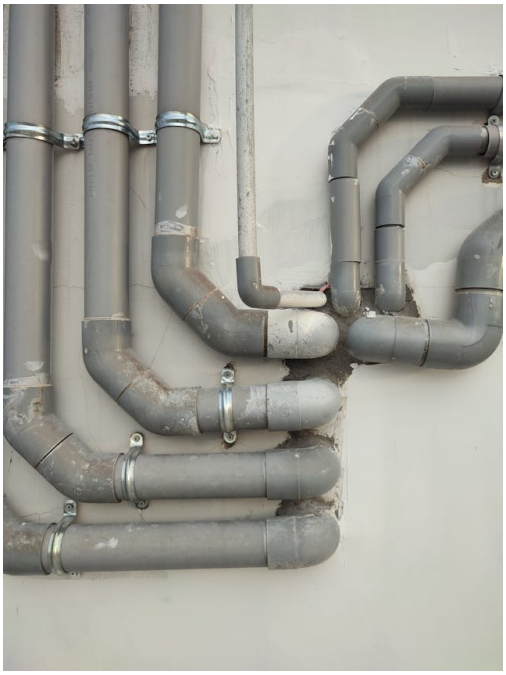

Figure 88 *Plastic Pipes joint (https://www.pexels.com/photo/plastic-pipes-on-wall-12142829/) (Bùi Hoàng Long/Pexels) Pexels license (https://www.pexels.com/license/).*

These procedures apply to all types of plastic: ABS, PVC, and CPVC.

1. Pipe preparation
    a. **Cutting:** Cut pipe square using a hand hacksaw and miter box, a power circular or hand saw with a

suitable guide, or a rotary cutter if the cutting wheel is specifically designed for cutting plastic pipe.

   b. **De-burring and bevelling:** Using a knife, de-burring tool, or coarse file, remove all burrs and sharp edges from the pipe. All pipe ends should be bevelled with a coarse file or bevelling tool. This will minimize the chance of wiping the solvent cement from the fitting socket during installation, which could result in a leaking joint. Do not use sandpaper on plastic pipes. It may remove too much material for successful joining.

2. **Fitting preparation:** Before solvent cementing, all fittings should be inspected for cracks or damages. Fittings should be exposed to the same temperature as the pipe for at least an hour, to ensure that they are thermally balanced before joining.
3. **Cleaning:** Clean the pipe end and fitting socket thoroughly. The surfaces to be joined must be clean, dry, and free of dirt and grease. Some plastics may recommend a liquid cleaner be used.
4. **Dry fitting:** Solvent cement joints are designed so that there will generally be interference of pipe wall with the fitting socket before the pipe is fully inserted. Usually this occurs when the pipe is inserted $\frac{1}{3}$ to $\frac{2}{3}$ of the socket depth during dry fitting. Therefore, do not use this step to check your measured lengths. Sometimes, when the pipe and fittings are at their tolerance extremes or when Schedule 80 pipe is used, it may be possible to fully insert the dry pipe into the fitting until it bottoms. If this occurs, the fit should be snug. If the fit is loose or wobbly other fittings or pipe should be selected to give a proper fit.
5. **Priming:** ABS, PVC, and CPVC are different materials. Although their cementing procedures are similar, they are different and are outlined separately below.
   a. **ABS:** Cleaner may be used to prime the mating surfaces. However, in most cases, experienced installers can achieve successful bonding without the use of a primer.
   b. **PVC and CPVC:** The use of a primer is recommended and is mandatory for all pressure applications. Our PVC-1, which is a one-step cement, does not require the use of a primer and can only be used on non-pressure applications. The function of the primer is to penetrate and soften the bonding surfaces, especially the high-gloss and hard-glaze surfaces of the pipe and fittings, before applying the cement. Apply primer to the fitting with a dauber or brush.

"One step" cement can be used when installing CPVC fire sprinkler piping.

6. Solvent cementing:
   a. Choose the proper CSA-certified solvent cement.
   b. Using an applicator, evenly apply a heavy coating of solvent cement to the pipe and a light coating to the socket. Now apply a second coating to the pipe, ensuring that sufficient material is present to fill all gaps.
   c. Making certain that the cement on the pipe and fitting is still "wet," insert the pipe into the fitting until it bottoms in the socket. Then give it a $\frac{1}{4}$ turn to ensure complete and even distribution of the cement. Make sure that the joint is positioned correctly, as the cement sets in a few seconds.
   d. If the pipe does not insert smoothly or does not twist easily, take the joint apart immediately. Apply more cement and rejoin. The use of a cleaner or primer will extend the open time and setting time.
   e. Hold the joint together until the cement has set. This may take up to two minutes depending upon pipe size. Avoid disturbing the joint until it is fully cured.
   f. Immediately after joining, wipe off all excess cement. A properly made joint will show a bead around its entire perimeter. Gaps may indicate a defective assembly resulting from insufficient cement.

Joint Integrity

Figure 89 *Outdoor pipes (https://pixabay.com/photos/tap-water-pipes-closed-water-pipe-5142411/) by (Alexei other/Pixabay) Pixabay Content License (https://pixabay.com/service/license-summary/).*

Joint integrity depends upon a tremendously wide variety of product and environmental conditions. These include size of pipe, ambient temperature, surface temperature of the joint, humidity, dry joint interference fit, and others. In general, drying times will be faster with smaller diameter pipe, higher surface temperatures, tighter interference fits, and lower humidity. Drying times will be slower when the opposite conditions exist.

Recommendations

1. Avoid joining at atmospheric temperatures below 5°C (41°F) or above 32°C (90°F) when exposed to direct sunlight. For work outside of this preferred range, refer to the sections below on hot-, cold- and wet-weather cementing.
2. Allow at least 48 hours of joint drying time before a joint is moved or subjected to any internal or external pressure. When in doubt about proper cementing techniques under particular conditions, contact the solvent cement manufacturer for expert advice.

Cementing Under Wet Conditions

Moisture inhibits the bonding of plastic pipes and fittings. In failed joints a white film or residue often appears, indicating the presence of water during the joining process. Cementing can be done in wet weather and in wet environments but it is imperative that the mating surfaces be dry when the joint is made.

The following suggestions may help in wet situations:

1. Work under a cover or canopy to keep rain off the pipe and fittings.
2. Use a cleaner or primer to aid in the removal of moisture.
3. Work quickly after drying the pipe and fitting to avoid condensation.

4. Use a very fast-drying and fast-setting cement to limit the period of time when the joint is vulnerable to moisture. A fast-setting cement requires the worker to apply more cement and to work very quickly to ensure that the cement is still fluid when the pipe is inserted into the fitting.
5. Allow a longer cure time before the system is tested or used.

Hot Weather Cementing

When atmospheric temperatures are above 32°C (90°F), certain precautions have to be taken to avoid excessive solvent evaporation from the cement. Such evaporation may cause the cement to set prematurely and adversely affect joint integrity.

The following steps can reduce these challenges:

1. The surface temperature of the mating surfaces should not exceed 45°C (113°F) at the time of assembly. Shade or shelter the joint surfaces from direct sunlight for at least an hour prior to joining and also during the joining process. Swabbing the surface to be cemented with cleaner may reduce the pipe temperature; wet rags may also be used, provided the parts are thoroughly dried before primer or cement are applied.
2. Make cement joints during the cooler, early morning hours.
3. Apply cement quickly. On 15 cm (6 in) and larger pipe we recommend that two workers apply cement to the pipe surface while a third applies it to the fitting socket.
4. Join pipe to the fitting as quickly as possible after applying cement.
5. To minimize solvent loss, keep cement container closed or covered when not in use.

Cold-Weather Cementing

Working in freezing temperatures is never easy. However, if the job of solvent cement welding is necessary, you can do it successfully with proper solvent cements. By following the manufacturer's standard instructions and using a little extra care and patience, successful solvent cemented joints can be made at temperatures even as low as –26°C (–14.8°F). In cold weather, solvents penetrate and soften the plastic pipe and fitting surfaces more slowly than in warm weather. In addition, the plastic is more resistant to solvent attack, making it more important to pre-soften surfaces withan aggressive primer. Because of the slower evaporation, a longer cure time is necessary. Cure schedules provided by the manufacturer will allow a margin for safety, but for colder weather, more time should be allowed.

Suggestions for Quality Joints in Cold Weather

1. Prefabricate as much of the system as is possible in a heated work area.
2. Store cements, cleaners and primers in a warmer area when not in use and make sure they remain fluid.
3. Joints that must be made outside should be protected with a portable shelter and heated with indirect heat to surface temperatures above 5°C (41°F) before joining. The shelter and heat should remain in place for at least two hours after joint assembly.
4. Although PVC-1 (one-step) cement can be used in cold weather, it is extremely important that extra care be taken when applying the cement, so that proper penetration and softening of the pipe and fitting surfaces are achieved.

The use of a primer when using PVC-1 during an extreme cold-weather installation will be beneficial to the final results if shelters and heating set-ups cannot be done in the welding area.

5. Take special care to remove moisture including ice and snow from the surfaces to be joined. On PVC and CPVC pipe and fittings the surfaces must be cleaned with a manufacturer-approved cleaner.
6. Before assembly, after the pipe has been cut, cleaned and dry-fitted as per the instructions on the label, primer must be used to soften the joining surfaces on PVC or CPVC installations before applying cement. On ABS installations, cleaner may be used as the primer. More than one application may be necessary.
7. Allow a longer cure period before the system is used. A heat blanket may be used to speed up the set and cure times.
8. It is extremely important to read and follow all of the manufacturer's directions carefully before installation. For all practical purposes, good solvent-cemented joints can be made in very cold conditions, with proper care.

Caution: Do not attempt to speed the setting or drying of the cement by applying direct heat to the solvent-welded joint. Forced rapid drying by heating will cause the cement solvents to boil off, forming porosity, bubbles and blisters in the cement film.

Estimating Solvent Cement Requirements

The actual number of joints can vary considerably due to installation conditions and techniques, tolerance variations, and socket depths. Since the cement is the least expensive material being used, it is better to use too much cement than not enough.

Refer to manufacturer documentation.

Set Times and Cure Schedules

During the initial setting of the cement (approximately 2 minutes), the joint should not be moved or disturbed. Numerous factors, such as application conditions and the specific cement used, affect the actual cure rates, which may be faster or slower than the times indicated. In damp or humid weather, allow 50% more set time and cure time; extended set times are required for chemical applications.

Refer to manufacturer documentation for exact curing schedules. The initial set schedule is the necessary time needed before the joint can be carefully handled.

PVC and ABS Testing

For testing, refer to manufacturer documentation and applicable local code requirements.

Joining ABS to PVC Piping

Transition solvent cement is solvent cement used to join ABS drainage and PVC drainage pipe and fittings. This solvent cement is white in colour and is typically used only for a single transition joint within a system. You are not permitted to switch back and forth from ABS to PVC several times. This solvent cement is often used to connect ABS DWV pipe to PVC sewer pipe after the ABS pipe leaves the building. Procedures for joining are the same as for ABS and PVC.

Threaded Piping Connections

Various types of iron, steel, heavy copper, and plastic piping may have threaded ends. The most common type uses external threads that are joined with internally threaded fittings.

Threading pipe is an essential skill in the piping trades. Pipe threads are widely used to join pipe and fittings. You must be able to produce high-quality threads and assemble leak-proof joints. Poor threading can lead to serious problems, especially in gas or pressurized systems.

A common question is, “How tight do you tighten the pipe and fittings?” The answer is: tight enough to prevent leaks, but not so tight that the fitting is damaged. Over-tightening may stretch a malleable fitting or crack a cast iron fitting. The correct feel is developed through experience.

The number of pipe threads that remain exposed after you have finished tightening the fitting onto the pipe will give some indication of the joint quality. Typically, two to three threads should remain visible. If no threads are visible, the joint may be over-tightened. If too many threads are visible, the joint may be under-tightened.

Figure 90 *Correctly threaded joint (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Procedures for Threaded Jointing

Installation of threaded joints involves the cutting of threads and assembling the joint. Threads may be cut using a power threader or by hand. When cutting threads by hand, follow these steps:

1. Select the proper size of die.
2. Clean the pipe surface. Be sure the end is square and free of burrs. Chamfering the pipe end will make it easier to start the die.
3. Mount the threader on the pipe with the die's leading threads facing the pipe.
4. Apply thread cutting oil.
5. Apply pressure to start the die on the pipe.
6. The thread length is correct when the outer surface of the die is even with the end of the pipe (for full-width dies).
7. Remove the die and clean the threads with a brush or rag.
8. Apply an approved joint compound or tape that is to the external threads only.
9. Hand-tighten the fitting, then tighten to the required degree using the correct wrench.

Precautions for Threaded Jointing

Figure 91 *Plumber installs (https://www.pexels.com/photo/plumber-installs-pipe-fittings-6419128/) (Anıl Karakaya/Pexels) Pexels license (https://www.pexels.com/license/)*

- Threaded components and threaded ends should be examined before assembly for cleanliness and continuity of threads, and to ensure they conform with applicable standards.
- Compound or lubricant used on threads must be suitable for the service conditions and should not react unfavourably with either the service fluid or the piping material.
- Threaded joints that are to be seal-welded are made up without thread compound or lubricants.
- When a design requires threaded piping to be seal-welded, seal welds must cover all exposed threads.

Compression and Flared Joint Guidelines

Figure 92 *Wrenches to tighten a fitting (https://commons.wikimedia.org/wiki/File:Plumber_uses_two_wrenches_to_tighten_a_fitting.jpg) (Tomwsulcer/Wikimedia Commons) CC0 1.0 (https://creativecommons.org/publicdomain/zero/1.0/deed.en)*

For the proper installation and maintenance of compression and flared fittings, use the following guidelines:

- Inspect flare surfaces for imperfections before assembly.
- Where the manufacturer's instructions call for a specified number of turns of the nut, count these from the point at which the nut becomes finger tight.
- Cut ends square using the recommended method as per the type of material.
- Deburr inside and outside for proper entry into fitting and to prevent system contamination and or restricted flow.
- Clean tube ends. Remove all filings, chips, and grit before attachment of fittings.
- Do not force an improperly fitted tube line into the fittings. The fabrication of tube lines (your bend angles and measured lengths) must be accurate. Check to see that the tube end easily enters the fitting in proper alignment.
- The tube end must be bottomed against the shoulder in the fitting body. This is necessary to prevent movement of the tube, while the nut forces the ***ferrule*** to grip the tube and to seal through any imperfections that may exist on the outside tube surface.
- Use two wrenches. Never permit the fitting body to rotate during tube end makeup. Assemble port connectors to components first and hold this with your first wrench while making up the tube joint. All types of union bodies must be held while each of the tube ends is made up.

Other Types of Pipe and Tube Jointing

Other types of pipe and tube jointing methods include:

- Mechanical joints with external clamping and sealing components, such as elastomeric gaskets and sealing rings.
- Insertion jointing where the pipe is pushed into the fitting, sealed with O-ring-type gaskets with a variety of

profiles to suit the particular manufacturer's fittings and applications. These connections often include components that use compression forces to hold the pipe together and seal the joint.

Many types of piping can be joined with special types of fittings, such as mechanical joint couplings used with cast iron drainage and vent piping, roll and cut grooved pipe couplings and fittings, compression fittings, slip-on fittings, or insert fittings. In some cases, plumbing codes will restrict where and when these types of fittings and jointing methods can be used.

Procedures for these types of fittings may require the pipe ends to be prepared in ways such as the following:

- Measuring
- Cutting the pipe or tubing ends square
- Reaming, de-burring or chamfering the pipe ends
- Cleaning the pipe or fitting end and sockets ends or checking both inside and outside for debris or damage
- Applying lubricants on the pipe or fitting when required
- Ensuring correct arrangement of any clamp components, such as retaining rings, washers sleeve, seals, etc.
- Attaching the clamp and any component parts fully to one end of the pipe or fitting
- Inserting fully the other pipe or fitting end into the clamp
- Aligning the pipe, fittings, and clamps correctly
- Tightening any components, keeping joint alignments as you proceed, following any specified tightening sequences as required to ensure proper seal and joint strength
- Testing all piping system as required by the engineering, manufacturers' and code specifications

Mechanical Joint Method

Mechanical joint or zip couplings use screws or bolts to tighten a stainless-steel collar that compresses a neoprene or rubber sleeve (gasket) around the joint. These couplings can join plain-ended pipe and fittings.

Figure 93 *Mechanical joint coupling (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

O-Ring or Gasket Joints (Slip-On Joints)

Hub-and-spigot piping and fittings can be joined with **O-rings** or special *elastomeric gaskets*. O-rings are usually rubber or neoprene ring gaskets that fit over the spigot pipe end and inside the hub of the fitting. The O-rings may be different profiles to match a particular pipe manufacturer.

The O-ring is held in place by the tight fit of the pipe and fitting and seals the pipe joint. In some pipes, a groove is machined into the hub end of the pipe to hold the O-ring in place. This type is often referred to as a ***slip-on joint***. This method of joining is commonly used with ductile iron water pipe.

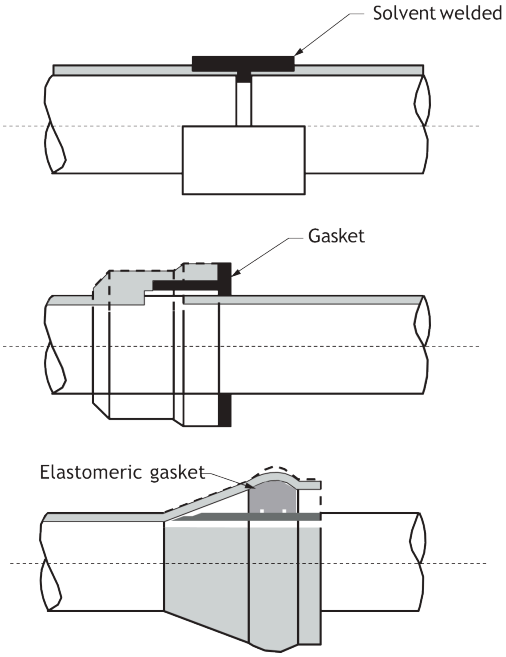

Figure 94 *Three types of slip-on joints (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

For calculation of fitting allowances, see the calculations for piping measurements in *Block B: Tools and Equipment* (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/).

Flanges

Flanges may be used to join plastic or metal piping. Flanges may be welded or screwed to metal pipe. Plastic flanges may be solvent welded or screwed together.

When measuring for flanged piping, allow for the thickness of the gaskets that will be installed between the flanges (Figure 95).

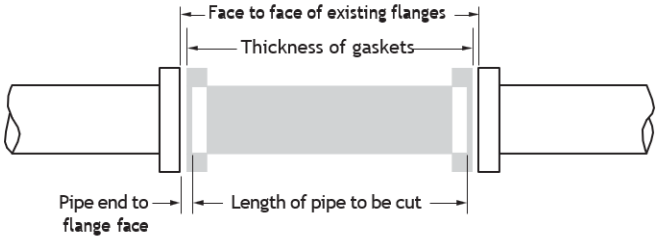

Figure 95 *Measuring piping joined by flanges (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

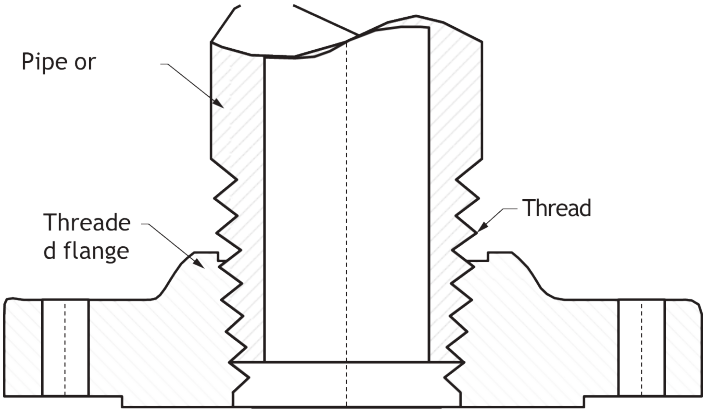

Figure 96 *Side view of threaded flange on pipe*
1. Threaded flange 2. Thread 3. Pipe or fitting (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

When installing a threaded flange, fully tighten the flange onto the pipe so that the end of the pipe is almost even with the face of the flange. Place the flanges on each piece of pipe together with a sealing gasket between each face. Align the bolt holes in each flange, then insert and tighten bolts to complete the seal.

Making a Flanged Joint

There are four basic steps in making a flanged joint:

1. Clean all surfaces on the parts, remove any grit or grease from the flanges, and make sure the gasket is clean.
2. Support the flanges and align the bolt holes. Support the part that you are installing and align the flanges both face-to-face and hole-to-hole (this is known as ***timing flanges***). Bevelled punches are often used to do this.
3. Insert the gasket. For ring gaskets, insert the bottom bolts first, rest the gasket on them and then insert the rest of the bolts. For full-face gaskets, first insert a bottom bolt through one flange, one hole of the gaskets and the other flange. Then roll the gasket into place and insert the other bolts.
4. Tighten the bolts evenly using the ***crossover method***. Apply a bit of thread lubricant to each bolt and run up the nuts by hand as far as they will go. Then use a wrench to snug the bolts using the crossover method. The crossover method ensures that bolts are tightened evenly. Start with the top bolt, then tighten the opposite bolt on the bottom, then tighten the bolt on the left side, then the right side, etc. Tighten all the bolts, following the same

numerical sequence shown in Figure 97. Be sure to not over-torque the bolts.

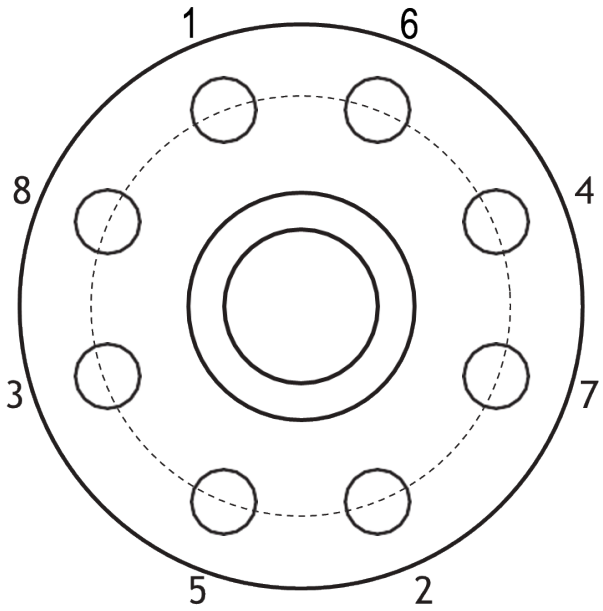

Figure 97 *Bolt-tightening order – crossover method (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Note: Sequence and torque method and values vary depending on flange size and ratings, temperature, pressure, etc. Always follow the manufacturer's recommendations and engineering specifications specific to the installation. For more information on bolt tightening sequence, refer to the section on valves in IPT's *Pipe Trades Handbook*.

Flange Alignment: Checking Highs and Lows

When installing a flange, it is critical to align the inside diameters so that they are exactly centred. Do this by making sure the OD of the mated flanges are flush with each other (adjust so the highs and lows are flush). If the inside diameters, including the gasket, are not flush, inside turbulence is created, resulting in friction loss and/or noise and erosion.

High and low piping termination describes surface misalignment of the outside diameters of pipes at the point where the two pipes are joined.

Bolt-Tightening Torque

Tighten the bolts in the correct sequence and torque.

- Torque bolts in stages
- Follow the recommended sequence (30%, then 60%, then final value)
  ▸ If this sequence is not followed, the flanges can be misaligned. Then, regardless of the amount of subsequent tightening, they cannot be brought back to parallel. This more of a problem on metallic gaskets than on non-

metallic ones.

On high-pressure, high-temperature applications, the flanges should be retightened after 24 hours at operating pressures and temperatures to compensate for any relaxation or creep that may have occurred.

Common Practices When Completing Flanged Joints

Be sure to:

- Inspect the gasket seating surfaces for damage.
- Make sure the gasket material is suitable for the contents of the system. Look for any defects or damage in the gasket.
- Inspect and clean each stud or bolt, each nut, each washer and the facing on the flanges against which the nuts will rotate.
- Lubricate all thread contact areas and nut facings. When flanges are to be subjected to high temperatures, consider using an anti-seize compound to facilitate subsequent disassembly.
- With raised face and ring gasket installation, loosely install the stud bolts on the lower half of the flange.
- Insert the gasket between the flange faces to allow the bolts to centre the gasket on the assembly. Install the balance of the bolts and nuts and bring all to a hand-tight or snug condition.

Pipe Flange Assembly

Using a Torque Wrench

A ***torque wrench*** is a tool used to precisely apply a specific torque to a fastener, such as a nut or bolt. It is used where the tightness is critical. The torque wrench is used to measure the torque applied to the fastener so it can be matched to the torque tension specifications required for an installation.

General Torque Wrench Guidelines

Follow these general rules when using a torque wrench:

- Never over-torque a fastener. Over-torquing can cause a fastener to stretch beyond normal limits, causing it to break or come loose.
- Never under-torque a fastener. The fastener could come loose or break.
- Follow torque specifications and sequences for torque application.
- Apply fastener lubricants as required by the manufacturer.
- Read and follow the manufacturer's direction for the torque wrench you are using.
- Do not re-use a fastener if it was installed with an impact wrench.
- Do not use a torque wrench to remove a fastener, especially if it was installed with an impact wrench. You could damage the torque wrench.

Fastener (Bolt) Failure

Fasteners such as bolts could fail under the following circumstances:

- Overloading caused when the torque force exceeds the fastener strength. The fastener may loosen or shear.
- Over-tightening (over-torquing) may cause damage to the threads or deforming of the parts.
- Under-torquing may cause the joint to come loose. It may also allow the joint to flex and thus fail when fatigue occurs.
- *Brinelling* caused by poor-quality washers, leading to a loss of clamp load and failure of the joint.
- Disintegration of a part due to oxidation or other forms of corrosion. This is why fasteners must be lubricated unless stated otherwise by the equipment manufacturer.

Brinelling is a material surface failure caused by contact stress that exceeds the material limit. This failure is caused by just one application of a load great enough to exceed the material limit. The result is a permanent dent or a permanent deformation of the metal surfaces.

Click-Type Torque Wrench Procedures

- Preset the torque value on the torque wrench as specified by the equipment manufacturer
- Torque the fastener using the specified tightening sequence to the point where the desired torque is reached. Listen for a click sound, which indicates that the torque value has been reached.
- Reset the torque value to zero before putting the wrench away.

For more information on torquing, refer to IPT's *Pipe Trades Handbook* (Section 5 Gasketed Joints).

Standard Flange Bolts and Flange Stud Bolts

Bolt up the flanges using stud bolts and the correct bolt-tightening sequence.

The flange stud bolt nuts, located on each side of the mated flanges, must have the same number of threads exposed past the nuts. The 2H or similar identifying mark must be visible.

Stud Bolt Grade Markings

Thread rods and nuts must be marked by the manufacturer with a unique identifier to identify the manufacturer or private label distributor, as appropriate. Figure 98 shows examples of ASTM markings.

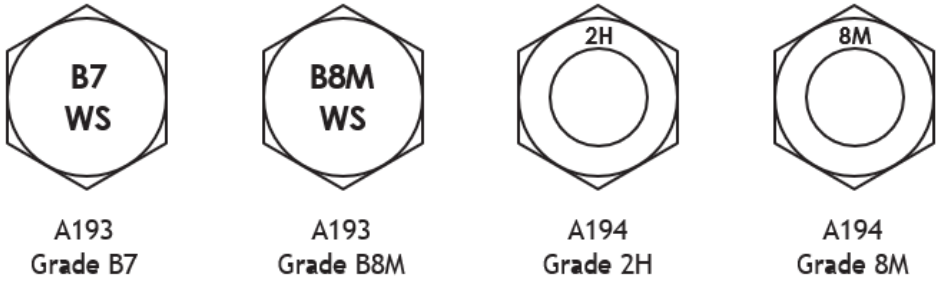

Figure 98 *Stud bolt markings (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Corrugated Stainless Steel Tubing (CSST)

Specialty piping such as ***Corrugated Stainless-Steel Tubing (CSST)*** is flexible gas piping suitable for connection to natural gas or propane appliances, and for natural gas and propane piping systems. CSST and its related fittings may have manufacturer-specific methods of installation and jointing that require specialized training. Figures 99–106 show examples of CSST tubing and fittings.

The following information is generic in nature. On the job, you must refer to the specific manufacturer specifications when selecting fittings and installing corrugated stainless-steel tubing (CSST) piping systems.

The installation of CSST flexible gas piping must be performed by a qualified installer who has successfully completed the manufacturer's training program. The installer must also meet all qualifications required by the authority having jurisdiction.

Figure 99 *Coil of CSST (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Straight fittings connect the flexible gas tubing to gas supply, distribution manifolds, or gas appliances.

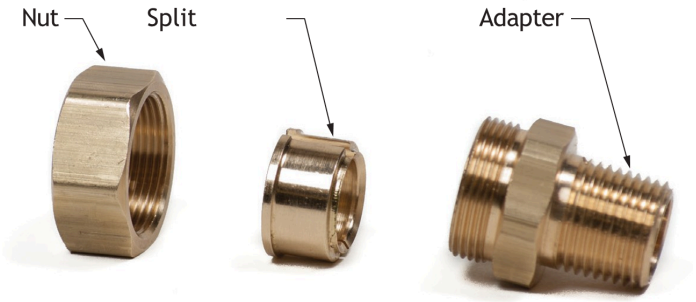

Figure 100 *Straight fitting (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Tee fittings create a branch line on tubing runs. Couplings allow for the splicing and additions to the flexible gas tubing.

Figure 101 *Tee fitting (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 102 *Termination fitting (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 103 *Marks on fitting indicate FlashShield (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 104 *Appliance stub-outs Gastite (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 105 *Striker plates (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 106 *Flexible steel conduit for protection (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

General Installation Requirements for CSST

These installation requirements must be used in conjunction with all applicable building standards and codes. In the event that there is a conflict between these guidelines and the local code, the more stringent requirement will take precedence.

- Store all tubing, fittings and hardware in a clean, dry location prior to installation.
- Temporarily plug or tape closed the open ends of tubing prior to installation, to prevent entrance of dirt, dust or other debris.
- The protective plastic jacketing should be kept in place as much as possible to protect the tubing from corrosive threats. Contact with chemicals containing chlorides must be followed by a thorough rinse and wipe dry. This includes fluxes used to solder copper tubing and acid-based cleaners used to wash masonry.
- Keep tubing away from sharp objects.
- Only qualified installers trained in the individual manufacturer's installation instructions can install CSST flexible gas piping.
- Use only the components provided or specified by the manufacturer (including ***striker plates*** and ***armour conduit***).
- Never use CSST flexible gas piping or system components as a ground electrode or as a grounding path for appliances or electrical systems.
- CSST flexible gas piping routed in a location that is concealed, constrained and within 7.5 cm (3 in) of a potential threat must be protected against damage by protection devices listed in the manufacturer's instructions. Contact with sharp objects or harmful substances should be avoided.
- Protect concealed tubing from puncture threats using provided striker plates at all points of penetration through studs, joists, plates or similar structures. The extent of protection is defined in the manufacturer's documentation.
- CSST greater than 25.4 mm (1 in) inside diameter installed within hollow cavity walls made of 2 × 4 construction shall be protected along the entire concealed length in the manner and using the shielding devices specified by the manufacturer.
- The width of the installed striker plate, at the points of penetration through wall studs, floor joists, plates, sills, etc., shall be out at least 1.5 times the outside diameter of the tubing.
- Temporarily plug or tape closed open ends of tubing prior to installation, to prevent entrance of dirt, dust or other debris.
- Keep protective yellow jacketing in place as much as possible to protect the tubing from corrosive threats. Contact with chemicals containing chlorides must be followed by thorough rinse and wipe dry. This includes fluxes used to solder copper tubing and acid-based cleaners used to wash masonry.
- Installation clearance holes for routing CSST are to be approximately 12.7 mm ($\frac{1}{2}$ in) greater than the OD of the CSST. Drilling of any structural member must be in conformance with the local building codes. See manufacturer's guidelines for the recommended drill hole sizing.
- Support CSST tubing with pipe straps (metal pipe straps are preferred), bands or hangers suitable for the size and weight of the tubing, at intervals specified in manufacturer's documentation and codes.
- Do not put stress or strain on the tubing and fittings. Avoid sharp bends, stretching, kinking or twisting of the CSST tubing.
- Sizing of CSST must be performed using the capacity tables found in the manufacturer's guidelines.
- Don't connect CSST flexible gas piping to movable appliances. Connections to movable appliances such as ranges and clothes dryers should be made with a flexible gas appliance connector.
- Regulators are suitable for multi-poise mounting. When using a vent-limiting device, the regulator must be mounted in a horizontal upright position. For outdoor venting, the vent line must be at least the same size as the vent connection and no longer than 914 cm (30 ft) before upsizing. When mounting a regulator outdoors, remove

vent limiting device and position regulator inverted with open port down.

- A manifold assembly shall include a shut-off valve ahead of the regulator and shall be installed in an accessible location so that the regulator can be inspected, maintained and serviced, if necessary.
- CSST shall not be buried directly in the ground or directly embedded in concrete (i.e., patio slabs, foundations and walkways). When it is necessary to bury or embed CSST, the tubing shall be routed inside a non-metallic,

  watertight conduit that has an inside diameter at least 1.27 cm ($\frac{1}{2}$ in) greater than the OD of the CSST tubing. For

  ends of conduit installed outdoors, the conduit shall be sealed at any exposed end to prevent water from entering. No mechanical joint fittings are permitted within the conduit. Note: CSST must be buried in accordance with all local building codes.

CSST flexible gas piping system must be pressure-tested for leaks during rough construction, in accordance with all local codes. In the absence of local requirements, test in accordance with Part 4 of the NFPA 54, National Fuel Gas Code ANSI Z223.1 and/or CSA B149.1 Installation Code or in accordance with the requirements of the applicable local codes. For a one-part pressure-test, the regulator should be removed from the system. For a two-part test, the regulator should be isolated from downstream test pressures.

Leak-test solutions may cause corrosion in some types of material in the gas piping system. Be sure to water rinse after the test and thoroughly dry all contacted material.

- CSST tubing installed along the outside of a structure (between the ground and a height of 183 cm [6 ft]) in an exposed condition shall be protected from mechanical damage inside a conduit or chase. A conduit or chase is not required if the tubing is installed in a location that will not subject the CSST to mechanical damage.
- Don't use CSST tubing as a means of support for the gas meter. Also check with your local code official or authority having jurisdiction on meter hook-ups. Some restrictions may apply. Local code requirements will always take precedence.
- For a piping system that includes manual gas valves listed as complying with requirements, the instructions shall state that these valves shall not be installed outdoors.
- When using CSST through metal enclosures, the CSST tubing must be protected by grommets, bushings or armour, PVC tape, shrink sleeve material or a minimum of four wraps of minimum 10 mil duct tape. This is to ensure that no physical contact will be made between the metal and the CSST tubing that would cause mechanical wear.
- Physical contact between CSST and a metallic chimney liner and/or vent is prohibited. If this physical separation cannot be specifically identified in the local building code and achieved or, any local building code requirements cannot be met along the entire length, then rerouting of the CSST is required unless such installation is specifically permitted by the local building authority.
- Gas code requirement: CSST systems and copper tubing shall only be connected to an appliance secured in place (not movable). (CSA B149.1 6.11.5)
- Gas code requirement: CSST system piping or copper tubing shall not be used to connect to a meter, unless the

meter assembly is independently supported. (CSA B149.1 6.14.8)

- Gas code requirement: CSST tubing shall be protected against physical damage in accordance with the manufacturer's certified instructions and with the gas code. (CSA B149.1 6.16.12)
- The corrugated stainless steel tubing system has a number of essential hardware and design differences from conventional gas piping using rigid steel pipe and copper tubing. These differences are described as follows:
    - In many applications, the tubing is sized for individual gas appliance loads and is therefore usually small in diameter. The tubing may also be installed in a parallel fashion from a central distribution manifold rather than a series layout commonly used for rigid pipe systems.
    - CSST is pulled through the structure similar in fashion to electrical wiring and therefore requires different handling and installation techniques than rigid pipe.
    - Rigid termination of the tube ends is required.
    - Flexibility and strike plates protect the CSST allowing it to be run in concealed spaces.

Identify CSST tubing, Fittings, and Supports

You should be able to identify and name corrugated CSST tubing, fittings, and supports, and identify the basic joint connection methods. You will also need to know how to describe basic installation requirements for CSST tubing. The following image shows the parts of a CSST joint.

Figure 107 *CSST MIP joint components left to right, nut, locking bushings and fitting (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Detailed CSST Assembly Procedures

The following is a manufacturer's installation procedure for completing a CSST joint. Other manufacturers of this CSST tubing system will provide similar procedures. But you will need to apply the installation requirements particular to the manufacture tubing you are using.

Important: Be advised that it is necessary that you comply with any applicable installation codes, such as the Gas Code.

Step 1: Cut to Length

Cut tubing to the desired length, leaving approximately 2.5 cm (1 in) for fitting the attachment. Centre the cut between two corrugations. Use light roller pressure with extra rotations in one direction to leave tubing round and free of burrs. **Note:** To ensure a quality flare, make all cuts on a straight section of tubing.

Figure 108 *Cut the pipe (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Step 2: Strip Jacket

Using a utility knife, strip the jacket back to the valley of the second corrugation. Do not cut the jacket in such a way that the sealing surface of the tubing is scored. The short piece of jacket can easily be removed by placing the utility knife blade under the jacket to peel the jacket off.

Caution: Tube ends are sharp. Use care when handling.

Figure 109 *Strip the jacket (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Step 3: Install Nut and Bushings

Thread fitting body into appliance or manifold. Slide nut over tubing. Separate bushings and position into the valley of

the first corrugation. Leave one corrugation exposed between the end of the bushings and tubing. At this point, the bushings will begin to capture the jacket for a contaminant-resistant seal.

Figure 110 *Bushing jacket locking feature (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pipe dope or sealant must not be used inside the fitting prior to assembly.

Step 4: Position Bushings

Insert bushings into fitting body. A small amount of resistance indicates the bushings are being compressed to further capture the jacket. Note: The piloting feature of the bushings ensures the tubing is aligned properly with the fitting body for a uniform flare and a gas-tight seal.

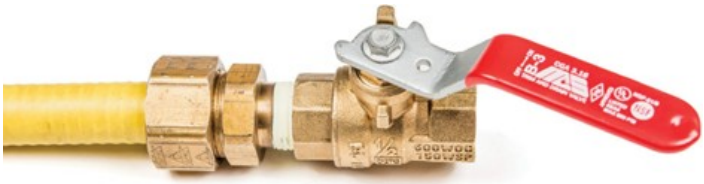

Figure 111 *Align components (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Step 5: Tighten the Fitting

Slide nut over bushings and thread onto fitting body. There will be some resistance as the nut begins to compress the tubing and create the double wall flare. Continue to thread the nut until resistance to wrenching increases greatly, and the double wall flare is tightly seated.

Note: During the tightening process, rotate the nut only. Do not rotate the fitting body. Any portions of the exposed stainless-steel tubing shall be wrapped with tape or sleeved to prevent threats by acids or chloride-based cleaning solutions for masonry. Self-bonding silicone tape is recommended here for durability.

Figure 112 *Tighten the fitting nut (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Consult the manufacturer's torque values or specifications for tightening instructions.

Describe Basic Installation Requirements for CSST Tubing

CSST can be installed in a variety of ways. Ensure that the manufacturer's instructions are followed and conform to applicable codes, such as the Gas Code.

Figure 113 *CSST installation, manifold and support bracket and regulator (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

A manifold assembly using a pounds-to-inch regulator should include a shut-off valve ahead of the regulator. It should also be installed in an accessible location so that the regulator can be inspected, maintained and serviced, if necessary.

CSST Tubing Basic Installation Practices and Tubing Protection

Open ends of CSST tubing are to be temporarily plugged or taped closed prior to installation to prevent entrance of dirt, dust or other debris.

CSST must be protected from electrical contact with stray electrical currents, or static buildup. Protection is provided by bonding (grounding) the tubing to a ground rod or source, as required by electrical codes. The ground clamp must be clamped directly (touching) to a metal component of the CSST system, not clamped over the plastic sheath.

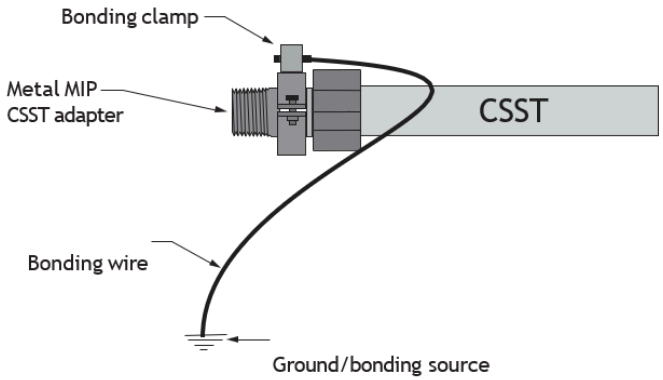

Figure 114 *Example of bonding of CSST tubing system (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Never use CSST flexible gas piping or system components as a ground electrode or as a grounding path for appliances or electrical systems. Refer to the manufacturer's instructions. Direct bonding of CSST will be required. When installing CSST tubing, take care to maintain as much separation as reasonably possible from other electrically conductive systems in the building. Any metal piping system, including CSST, that is not adequately bonded may cause any electrical charge to arc from one system to another. Arcing can cause damage to CSST. Ensure the bonding of the CSST is complete to a ground rod or the electrical panel. A qualified electrician may be responsible for this work.

Protection of Concealed CSST

The following are examples of methods used to protect concealed CSST tubing—always refer to manufacturer installation guides and the authority having jurisdiction [AHJ].

- Protect concealed tubing from puncture threats, using the striker plates provided, at all points of penetration through studs, joists, plates, or similar structures.
- For all points of penetration less than 2 in (50.8 mm) from any edge of a stud, joist, plate, etc., a striker plate is required to provide protection at the area of support and within 5 inches (127 mm) of each side (if appropriate) of the support.
- At points of penetration 2 to 3 inches (50.8 to 76.2 mm) from any edge of a stud, joist, plate, etc., a striker plate is required to provide protection throughout the area of support.
- At points of penetration greater than 3 inches (76.2 mm) from any edge of a stud, joist, plate etc., no protection is required.

Protecting CSST from Puncture Damage

CSST tubing can be damaged after it has been installed and when the ***wall cladding*** is attached to the rough wall framing. As the cladding is attached, screws or nails are driven through wall cladding and can penetrate the CSST tubing. This results in gas leakage.

To prevent this from happening, metal shields called striker plates or steel conduit are installed at locations where a nail or screw will likely be used. CSST tubing routed horizontally through studs should also be protected from puncture threats between the studs with provided shielding devices.

The following diagrams show where the strike plates are used.

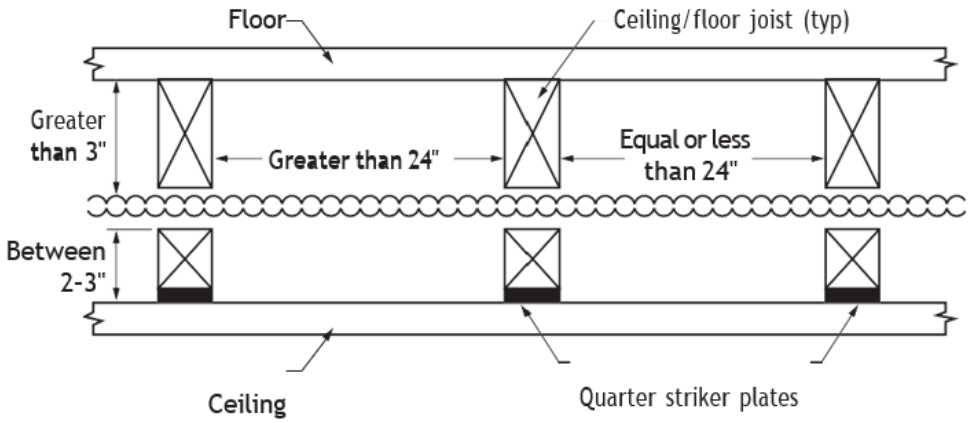

Figure 115 *Location of quarter striker plates and steel conduit (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

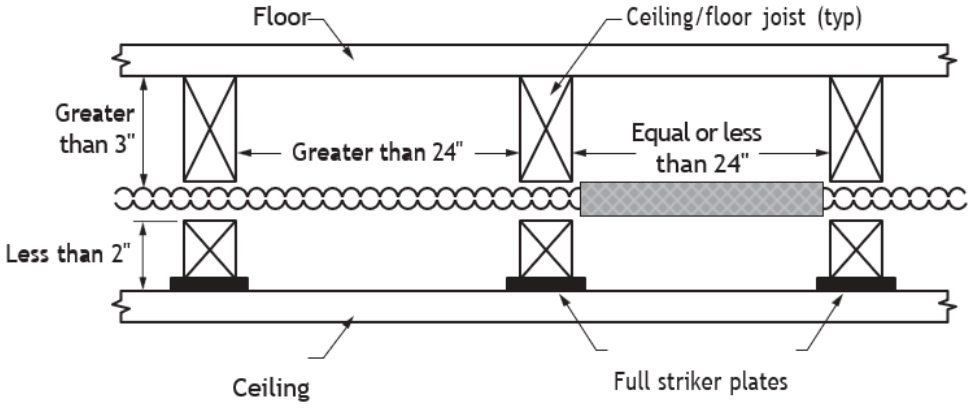

Figure 116 *Location of full striker plates and steel protective conduit (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

CSST tubing needs to be supported with pipe straps, bands, or hangers suitable for the size and weight of the tubing. The supports should be placed at intervals not to exceed those shown in the tables outlined in the manufactures installation guide and/or applicable codes.

Avoid undue stress or strain on the CSST tubing and fittings. Also avoid sharp bends, stretching, kinking, or twisting of the CSST tubing.

The following pictures show examples of striker plates and steel conduit used to protect CSST tubing from damage from penetration by nails, screws, or other items used to attach drywall or other wall claddings or attachments.

Figure 117 *Floppy steel conduit installation (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 118 *Striker plate applied at upper wall plates (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The width of the installed striker plate, at the points of penetration through wall studs, floor joists, plates, sills, etc., should be out at least 1.5 times the outside diameter of the tubing.

Flexible gas piping routed in a location that is concealed, constrained, and within three inches of a potential threat should be protected against damage by approved protection devices, as shown below.

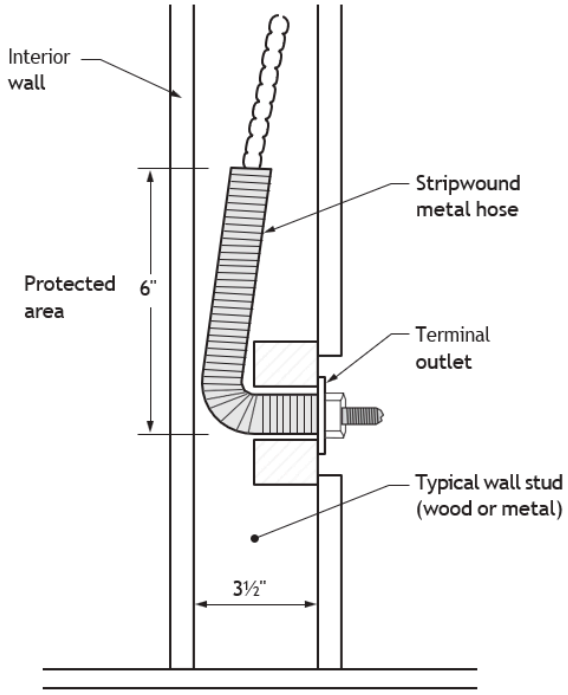

Figure 119 *CSST Termination with strip wound metal hose placed over the CSST when the CSST comes too close to the surface of the wall. (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The following is an example of a grommet used when CSST passes through a metal stud.

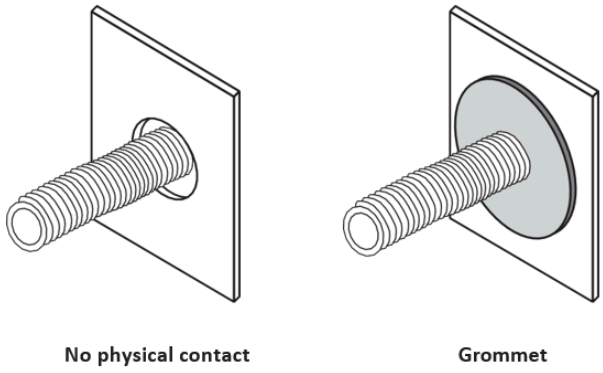

Figure 120 *Grommet used with CSST (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

A grommet keeps CSST centered in the hole, avoiding contact damages from sharp edges.

For installations buried underground, concrete, asphalt or embedded in concrete, CSST flexible gas piping must be

routed in a non-metallic watertight conduit that has an inside diameter at least ($\frac{1}{2}$ in) inch larger than the outside diameter of the tubing. No mechanical joints are permitted within the conduit.

Self-Test D-1.6: Install Tubing and Pipe

Complete Self-Test 1.6 and check your answers.

If you are using a printed copy, please find Self-Test D-1.6 (#chapter-self-test-d-1-6-section-6) and Answer Key (#chapter-answer-key-self-test-d-1-6-2) in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://d-pipingcomponents-bcplumbingapprl1.pressbooks.tru.ca/?p=1936#h5p-6 (https://d-pipingcomponents-bcplumbingapprl1.pressbooks.tru.ca/?p=1936#h5p-6)

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- Plumber: Competency D-1 Prepare Pipe

- Steamfitter: Competency D-4 Layout and Install Piping and Tubing
- Sprinkler Fitter: Competency D-1 Prepare Pipe and Tubing

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- **Figure 87** Glueing lengths of pipes (https://commons.wikimedia.org/wiki/File:David_Caldwell_glueing_lengths_of_pipe_(12366938823).jpg) by USFWS/Southeast from Wikimedia Commons is used under a CC BY 2.0 (https://creativecommons.org/licenses/by/2.0/deed.en) license.
- **Figure 88** Plastic Pipes joint (https://www.pexels.com/photo/plastic-pipes-on-wall-12142829/) by Bùi Hoàng Long from Pexels, is used under the Pexels license (https://www.pexels.com/license/).
- **Figure 89** Outdoor pipes (https://pixabay.com/photos/tap-water-pipes-closed-water-pipe-5142411/) by Alexei other from Pixabay is used under the Pixabay Content License (https://pixabay.com/service/license-summary/).
- **Figure 91** Plumber installs (https://www.pexels.com/photo/plumber-installs-pipe-fittings-6419128/) by Anıl Karakaya from Pexels, is used under the Pexels license (https://www.pexels.com/license/).
- **Figure 92** Wrenches to tighten a fitting (https://commons.wikimedia.org/wiki/File:Plumber_uses_two_wrenches_to_tighten_a_fitting.jpg) by Tomwsulcer from Wikimedia Commons is used under a CC0 1.0 (https://creativecommons.org/publicdomain/zero/1.0/deed.en) license.

Self-Test D-1.1 Describe Piping and Tubing Materials

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

1. What is piping marked with the word “potable” used for?
    a. Clear waste
    b. Footing drain
    c. Rain water
    d. Drinking water
2. What is thermoplastic pipe?
    a. Capable of softening or fusing when heated
    b. Capable of becoming permanently rigid when heated or cured
    c. Sensitive to shattering when struck
    d. Permanently soft and flexible
3. What does the term “nominal pipe size” refer to?
    a. Actual inside diameter
    b. Actual outside diameter
    c. Approximate inside diameter
    d. Approximate outside diameter
4. What pipe or tubing has the largest outside diameter for the same nominal size of pipe or tubing?
    a. Copper tubing size
    b. Iron pipe size
    c. Air conditioning tube size
    d. Nominal pipe size
5. What is the thread angle of National Pipe Thread?
    a. 45 degrees
    b. 56 degrees
    c. 60 degrees
    d. 65 degrees
6. What schedule number is standard weight pipe?
    a. 20
    b. 40
    c. 60
    d. 80
7. What formula is used to determine the standard dimension ratio (SDR)?
    a. Minimum wall thickness to the average outside diameter
    b. Average outside diameter to the minimum wall thickness
    c. Average inside diameter to the average outside diameter
    d. Average outside diameter to the average inside diameter
8. What type of tubing material would be identified by a stamping of K, L, M, or DWV?
    a. Aluminum
    b. Copper
    c. Plastic
    d. Steel

9. What pipe or tubing is typically used in heavy industry such as marine seawater and ship building, pulp and paper manufacturing, medical gas systems, and chemical manufacturing?
    a. Bronze alloys
    b. Carbon steel
    c. Zinc alloy
    d. Nickel and nickel alloys
10. What piping or tubing is an alloy of copper and zinc?
    a. Bronze
    b. Monel
    c. Brass
    d. Stainless steel
11. What piping material contains amounts of silicon and cast iron and could be used for acids, solvents, or bleaches?
    a. Duriron
    b. Wrought iron
    c. Black iron
    d. Stainless steel
12. What piping material that contains chromium is often used where corrosion and oxidation occur?
    a. Copper nickel
    b. Stainless steel
    c. Brass
    d. Aluminum
13. What piping material is used for potable water distribution, is very strong, fracture-resistant, and centrifugally spun?
    a. Ductile cast iron
    b. Cast iron
    c. Duriron
    d. Austenitic cast iron
14. What piping material is suitable for fire sprinkler systems?
    a. PVC CSA B181.1
    b. PE CSA B137.1
    c. CPVC standard B137.6.09
    d. CPVC Type IV Grade 1 cell class 23447

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

Answer Key: Self-Test D-1.1

1. d. Drinking water
2. a. Capable of softening or fusing when heated
3. c. Approximate inside diameter
4. b. Iron pipe size
5. c. 60 degrees
6. b. 40
7. b. Average outside diameter to the minimum wall thickness
8. b. Copper
9. d. Nickel and nickel alloys
10. c. Brass
11. a. Duriron
12. b. Stainless steel
13. a. Ductile cast iron
14. d. CPVC type IV Grade 1 cell class 23447

Self-Test D-1.2 Describe the Methods of Manufacture of Piping and Tubing

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

1. What pipe is manufactured by passing strips of high-temperature metal through rollers until shaped and electrically welded at a seam?
    a. Cast iron
    b. Ductile iron
    c. Stainless steel
    d. Carbon steel

2. What tube or piping is manufactured by forcing a heated billet through a die orifice and over a mandrel?
    a. Brass
    b. Copper
    c. Ductile iron
    d. Cast iron

3. What copper tube is identified by its outside diameter?
    a. Type ACR
    b. Type L
    c. Type K
    d. Type DWV

4. What piping is made from a heated raw pellet material, continuously extruded through an annular die, then cooled into a particular size?
    a. Carbon steel
    b. Plastic
    c. Aluminum
    d. Stainless

5. What piping is manufactured using the (Engel) method?
    a. PEX
    b. ABS
    c. PE
    d. PB

6. What pipe is manufactured using an extruding head that allows air to be inserted in the middle of the pipe?
    a. PEX
    b. ABS
    c. PE
    d. PB

7. What is one of several methods used to manufacture steel pipe?

a. Extrusion
b. Mandrel piercing
c. Electro-resistant weld
d. Pressure weld

8. What method of manufacturing steel pipe starts with a coiled ribbon of steel plate called a skelp?
    a. Seamless weld
    b. Mandrel piercing
    c. Electro-resistant weld
    d. Pressure weld

9. What pipe is manufactured in sizes from 1/8–26″ diameter and is typically used in construction, oil refining, chemical, and petro-chemical industries where chemical and oxidation are an issue?
    a. PE
    b. Copper
    c. PVC
    d. Seamless steel

10. What pipe is produced in a cupola furnace and uses either casting molds or a centrifugal casting process?
    a. Cast iron soil pipe
    b. PVC pipe
    c. Galvanized iron
    d. Seamless steel

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

Answer Key: Self-Test D-1.2

1. d. Carbon steel
2. b. Copper
3. a. Type ACR
4. b. Plastic
5. a. PEX
6. b. ABS
7. c. Electro-resistive weld
8. c. Electro-resistant weld
9. d. Seemless steel
10. a. Cast iron soil pipe

Self-Test D-1.3 Describe the Methods of Pipe and Tubing Support

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

1. What is the maximum distance between supports for ABS piping?
    a. 900 mm (3′)
    b. 1219 mm (4′)
    c. 1524 mm (5′)
    d. 3048 mm (10′)

2. What description best describes a consideration for seismic restraint for a hot water storage heater tank?
    a. Install the heater 300–500 mm away from the wall
    b. Install one perforated iron strap at the bottom of the heater
    c. Use rigid water supply connections to hold the tank secure to the wall
    d. Provide wooden blocks to prevent the heater from sliding backwards

For each image (3–13), choose the correct component name from the list below.

a. Pipe covering protection shield
b. Single expansion insert
c. Pre-cast hanger anchor insert
d. Constant spring support
e. One-hole strap
f. Side beam bracket
g. Wood-form cast-in-place insert
h. Horizontal rod hanger (hanger-up)
i. Clevis hanger
j. U-clamp pipe to sway brace
k. Adjustable swivel ring hanger

3.

4.

5.

6.

7.

8.

9.

10.

11.

12.

13.

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

Answer Key: Self-Test D-1.3

1. d. Provide wooden blocks to prevent the heater from sliding backwards
2. b. 1219 mm (4')
3. e. One hole strap
4. k. Adjustable swivel ring hanger
5. f. Side beam bracket
6. d. Constant spring support
7. h. Horizontal rod hanger (hanger-up)
8. i. Clevis hanger
9. j. U-clamp pipe to sway brace
10. g. Wood form cast-in-place insert
11. c. Pre-cast hanger anchor insert
12. a. Pipe covering protection shield
13. b. Single expansion insert

Self-Test D-1.4 Describe the Methods of Protecting Piping

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

1. What can be done to protect a pipe from internal corrosion?
    a. Polymer coating
    b. Polyester fibre coating
    c. Sandblasting
    d. Laminar flow

2. What determines the type of external coatings applied to a pipe?
    a. Velocity of the fluid
    b. Colour of the piping
    c. Thickness of the pipe wall
    d. Expected damage

3. What is used to protect pipes from damage caused by rocky backfill?
    a. Treated wood
    b. Rock guards
    c. Rock screen mesh
    d. Mastic coating

4. What is the purpose of a transition sleeve?
    a. To join two pipes of different materials
    b. To protect underground welded joints
    c. To join two pipes of different diameters
    d. To provide internal alignment of pipe joints

5. What does constant circulation prevent?
    a. Turbulence
    b. Oxidation
    c. Freezing
    d. Corrosion

6. What type of pipe insulation is shown in Figure 1?
    a. Closed-cell poly
    b. Rock wool
    c. Fibreglass
    d. Mineral wool

7. Which of the following terms is used to describe the application of heat with an electric cable to prevent a pipe from freezing?

    a. Circulation
    b. Insulation
    c. Boxing in
    d. Heat trace

Figure 1 Closed-cell polyethylene foam pipe

8. Which of the following is an example of rigid pipe insulation?

    a. Rock wool
    b. Heat trace
    c. Styrofoam
    d. Mineral wool

9. Which of the following is installed to prevent punctures of piping passing through wood studs?

    a. Rock wool
    b. Steel plates
    c. Plastic grommets
    d. Closed-cell poly

10. Which piping material needs protection against ultraviolet light when in storage?

    a. Copper
    b. PEX
    c. PVC
    d. Fibreglass

11. Under what conditions can condensation form on a pipe?

    a. Pipe warmer than the ambient air temperature
    b. Pipe colder than the ambient air temperature
    c. Heavily insulated pipe
    d. Low-humidity air and a warm pipe

12. What can be done to prevent condensation on piping?

    a. Enclose the pipe in a wall
    b. Apply reflective moisture paint
    c. Reduce moisture content in the air
    d. Increase moisture content in the air

13. What is the purpose of a pipe expansion joint?

    a. Prevent expansion
    b. Keep the pipe cool
    c. Increase expansion range
    d. Control expansion

14. What is the purpose of a pipe guide?

    a. Allow the pipe to buckle
    b. Keep the pipe in line

c. Support the pipe
d. Show where the pipe is located

15. What is the minimum number of elbows in a swing joint?

a. 1
b. 2
c. 3
d. 4

16. A 40 m (43.7 yards) copper pipe is heated from 8 to 61°C (46 to 142°F). The thermal expansion coefficient is 0.0000166 per degree Celsius (0.0000093 per degree Fahrenheit).
What is the total expansion of the pipe, expressed in metres?

a. 0.352
b. 0.035
c. 0.532
d. 0.875

17. Which of the following terms is used to identify corrosion protection for pipe caused by an electrochemical reaction?

a. Anodic protection
b. Cathodic protection
c. Electrolysis
d. Galvanic

18. Which metal is the least noble?

a. Copper
b. Stainless steel
c. Magnesium
d. Brass

19. What is the name given to the fitting in Figure 2?

a. Galvanized union
b. Stainless coupling
c. Eccentric reducer coupling
d. Dielectric union

Figure 2 Example fitting

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

Answer Key: Self-Test D-1.4

1. a. Polymer coating
2. d. Expected damage
3. b. Rock guards
4. b. Protect underground welded joints
5. c. Freezing
6. a. Closed cell poly
7. d. Heat trace
8. c. Styroform
9. b. Steel plates
10. b. PEX
11. a. Pipe warmer than the ambient air temperature
12. c. Reduce moisture content in air
13. d. Control expansion
14. b. Keep the pipe in line
15. c. 3
16. b. 0.035
17. a. Anodic protection
18. c. Magnesium
19. d. Dielectric union

Self-Test D-1.5 Describe the Methods of Manufacture of Piping and Tubing

Complete Self-Test D-1.5 and check your answers.

1. What is the result of using defective materials?
    a. Lower costs
    b. Time savings
    c. You will not need to replace the material
    d. Invalid manufacturer's warranty

2. What would be the correct action to take if the end of a cast-iron pipe is damaged?
    a. Cut the damaged end off
    b. Use a clamp to seal over the cracked end
    c. Seal the crack with a sealing compound
    d. Discard the entire pipe

3. What would you do to inspect coiled copper tubing when it arrives at the job site?
    a. Pressure-test the pipe
    b. Straighten the pipe out to full length
    c. Solder caps on the ends
    d. Inspect coils for pinching or flattening

4. What would you do to inspect a steel pipe length when it arrives at the job site?
    a. Remove the protective shipping coating from the entire pipe length
    b. Inspect the internal bore for debris
    c. Thread the pipe end and cap
    d. Grind off any bevels

5. What type of pipe has the SDR rating printed on it?
    a. Cast iron
    b. Copper
    c. Polyethylene
    d. PEX

6. What would you do to help detect a crack in a cast iron pipe or fitting before use?
    a. Test the fitting with air
    b. Test the fitting with water
    c. Blow air on the fitting
    d. Tap the fitting on a hard surface

Answer Key: Self-Test D-1.5 (#chapter-answer-key-self-test-d-1-5) is on the next page.

Answer Key: Self-Test D-1.5

1. d. Invalid manufacturer's warranty
2. a. Cut the damaged end off
3. d. Inspect coils for pinching or flattening
4. b. Inspect the internal bore for debris
5. c. Polyethylene
6. d. Tap the fitting on a hard surface

Self-Test D-1.6 Install Tubing and Pipe

Complete Self-Test D-1.6 and check your answers.

1. Who is responsible for making a pipe joint correctly?
    a. Owner of the premises
    b. Engineer who designed the joint
    c. The manufacturer who made the fitting
    d. The tradesperson who installed the joint
2. Which of the following best describes the action by which liquid solder is drawn into the annular space between the inside fitting wall and the tubing outside wall?
    a. Capillary action
    b. Osmosis
    c. Attraction
    d. Adhesion
3. Which pipe joining method uses temperatures below 427°C (800° F)?
    a. Brazing
    b. Eutectic
    c. Soldering
    d. Fusion
4. Which solder filler metal is not approved for use in potable water systems?
    a. Antimony
    b. Lead
    c. Nickel
    d. Tin
5. What is the purpose of a soldering and brazing flux?
    a. Promote oxidation
    b. Keep the metal surface dry
    c. Prevent oxidization
    d. Prevent overheating
6. Which of the following is the first step when preparing a pipe for soldering?
    a. Cut the pipe
    b. Deburr the pipe
    c. Clean the pipe
    d. Measure the pipe
7. Which method of joining copper tube is used with an extracted tee joint?
    a. Push–fit
    b. Brazing
    c. Press-fit
    d. Soldering
8. How big should the branch connection of an extracted tee be?
    a. Same size as the tee mainline
    b. One size smaller than the tee mainline
    c. One size larger than the tee mainline

d. 1-½ times smaller than the tee mainline

9. Which method of joining copper tube requires no tools?

   a. Push-connect
   b. Pressure fit
   c. Compression fit
   d. Roll groove fit

10. Which method of joining polyethylene uses a heating iron?

    a. Solvent cement
    b. Heat tracing
    c. Fusion welding
    d. Soldering

11. What is the purpose of bevelling the end of ABS or PVC pipe before assembly?

    a. Allow solvent cement to cure properly
    b. Let the pipe and fitting slip together loosely
    c. Stop the pipe from bottoming out in the fitting
    d. Minimize wiping solvent cement from the socket

12. What colour is ABS DWV solvent cement?

    a. Yellow
    b. Clear
    c. Grey
    d. Purple

13. What is the percentage increase in setting time of solvent cement in damp and humid weather?

    a. 25%
    b. 50%
    c. 70%
    d. 100%

14. Which of the following describes a procedure used when tightening a flange joint?

    a. Star pattern
    b. Hexagonal pattern
    c. Crossover
    d. Opposed pattern

15. Which of the following is never acceptable as a method of testing PVC?

    a. Air pressure test
    b. Running water test
    c. Water pressure test over 345 kPa (50 psi)
    d. Water pressure test over 689 kPa (100 psi)

16. Which drawings show the arrangement of fixtures or equipment in relation to the building?

    a. Site
    b. Piping isometric
    c. Structural
    d. Architectural

17. Which drawings are a useful aid to visualizing piping arrangements and for preparing a materials list?

    a. Architectural
    b. Piping isometric
    c. Structural

d. As-built

18. What do mechanical drawings show?
    a. Where piping lines travel
    b. Dimensions of fixtures
    c. Where electrical wires travel
    d. Details of wall and floor finishing
19. The location of light fixtures and air grilles are shown on which drawing?
    a. Piping isometrics
    b. Architectural drawings
    c. Rough-in sheets
    d. Reflected ceiling plan
20. The size of pipes is likely to be found on which drawings?
    a. Piping isometrics
    b. Architectural drawings
    c. Rough-in sheets
    d. Mechanical drawings
21. More detailed information, including the lengths of piping and the exact placement of fittings, is calculated and indicated on which drawings?
    a. Piping isometrics
    b. Piping layouts
    c. Rough-in sheets
    d. Architectural drawings
22. The detailed dimensions and location of necessary connections for equipment are indicated in which literature?
    a. Rough-in literature from equipment manufacturers
    b. Piping layouts from the project engineer or architect
    c. Rough-in sheets, which should then be drawn in chalk
    d. Piping isometrics, which should be drawn based on project drawings
23. On larger projects, where is information found that specifies the types of hangers that are to be used?
    a. Plumbing code
    b. Book of hangers
    c. Book of specifications
    d. Structural or site drawing

Answer Key: Self-Test D-1.6 (#chapter-answer-key-self-test-d-1-6-2) is on the next page.

Answer Key: Self-Test D-1.6

1. d. The tradesperson who installed the joint
2. a. Capillary action
3. c. Soldering
4. b. Lead
5. c. Prevent oxidization
6. d. Measure the pipe
7. b. Brazing
8. b. One size smaller than the tee mainline
9. a. Push-connect
10. c. Fusion welding
11. d. Minimizes wiping solvent cement from the socket
12. a. Yellow
13. b. 50%
14. c. Crossover
15. a. Air pressure test
16. d. Architectural
17. b. Piping isometric
18. a. Where piping lines travel
19. d. Reflected ceiling plan
20. d. Mechanical drawings
21. a. Piping isometrics
22. a. Rough-in literature from equipment manufacturers
23. c. Book of specifications

Version History

This page provides a record of changes made to this learning resource, Plumbing Apprenticeship Level 1, Block D (https://d-pipingcomponents-bcplumbingapprl1.pressbooks.tru.ca/). Each update increases the version number by 0.1. The most recent version is reflected in the exported files for this resource.

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

Table 1: Version History Table

Version	Date	Change	Details

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.