Block B: Tools and Equipment

TRU
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Plumbing Apprenticeship Program Level 1 Series

Block B: Tools and Equipment

BC Plumbing Apprenticeship, Level 1

SKILLEDTRADESBC

AUDREY CURRAN; MARK OVERGAARD; BC PIPING ARTICULATION AND CURRICULUM SUBCOMMITTEE; AND PAUL SIMPSON

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Block B: Tools and Equipment of the Plumbing Apprenticeship Program Level 1 Series features Skilled Trades BC industry-authority content that builds on the safety foundations introduced in Block A by focusing on the correct selection, use, and care of essential plumbing tools and equipment. Safe work practices remain central, but the emphasis in this block is on developing hands-on technical competence in the tools apprentices use every day on the job.

In Block B, apprentices learn how to safely and effectively use hand tools and measuring tools; operate portable power tools; access work areas using ladders, scaffolds, and other access equipment; and perform rigging, hoisting, lifting, and positioning tasks. This block also introduces the safe use of soldering, brazing, oxy-fuel cutting, and welding equipment. Mastery of these skills supports workplace efficiency, reduces the risk of injury or equipment damage, and lays the groundwork for more advanced plumbing tasks in later levels of the apprenticeship.

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

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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

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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.

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- Line C: Tools and Equipment: Competency C-3: Describe Rigging and Hoisting Equipment (https://collection.bccampus.ca/resource/hDUEqpfn)
- Line C: Tools and Equipment: Competency C-4: Describe Ladders and Work Platforms (https://collection.bccampus.ca/resource/7c8Ymhnk)

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The Open Press

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

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

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

One or more interactive elements has been excluded from this version of the text. You can view them online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2446 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2446)

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Camosun College. (n.d.). *Line C: Tools and Equipment*. BCcampus. https://collection.bccampus.ca/resource/BzEe9fcq/

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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PART I

B-1 USE HAND TOOLS AND MEASURING TOOLS

Plumber Apprenticeship Program – Level 1

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B-1 Use Hand Tools and Measuring Tools Introduction

Hand tools are used in almost every trade, though many are designed for specific tasks within particular industries and trades. You may have already used some of these tools at work, at school, or at home. However, this may be your first opportunity to examine their design, function, and applications in greater detail. Understanding how tools are designed and why they are used in certain ways will help you work more safely, efficiently, and confidently in your trade.

Learning Objectives

After completing this section, you should be able to:

- Recognize and identify common hand tools and their proper uses.
- Describe the care and maintenance of common hand tools.

You will be required to reference publications and videos available online at WorkSafeBC (https://www.worksafebc.com/en). Supplementary videos by Camosun College: Trades Access Common Core Line C: Tools and Equipment Videos – BCcampus (https://media.bccampus.ca/playlist/details/0_3g8xp22x/categoryId/175673) by Camosun College.

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 for Section B-1 can be found in the **Glossary.**

- **bevel:** A slanted or angled edge cut into a material, often used to prepare surfaces for cutting, joining, or welding. (Section B-1.1)
- **burr:** A rough edge or small metal fragment left on a material after cutting, drilling, or machining. (Section B-1.1)

- **chalk-line bob:** The weighted end of a chalk line tool that helps keep the string tight and straight. It allows workers to snap a straight chalk line on a surface for marking and layout. (Section B-1.1)
- **chamfer:** A beveled edge that removes the sharp corner of a material, usually to make assembly easier or safer. (Section B-1.1)
- **combination square:** A measuring tool used to check right angles (90°) and measure distances. It has a ruler and an adjustable head. (Section B-1.1)
- **crimping:** A method of joining pipe or tubing by squeezing a metal ring or fitting tightly around it with a special tool. (Section B-1.1)
- **deburring:** The process of removing burrs or rough edges from metal, plastic, or other materials after cutting or drilling. (Section B-1.1)
- **flaring:** The process of spreading the end of a pipe or tube outward so it can connect securely to a fitting. (Section B-1.1)
- **kerf:** The width of material removed by a cutting tool such as a saw blade. (Section B-1.1)
- **National Pipe Thread:** A standard type of pipe thread used in North America. The threads are slightly tapered so they seal tightly when pipes are screwed together. (Section B-1.1)
- **PEX:** Cross-linked Polyethylene (PEX) is a type of flexible plastic pipe used for plumbing and heating systems. (Section B-1.1)
- **pitch (thread pitch):** The distance between corresponding points on adjacent threads, often measured as threads per inch (imperial) or millimeters (metric). (Section B-1.1)
- **plumb bob:** A pointed weight attached to a string that is used to find a perfectly vertical (plumb) line. When the weight hangs freely, the string shows a straight up-and-down direction. (Section B-1.1)
- **reamer:** A precision tool used to enlarge, smooth, or finish an existing hole or pipe end to an accurate diameter. (Section B-1.1)
- **spiralling (pipe cutting):** A cutting problem that occurs when a pipe cutter does not stay in a straight line around the pipe. Instead of following the same groove, the cutter wheel gradually moves along the pipe in a spiral pattern, resulting in an uneven or angled cut that is not square to the pipe; sometimes referred to as a barber's pole. (Section B-1.1)
- **spirit level:** A tool used to check if something is level or plumb. It has a small bubble inside a liquid-filled tube. (Section B-1.1)
- **square cut:** A cut made at a 90-degree angle to the length of a pipe or material. (Section B-1.1)
- **swaging:** A process used to change the shape or size of a pipe or tube end, usually to make it fit inside another pipe. (Section B-1.1)
- **tang (file tang):** The narrow-pointed section at the end of a file that fits into the handle. (Section B-1.1)
- **tangent chart:** A printed chart on some pipe layout tools that helps workers find angles and measurements when laying out cuts or fittings on pipe. It uses tangent values to calculate distances needed for accurate pipe layouts. (Section B-1.1)
- **tapered thread:** A thread that gradually decreases in diameter along its length to create a tighter seal as it is tightened. (Section B-1.1)
- **tempered steel:** Steel that has been heat-treated to increase hardness and durability. (Section B-1.1)
- **thread:** A spiral ridge formed on a bolt, screw, or pipe used for fastening or sealing. (Section B-1.1)
- **torque:** A twisting force applied to a fastener or tool. (Section B-1.1)
- **tubing:** Thin-walled pipe used to transport fluids or gases. (Section B-1.1)
- **vise:** A mechanical tool used to securely hold a workpiece during cutting, drilling, or assembly operations. (Section B-1.1)

B-1.1 Describe Hand Tools Used in the Pipe Trades

This section presents the hand tools most commonly used by pipe trades workers. Many of these tools are used during your in-school training, while others may be encountered on a job site or in a fabrication shop. While reading, pay special attention to the safety precautions required when using hand tools.

Cutting Tools

Cutting tools are used by pipe trades workers to shorten a piece of material to a desired length, or to remove part of a material from an object.

Compass and Keyhole Saws

Compass and keyhole saws have narrow, tapered blades.

Figure 1 *Keyhole saw (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

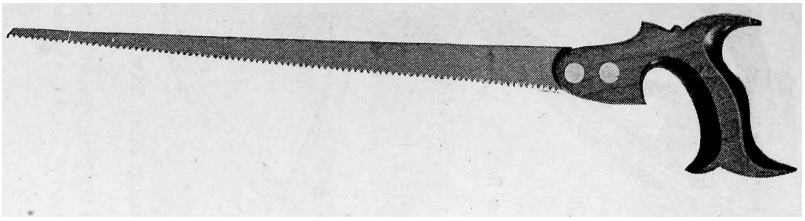

Figure 2 *Compass saw (Cassells' Carpentry and Joinery/Wikimedia) Public Domain (https://en.wikipedia.org/wiki/Public_domain)*

The section of blade used depends on the curve to be cut. The wide part of the blade should be used for large-radius curves and the narrow part for small cutouts. Because the blade is so narrow, care must be taken to prevent it from buckling. The blade on these saws varies in length from 250 mm (9.8 in.) to 350 mm (13.8 in.), and the teeth are filed in the same manner as the teeth on a crosscut saw.

Hacksaws

The hacksaw consists of a handle, metal frame, and saw blade. The adjustable type accommodates different sizes of blades, from 200 mm (8 in.) to 400 mm (16 in.) in length. The non-adjustable type holds only one size of blade, typically 300 mm (12 in.) in length. A hacksaw has a protective handle that helps guard your fingers in case the blade breaks or your hand slips while you are using the saw.

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

Hacksaw blades are made of hard, tempered (***heat-treated***) steel. The blade may be "***all-hardened***" or flexible. The flexible blade has only the teeth hardened, while the all-hardened blade has been tempered throughout. Since hacksaw blades are tempered, they are too hard to be resharpened. Once a blade becomes dull, it must be discarded.

The ***pitch*** (number of teeth per inch) may be 14, 18, 24 or 32. The part number, stamped on each blade, is occasionally a code number that may indicate the blade length and number of teeth per inch. For example, code number 1018 identifies a blade 10 in. (250 mm) long with 18 teeth per inch, while code number 1032 identifies a 10 in. (250 mm) blade with 32 teeth per inch. The blade below shows that there are 18 teeth per inch and a blade length of 10 in. (25 cm).

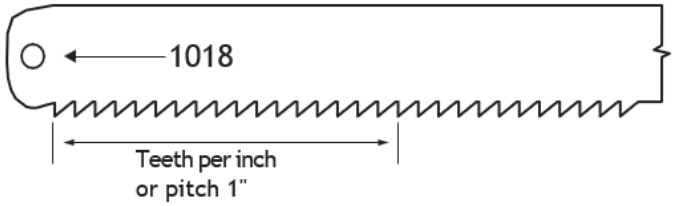

Figure 4 *Hacksaw blade (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Wood Handsaw

The tool most people think of as the handsaw is either a ***crosscut saw*** or a ***ripsaw***. The crosscut saw is designed to cut across the grain of wood, and the ripsaw is designed to cut with the grain. The number of points, usually shown on the saw, indicates the number of points per 25 mm (per inch) of cutting edge.

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

The blade of the saw is made of spring steel, tempered to provide a longer-lasting edge on the teeth after they are filed and *set* (offsetting of the teeth). The face of the blade is ground and polished. The smooth surface reduces friction between the saw and the wood. A handsaw of good quality has a taper-ground blade, where the back of the blade is thinner than the tooth edge. With this design, less set is required.

The set of the saw is just as important as the sharpness of the teeth, for the set is the clearance the saw blade has when it cuts wood. The width of the cut is called the ***kerf***. The kerf is important.

Handsaws are generally specified by the shape of the teeth (i.e., crosscut or rip).

The length of the blade and the number of points per 25 mm (or per inch). The number of points (which are the valleys between the teeth) is usually stamped on the heel or printed with the manufacturer's label on the side of the saw. Figure 6 shows a diagram of 7 points and 6 teeth in 25 mm (1 in.). The number of teeth is always one fewer than the number of points.

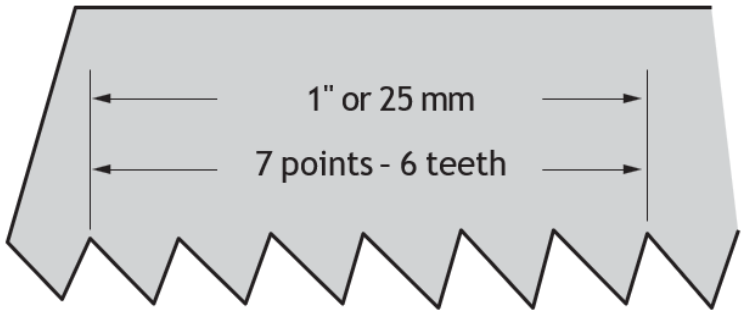

Figure 6 *Teeth/points (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Crosscut Saw

The crosscut saw varies in length from 500 mm to 700 mm (20 in. to 28 in.). The points also vary from 6 to 14 per 25 mm (1 in.). The crosscut saw used for framing has fairly coarse teeth. The saw used for finishing work has finer teeth.

The framing saw is normally 700 mm (28 in.) long and has 7 or 8 points per 25 mm (1 in.). It is used mostly for cutting common lumber and making the rougher cuts for framing.

The finishing saw, also called a panel saw, is about 550 mm (22 in.) long, with 10 to 11 points. It is mostly used for making fairly precise cuts through exterior and interior trim and through panelling.

The teeth of a crosscut saw are shaped like knives to give a scoring action for cutting across the grain of wood. Most of the cutting is done on the forward stroke of the saw. The images below show the cutting action of the crosscut.

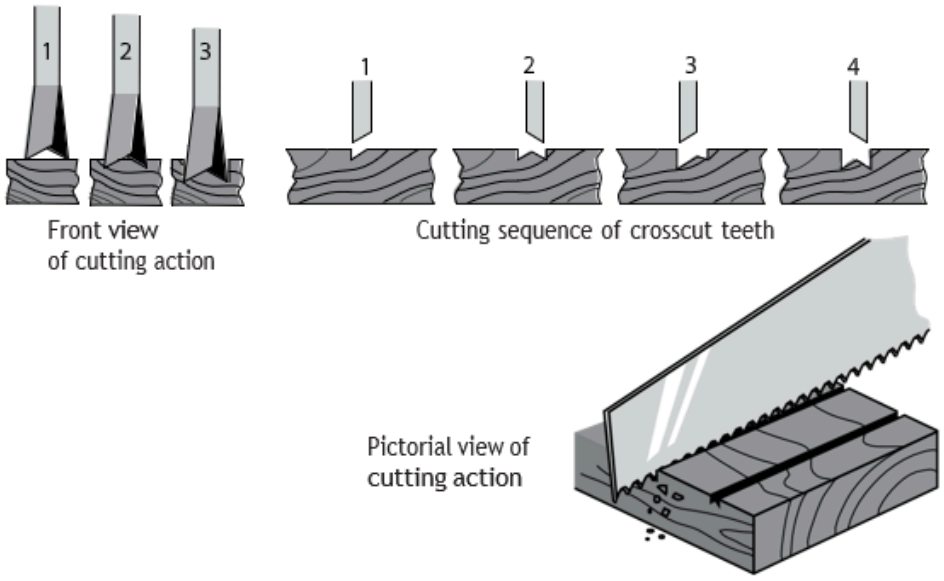

Figure 7 *Crosscutting (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Ripsaw

The ripsaw is designed to cut with the grain of wood. Its teeth are shaped like tiny chisels. A common ripsaw for carpenters has 5 $\frac{1}{2}$ points per 25 mm (1 in.) and the blade is about 700 mm (28 in.) long. Figure 8 shows its cutting action. The portable circular handsaw has made the use of the ripsaw virtually obsolete.

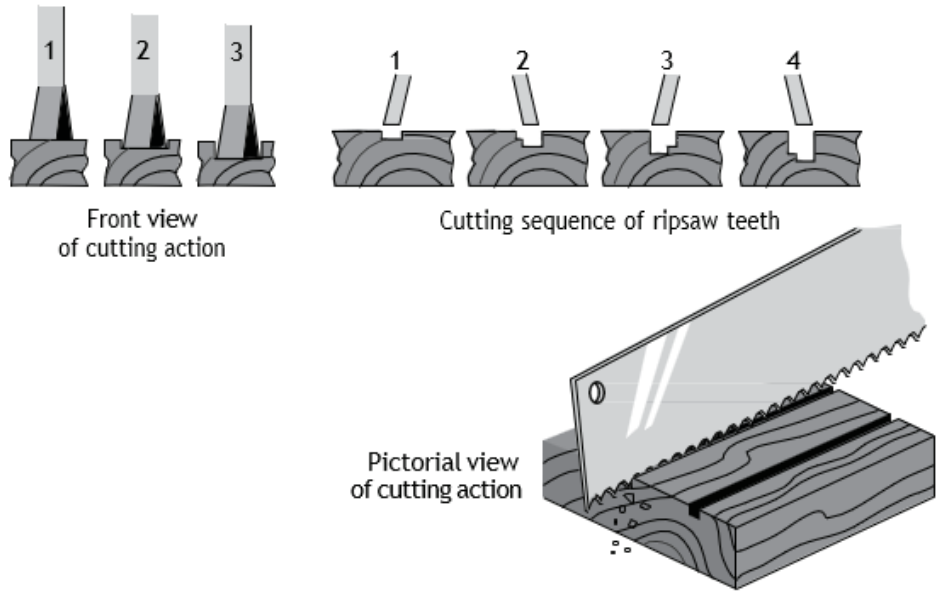

Figure 8 *Ripsaw cut (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Files

There are many different kinds, sizes, and cuts of files available. Only the more common ones are discussed here. While files can be used for both metal and wood, in the piping trades we generally use files primarily for metal.

Files have the following general uses:

- Removing excess material
- Fitting materials together more accurately
- Correcting errors resulting from inaccurate machining (for example, ***threads*** on bolts)
- Creating a flat or smooth surface
- Forming an edge
- Creating a notch or slot
- Creating a square or round hole

The size of a file is determined by its length from point to heel; the ***tang*** is not included in this measurement.

Each part of a file has a particular name. You will need to be familiar with these names as they will be referred to in descriptions of the different kinds of files and their characteristics.

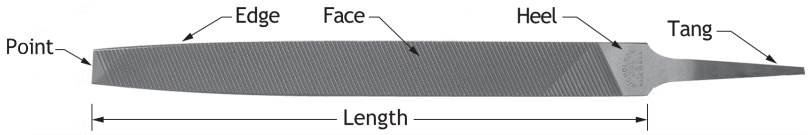

Figure 9 *Parts of the file (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

All files are classified by shape and by cutting face. The most common shapes of files are flat, round, half-round, and triangular and are used in the piping trades, primarily on metals. The flat file has teeth on both edges and is used for general-purpose filing. The round file (also known as the rat-tail file) has teeth covering the full circumference. This file is used primarily for enlarging circular openings or filing curved surfaces. The half-round file has one flat side and teeth on all surfaces. The triangular or three-square file is used to clean out corners of a square shape or to file at odd angles. All faces have teeth and the corners between the faces are left sharp.

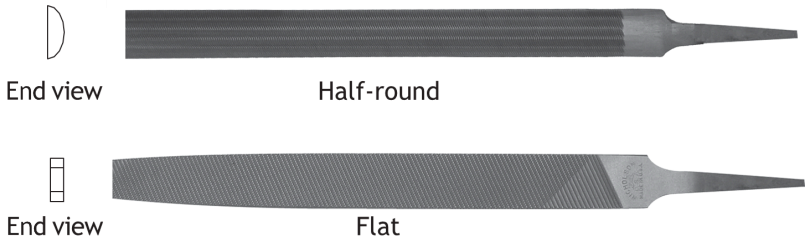

Figure 10 *Types of file (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Cutting Faces

Cutting faces are classified according to the design of the cutting and according to the grade of their teeth.

There are three designs of cutting face: the single-cut, the double-cut and the curved tooth.

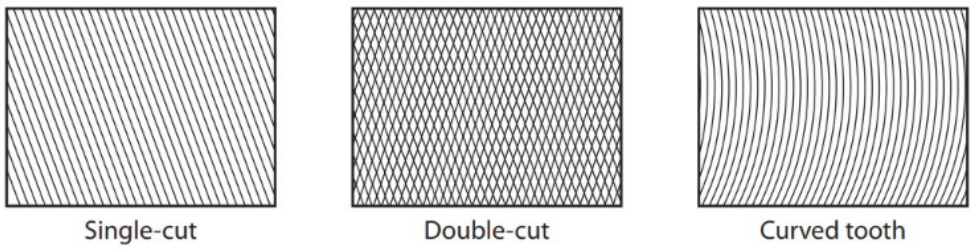

Figure 11—File Faces

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

The single-cut file has one unbroken course of teeth running across the face of the file and is used when a smooth finish is desired. The double-cut file has two broken courses of teeth crossing each other. It is used for rough, fast metal

cutting or where large amounts of material must be filed off. The curved tooth file is used to file soft metals such as lead or aluminum. It removes material very quickly and produces a smooth surface after each filing stroke.

The second classification identifies the grade of the file teeth. There are six different grades for both single- or double-cut files. However, the curved tooth file is available in only three grades: the bastard cut, second cut and smooth cut.

- Rough cut
- Second cut
- Coarse cut
- Smooth cut
- Bastard cut
- Dead-smooth cut

The only difference in the grades is the spacing between the teeth. The rough-cut file has the greatest space between the teeth. As the spacing decreases, the cut becomes smoother. Remember, though, the spacing is in relation to the overall size of the file. For example, a large bastard-cut file has more space between the teeth and larger teeth than a small bastard-cut file, even though both are bastard-cut files. Figure 12 shows different grades of a single-cut file.

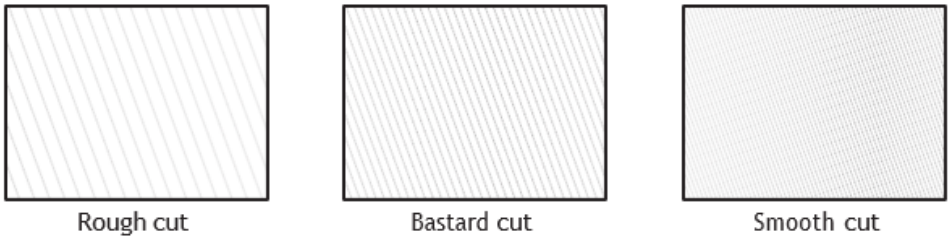

Figure 12 *Single-cut file grades (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hand Shears

Hand shears are also called tin snips or aviation shears. They will generally cut sheet metal up to 1.5 mm ($\frac{1}{16}$„ in.) thick.

The construction of hand shears varies greatly; some are made to cut only straight, while others are made to cut left or right curves.

Yellow-handled snips are used for straight cuts and general purpose tin work, red-handled snips have blades that are designed for left-curved cuts, and green-handled snips are designed for right-curved cuts.

Figure 13 *Hand shears: (red) left cuts, (green) right cuts, (yellow) straight cuts (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Chisels

Chisels are made of ***tempered steel*** and have a sharp ***beveled*** edge for cutting or shaping different types of material. To do so, place the sharp edge against the material and push or pound the end. The size, shape, and sharpness vary with the different types of material to be cut.

Cold Chisels

Cold chisels are forged from square, rectangular, hexagonal and octagonal high carbon steel stock and are used for metals. The steel is ***machined*** and then hardened (cold tempered). The body and head are softer than the cutting edge so that they can withstand a striking force without chipping. The upper end of a chisel has a slight taper (***chamfer***) to compensate for the mushrooming caused by repeated hammer blows.

Pipe trades workers generally use chisels for the removal of rusted machine parts, shearing of bolts, chipping metal and removing pins. Cold chisels are generally used for metal and not wood.

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

The flat cold chisel is used for most general cutting and chipping work. The cutting edge is bevelled (tapered) from both sides toward the center. The angle of the bevel is generally between 60° and 70°. For soft metals, the angle should be reduced; for very hard metals, it should be increased.

Flat cold chisels have cutting edges that vary in width from 6 mm to 25 mm ($\frac{1}{4}$ in. to 1 in.) and they are usually from 150 mm to 200 mm (6 in. to 8 in.) in length.

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

Wood Chisels

Wood chisels are classified according to length, width and thickness of the blade. They are also classified according to purpose, type, blade shape and method of holding the handle.

Types of wood chisels:

- framing chisels: the heaviest of the chisels
- finishing chisels: for lighter specific work
- gouges: a curved chisel with different blade sweeps or patterns

Framing chisels are usually used for heavy-duty type framing work, so they are referred to as such.

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

The framing chisel is made so that it can be driven with a steel hammer. The steel continues from the blade to the end of the handle, and the handle is moulded on each side of the steel. The framing chisel is the heaviest of the chisels. It varies in width from 20 mm to 50 mm and in blade length from 150 to 200 mm.

Check Your Knowledge: Saws, Files, and Chisels

Complete the Complete the interactive knowledge test below.

If you are using a printed copy, you can scan the QR code with your digital device to go directly to the interactive knowledge test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2725#h5p-23 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2725#h5p-23)

Pipe Cutters

Pipe cutting may be done either by hand or with power accessories. Cutters are available in a number of designs and sizes. Their use depends on the situation and on the size and material of the pipe being cut.

For any type of jointing operation, it is very important that the pipe end be cut squarely. The correctly selected cutter provides the best results, quickly and accurately. A hacksaw should never be used to cut pipe, because it's difficult to achieve a square end. Chips from the cut may fall into the pipe and, if not removed, can cause problems with joints (especially if the piping is the type that is glued together). Chips can also contaminate the fluid that will eventually be carried through the pipe.

Most pipe cutters have a hook-shaped frame, with a cutter wheel at the end of the hook. On the stem of the hook, a sliding housing containing two rollers is mounted. These rollers hold the pipe in position against the cutter wheel. The sliding housing is moved by a long feed-screw, which is tightened as the tool is rotated around the pipe, forcing the cutter wheel into the pipe. The rollers tend to roll down the external ***burr*** that is usually raised on the pipe as the cutter wheel moves the metal. Note that these types of cutters don't actually remove any material, but rather they *spread* the material into two sections. Note that wider rollers create less chance of the cutter wheel spiralling up the pipe. This provides for better cutting performance and greater accuracy when cutting pipe.

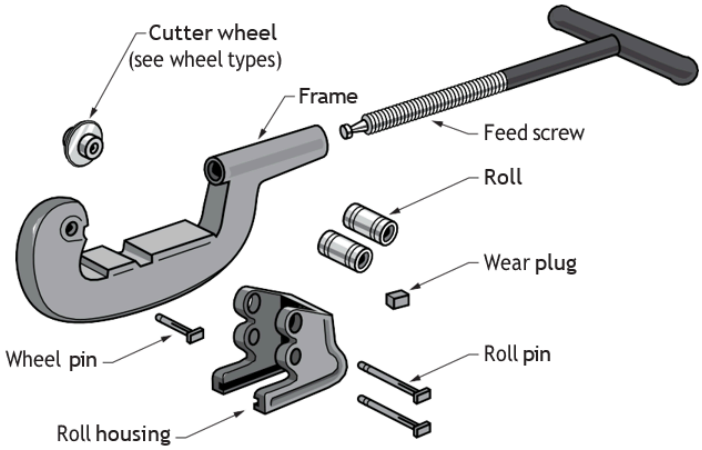

Figure 17 *Parts of a standard wheel-and-roller cutter for steel pipe (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Care must be taken that the cutter wheel is appropriate for the cutter being used and is suited to the material being cut. The illustration below shows the main types of cutter wheels. The standard thin wheel is designed for cutting ordinary steel pipe; stronger, heavier wheels are for cutting heavy-walled steel pipe; and thinner wheels are used for materials like thin-walled ***tubing*** or soft materials like plastic pipe.

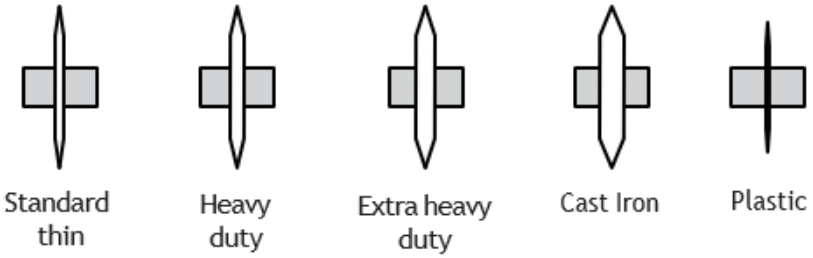

Figure 18 *Types of cutter wheels (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Before using a cutter wheel, always inspect it to make sure that it is not blunt or damaged. A blunt or dulled cutter tends to crush rather than cut the pipe. Also, ensure that no rollers and screw ***fasteners*** on the cutters are loose or missing. Misalignment or an incomplete cut could result.

Cutters may be classed as:

- Standard wheel-and-roller cutters
- 3-wheel or 4-wheel cutters (without rollers, only cutting wheels)

Heavy-Duty Pipe Cutters

These cutters can be used as single-wheel-and-roller cutters for work on heavier piping materials like steel. For cutting in confined areas, these cutters can be converted to 3-wheel cutters by replacing the two rollers with extra cutter wheels.

Figure 19 *Heavy-duty pipe cutters (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

As shown in Figure 20, a 360° rotation of the wheel-and-roller cutter is necessary to cut pipe. With a three-wheel cutter, a rotation of just over 120° is all that is required. However, more care must be taken when starting a cut with the three-

wheel cutter to make sure the cut is straight. These cutters can be challenging to line up correctly to achieve ***square cuts***. The three-wheel cutter also leaves more of an outside burr, which must be removed on every cut to avoid difficulty when using threading or grooving equipment.

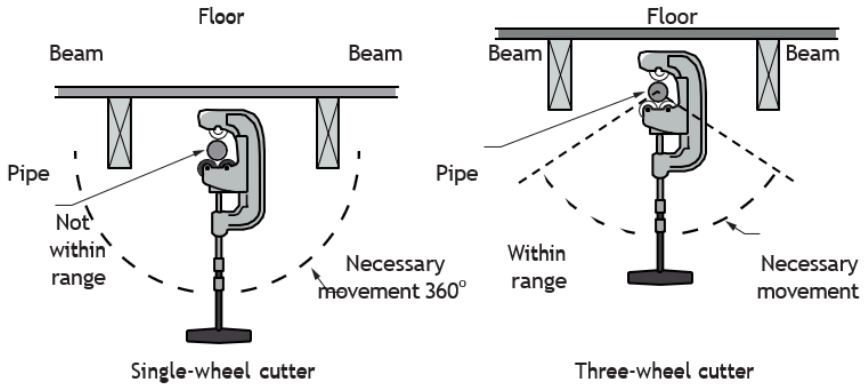

Figure 20 *Wheel-and-roller cutters (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Four-Wheel Cutters

This cutter is designed for work in areas where a complete turn is not possible.

One style has a short handle for extra-tight areas where only a 130° turn can be accomplished. Pipe capacity is for this style of cutter is often 20 mm ($\frac{3}{4}$ in.) to 50 mm (2 in.).

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

Some larger options are available with the addition of a second handle, making it possible for two people to cut large pipe sizes in confined areas. Pipe capacity can easily be in the range of 6.5 cm (2 $\frac{1}{2}$ in.) to 10 cm (4 in.).

Heavy-Duty Wide Roll Cutter

This style of cutter was developed for use with a power ***vise***. The extra wide rollers prevent the cutter from wobbling during the cutting operation, and prevent ***spiralling*** (or what is sometimes referred to as a barber's pole). Pipe capacity is typically 3 mm ($\frac{1}{8}$ in.) to 50 mm (2 in.).

Figure 22 *Heavy-duty wide roll cutter (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hinged Cutter

Hinged cutters are used for pipe in the ranges of 10 cm (4 in.) to 30 cm (12 in.). They can be used in tight quarters where cutter rotation is limited, like in a ditch or trench. A hinged cutter has four cutter wheels, a long handle for ***leverage***, and a latch to engage the cutter head around the pipe. A second handle may be added for extra cutting leverage.

Soil Pipe Cutters

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

These types of *non-rotational* cutters (often simply called snap cutters) are designed for cutting straight lengths of cast iron soil pipe and other materials that are brittle, or easily broken. Each "wheel" is actually more like a tooth that bites into the pipe, applying even pressure at multiple points until the cutting process is achieved.

Operating the handle of the ratchet type cutters tightens the chain until the pipe is snapped by the cutting wheels between the chain links. This style has an advantage in confined quarters or when making a cut on an existing pipe that must be cut in-position.

Figure 24 *Ratchet type soil pipe cutters (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The scissor-type cutters open and close quickly and are suited to multiple cuts in new construction work. To make the cut, squeeze the handles toward each other until the cutting wheels in the chain have completed the cut.

Figure 25 *Soil pipe cutters (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Both cutters cut 5 cm to 15 cm (2 in. to 6 in.) clay tile pipe, cast iron drainage pipe, and water mains up to 10 cm (4 in.) made from these types of brittle materials.

External Glass Pipe Cutter

External glass pipe cutters are available as small, pocket-size tools having a chain with cutting wheels to cut glass tubing, glass pipe, and other fragile, tubular material. The chain is wrapped around the tube. Twist of the wrist and squeeze of the handles, the material is cut. Maximum pipe capacity is often 38 mm (1 $\frac{1}{2}$ in.).

Figure 26 *External glass pipe cutter (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Internal Glass Pipe Cutter

This type of cutter is used for scoring the inside of a glass pipe prior to heating and breaking it. The cutter is inserted in the pipe and the cutter wheel is set to the desired length. The cutter is rotated one full turn only and then carefully removed. The glass pipe is then heated with a small gas torch, and the pipe will break cleanly along the internally scored line. Cutters are available for pipe from 13 mm to 25 mm ($\frac{1}{2}$ in. to 1 in.) and from 38 mm to 150 mm (1 $\frac{1}{2}$ in. to 6 in.).

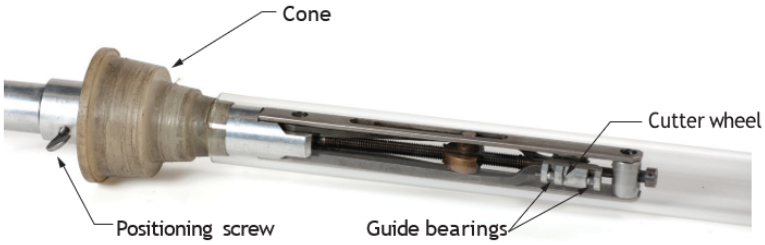

Figure 27 *Internal glass pipe cutter (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Internal Pipe Cutter

This cutter is available in models that will cut either plastic pipe or metallic tubing.

It can be used for trimming tubing below floor ***level*** for shower, floor drain or floor flange installations, or above the ceiling for sprinkler-head installations.

Tubing Cutters

The tubing cutter is used to make clean, square cuts on copper, brass, aluminum, and thin-walled conduit. These light-weight cutters commonly have a foldaway ***reamer*** attached to them that may often have a small square hole in it to operate the valve stem of a B-size acetylene tank. Other tubing cutters will have a slide-out ***deburring*** tool with a small blade that spins as it is rotated inside the pipe.

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

It is extremely important that tubing cutters not be used to cut pipe, as the thin cutting wheel used for tubing would be immediately damaged.

A tube is a thin-walled pipe, commonly made of copper, aluminum, brass, carbon steel, stainless steel, or plastic. Because of the thin wall, standard ***pipe thread***s cannot be formed on tubing. Instead, procedures such as soldering or brazing may be utilized. Special fittings are also available for tubing that use compression or flared connections, for example.

Close-Quarters Tubing Cutters

These miniature cutters are specifically designed for use in restricted spaces on small diameter, hard and soft copper, aluminum, brass and plastic tubing. They are designed with rollers with grooves in them. The grooves allow the cutter to make a cut close to the end of a tube that has been flared. They have common capacities of 6 mm to 29 mm ($\frac{1}{4}$ in. to $1\ \frac{1}{8}$ in.).

Plastic Tubing Cutters

These scissor-style quick-opening cutters are designed for speedy cuts on all sorts of plastic tubing up to about 4 cm (1 $\frac{5}{8}$ in.) outside diameter (OD). To complete a square cut, rotate the handle slightly while applying pressure.

Larger ratcheting cutters of a similar design are also available for cutting plastic tubing, or plastic pipe, up to approximately 6 cm (2 $\frac{3}{8}$ in.) OD.

Figure 29 *Plastic tubing cutters (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pipe Reamers and Deburring Tools

A reamer is a precision tool used to slightly enlarge and smooth an existing hole or pipe end to a specific diameter. A deburring tool removes rough edges, burrs, or sharp fragments left after cutting, drilling, or threading. The objective is to bring the interior diameter of the pipe back to its original full bore, avoiding turbulent flow and unwanted restriction to fluid flow. Reaming and deburring can be done by hand. Certain types of reamers are designed for use on power vises. Reaming is always done before threading to avoid deforming or ***flaring***-out the threaded end.

Straight Fluted Ratchet Reamer

This reamer works fast and clean, with light pressure. It is designed for use when pipe is to be held stationary in a vise or when the pipe is being rotated in a power vise. It is the only reamer discussed that is safe for using with a power vise.

Two models of the straight ratchet reamer are available. One has a pipe capacity of 3 mm to 2.5 cm ($\frac{1}{8}$ in. to 2 in.). The other has a pipe capacity of 10 mm to 8 cm ($\frac{3}{8}$ in. to 3 in.).

Spiral Ratchet Reamer

This reamer is designed for hand use only. This tool is made for reaming large pipe by hand up to 10 cm (4 in.) in size. The type of work being done will dictate the size and type of reamer to be used.

Hand-held spiral reamers should not be used in conjunction with power vises because the reamer may bind into the pipe and be pulled from your hand, possibly causing a serious injury.

Deburring Tools

For light-wall tubing and soft materials like plastic pipe, other styles of deburring tools are available.

Blade-type deburring tools are ideal for removing internal burrs in copper, plastic, aluminum and steel tubing. Most types feature long-lasting replaceable steel blade attached to a small handle with a built-in pocket clip. Some have a larger handle that can be used for storing of surplus blades.

Figure 30 *Articulating blade deburring tool (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Plastic pipe deburring ***chamfering*** tools are lightweight and easily fit in your hand (chamfering means to cut off the edge, or bevel). These tools can quickly smooth out rough edges from the inside diameter (ID) and outside diameter (OD) of materials like ABS and PVC. A few spins of the tool can easily produce a 15° bevel for a smooth, chamfered pipe end so that solvent spreads evenly as pipe is joined.

Figure 31 *Plastic pipe deburring/reaming tool (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Check Your Knowledge: Pipe Cutters, Reamers, and Deburring Tools

Complete the interactive knowledge test below

If you are using a printed copy, you can scan the QR code with your digital device to go directly to the interactive knowledge test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2725#h5p-24 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2725#h5p-24)

Utility Knife

The utility knife is used for general-purpose or utility tasks. The utility knife was originally a fixed blade knife with a cutting edge suitable for general work such as cutting hides and cordage, scraping hides, butchering animals, cleaning fish, and other tasks. Today, the term "utility knife" also includes small folding or retractable-blade knives suited for use in the general workplace or in the construction industry.

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

Gasket Cutters

A tool incorporating a blade and designed to pivot around a center pin. It is used to make accurate circular cuts in a variety of materials that are used for ***gaskets*** in the piping industry. One design is the extension-style blade cutters shown in the figure below.

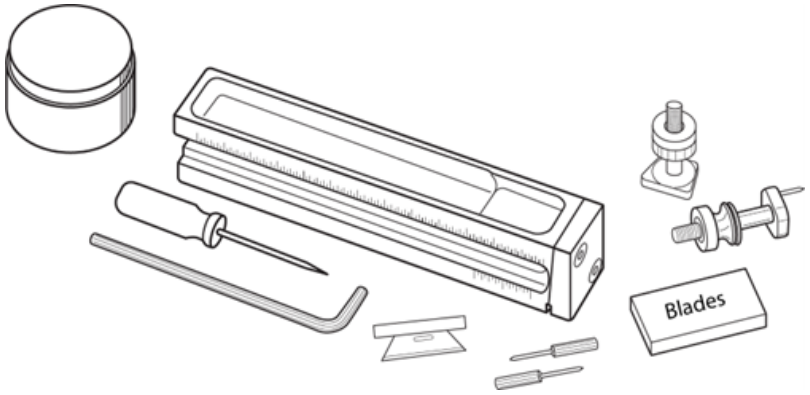

Figure 33 *Extension-style blade cutters (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Measuring Tools

Measuring tools allow the pipe trades worker to verify accurate positions and dimensions. When using measuring tools, you may be required to use both metric and imperial measurement systems.

Imperial

Feet (ft or ‘) are divided into 12 equal parts called inches (in. or “). Inches may be further divided into equal parts called fractions. These fractions can be as large as $\frac{1}{2}$, but greater accuracy is achieved by dividing these parts of an inch into quarters, eighths, sixteenths or thirty-seconds.

The degree of accuracy you are likely to require in the pipe trade is generally no more than $\frac{1}{32}$ of an inch.

Metric

The base unit in metric measurement is the metre (m). A metre is divided into 100 centimetres (cm) or 1000 millimetres (mm). A millimetre is one-tenth of a centimetre. Millimetres are the most commonly used unit for precise metric measurement in construction and the pipe trades.

There is a wide range of measuring instruments used for checking clearances and tolerances. These include:

- Measuring tapes
- Steel rule
- Calipers
- Gauges

Pocket Measuring Tape

The pocket tape shown in Figure 34 is used to measure large layouts. It is the most widely used measuring instrument in the construction trades.

Figure 34 *Measuring tape (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

This tape is usually made from steel and is spring-loaded, allowing it to retract into its carrying case when released. The zero end of the tape is equipped with a hook that should slide along the tape a distance equal to the thickness of the hook. The sliding of the hook permits accurate internal and external measurements.

Pocket tapes range in length from 2 m to 7.5 m (6 ft to 25 ft.). Metric tapes are marked in one-millimetre graduations, while imperial tapes are graduated in thirty-seconds of an inch for the first 6 in. or 12 in., and in sixteenths of an inch for the remainder of the tape.

Pocket tapes often feature a retraction lock and belt clip and often have the case length indicated so that it can be used to measure inside dimensions (though not very accurately). Construction-grade pocket tapes are available in extra-wide widths to allow for greater standout length and to avoid buckling when taking long measurements unassisted.

Steel Tape

Although it is still commonly called the steel tape, it may be made of either flexible spring steel or plastic and is housed in a case with a crank-type handle for rewinding. Usually, it is 30 to 50 metres (100 to 165 ft.) long. It is ideal for large layouts in construction.

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

At the end of the steel tape is a combined ring and hook. When taking measurements, the hook is placed over the end of the object or, if possible, a nail is inserted through the ring to hold it in place. It is important when placing the nail that the very end of the ring marks the start of the measurement.

Figure 36 *Steel tape ends (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

When you pull the tape out of its case, it is important to pull it out as shown in Figure 37. Rewind the tape in the same direction. Winding the wrong way stretches one side of the tape, causing the tape to curl when it is pulled from its case.

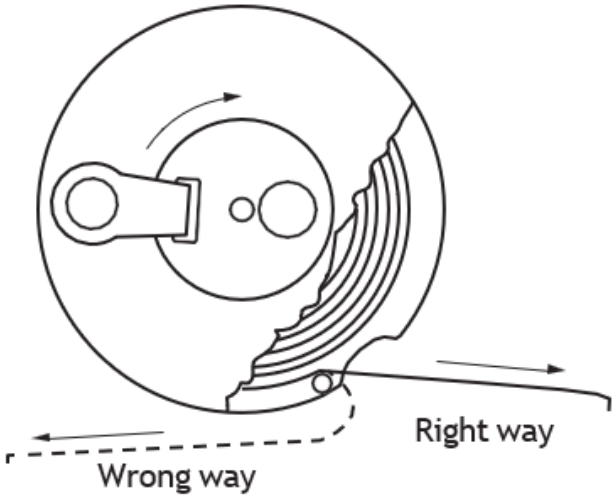

Figure 37 *Right way and wrong way to extend and rewind steel tape (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The winding handle of the steel tape is released by pushing a button on the opposite side of the case. If the tape seems to stick during rewinding, tap the case slightly on the side. If it continues to stick, pull out the tape fully and rewind it.

Circumference Tape/Pipe Diameter Tape

These tape measures typically have dual scales. Most models have a diameter scale on one side and a pocket tape measure scale on the other side used for measuring circumference at the same time. The user wraps the tape around a pipe and reads the number at the point where the tape overlaps.

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

Wrap-Around

The wrap-around is an inexpensive, yet indispensable pipe layout tool. It is often used by pipe trades workers who fabricate steel pipe. Wrap-arounds are about 12.5 cm (5 in.) wide and come in various lengths.

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

This tool is used for marking straight lines around pipe or as a straightedge. It is made of a flexible gasket-like material that has reasonable resistance to heat and cold. All wrap-a-rounds are available in two colours that designate material type and service temperature. Black material has a service temperature up to 175°C (350°F). Grey material is used for high-temperature applications up to 290°C (550°F).

Both material types are asbestos-free and are printed with a scale in inches or millimetres, a pitch chart, a ***tangent chart*** and other useful layout markings.

Carpenter or Framing Square

Another tool frequently used to measure and lay out larger dimensions on sheet and plate is the carpenter's or ***framing square***. It is also frequently used for layout and squaring large pipe. These squares can be marked in either imperial or metric measurements. The square has two blades set at 90° to each other. One blade (known as the body) is approximately 600 mm by 50 mm (24 in. × 2 in.), and the other, known as the tongue, is approximately 400 mm by 37.5 mm (16 in. × $1\frac{1}{2}$ in.).

Various angles can be laid out with a framing square. For example, a 45° angle can be accurately laid out if you place the framing square so that the edge of a board intersects the sides of the framing square at equal measurements along each side.

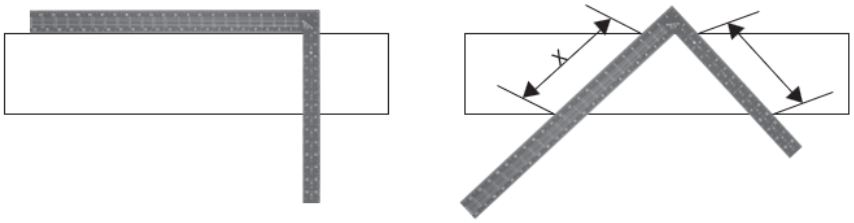

Figure 40 *Carpenter or framing square* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Combination Squares

A ***combination square*** consists of a tempered steel blade onto which three interchangeable heads can be mounted. The three heads are the square head, the protractor head, and the centre head. The blade has scales engraved on it, and the heads slide on the blade in a central groove for easy adjustment. The heads can be adjusted to any position along the blade, or they can be removed easily so the blade can be used as a ***steel rule***.

Pipe trades workers make regular use of the combination square (or *combination set*, as it is often called) because it can be used for many different purposes. Fitters use the combination set to:

- Square work
- Transfer measurements
- Lay out work
- Level surfaces
- Determine plumb
- Establish centres
- Lay out and check angles
- Measure recesses

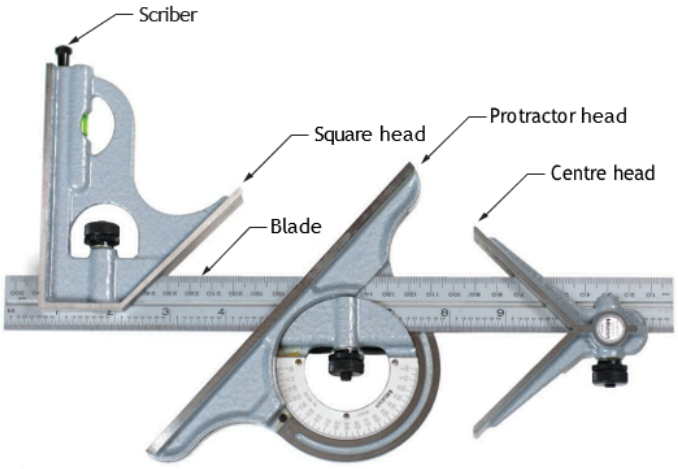

Figure 41 *Combination square* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Square Head (Set Square)

Square heads have a 90° square face and a 45° ***mitre*** face. Most square heads are equipped with a ***spirit level*** and a ***scriber***. The square head can be used separately as a level. The figure below shows how the square head of a combination square is used to hold the blade at right angles to the edge of stock or flat bar.

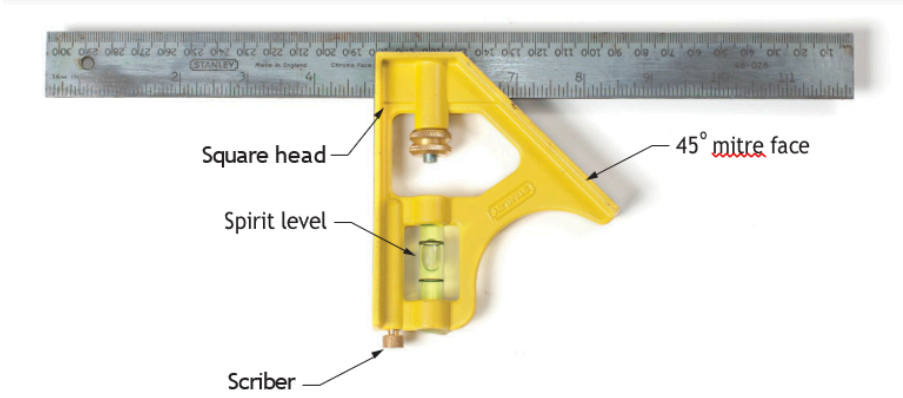

Figure 42 *Square head (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Centre Head

Centre heads have two equal arms that permit you to find the centre of large or small ***round stock***. The centre head is used in combination with the steel blade to quickly locate the centre of the piece. To use the centre head, place it firmly against the round stock and scribe several lines in the stock along the blade, rotating the stock about 60° between each scribing. The point where the lines intersect marks the centre of the stock.

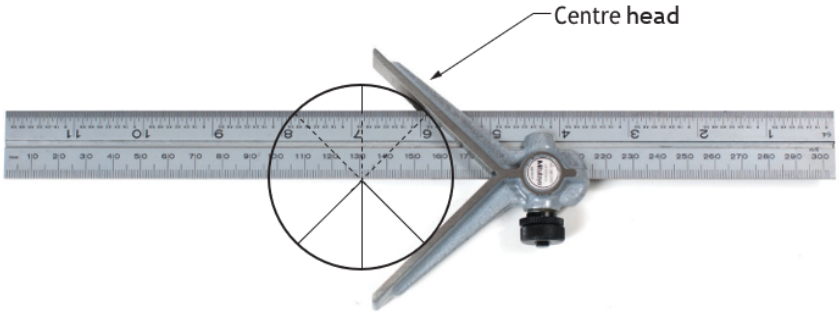

Figure 43 *Centre head (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Protractor Head

The ***protractor head*** is marked in degrees from 0 to 180°. With this head you can determine and check layout angles.

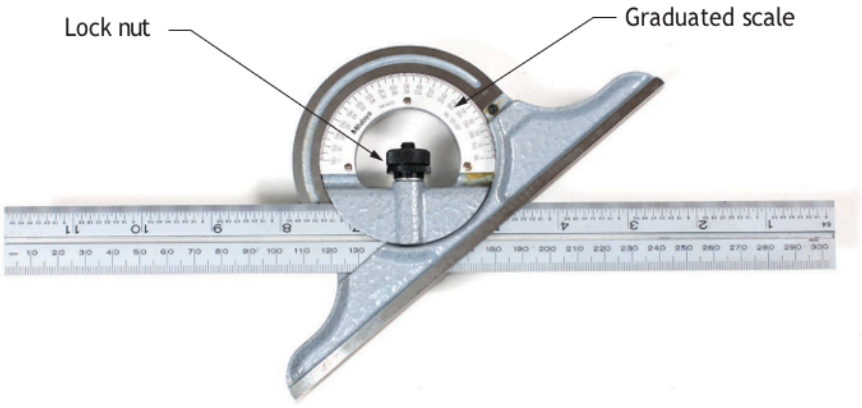

Figure 44 *Protractor head (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Thread Gauge

A ***thread gauge*** or *screw pitch gauge* is used to determine the pitch of various thread forms on bolts, screws, studs, or any threaded component.

Figure 45 *Thread gauge (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Screw threads are spiral grooves of uniform shape and size formed on the inside of a hole or on the outside of a rod or pipe. Some types of thread taper to form a tight seal (pipe thread) while others don't (bolt thread). These threads are measured as the number of threads per inch on imperial fasteners and as a direct measurement of pitch on metric fasteners.

The pitch of a screw thread is the distance from a point on one thread to the same or corresponding point on the next

thread. Expressed in *threads per inch*, the pitch is equal to 1 divided by the number of threads per inch. For example, a screw with 10 threads per inch has a pitch of $\frac{1}{10}$ -inch (1 divided by 10).

In the metric system, the pitch is not expressed in inches or threads per inch, but as the distance between threads in millimetres, such as 1.0 mm, 1.25 mm, or 1.75 mm.

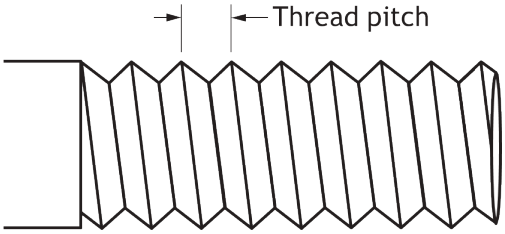

Figure 46 *Thread Pitch (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

With a thread or screw pitch gauge, you can find pitch without using direct measurement or calculation.

These instruments are made up of a number of thin blades, each having V-shaped teeth cut along one edge that match a standard thread shape. Each blade also has a number indicating the number of teeth per inch or the pitch in millimetres.

To find the pitch of a screw thread, try to fit the appropriate gauge blade to the threads of the fastener being measured. Read the number on the gauge blade that matches your sample. The gauge blade must be held parallel with the fastener to get a correct reading.

Centring heads (Figure 47) are used for fitting up welded pipe fittings and aiding in the setting of centre lines, establishing angles and marks for butt-ins, and locating points on pipes and tanks, One model, the Curv-O-Mark™ Standard Model, is used on pipe $\frac{1}{2}$ -in. diameter and larger. It has a 4-in. Y-type head and is fitted with an adjustable dial bubble protractor and a manually operated hardened centring pin.

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

Contour Marker

A contour marker tool is used for fitting up welded pipe fittings and may be used on almost any wye, tee, lateral or mitre joint directly on the pipe. This eliminates the time-consuming job of laying out a template. These instruments are very accurate but require some practice to use effectively when making fittings. These instruments consist of a frame that rests on the pipe or flange, a calibrated protractor, and a triple joint marking arm with a soapstone marking point (Figure 48).

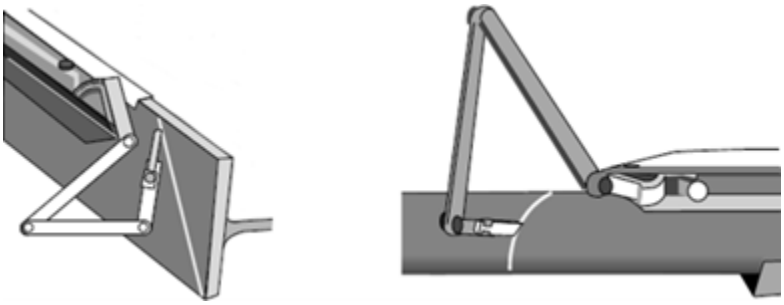

Figure 48 *Contour marker (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Refractometer

Refractometers are handheld, lightweight, portable instruments that utilize the measurement of ***refractive index*** to determine the concentration of ethylene glycol or propylene glycol antifreeze in sprinkler and heating/cooling systems. The two commonly used types of refractometers are analog and digital handheld units.

Figure 49 *Refractometer (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hydrometer

A ***hydrometer*** is an instrument used to measure the relative density of liquids based on the concept of buoyancy. They are typically calibrated and graduated with one or more scales, such as specific gravity.

The hydrometer makes use of ***Archimedes' principle***, so the lower the density of the fluid, the deeper a hydrometer of a given weight sinks. Hydrometers are calibrated for different uses, including measuring the concentration of ethylene glycol or propylene glycol antifreeze in sprinkler and heating/cooling systems.

Figure 50
Hydrometer (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Levelling and Plumbing Tools

Levelling and plumbing tools include the ***hand level***, ***torpedo level***, ***line level***, ***plumb bob***, and ***chalk-line plumb bob***. It is important that all levels be kept accurate. In a well-constructed project, every member is properly located, every horizontal pipe is level or properly graded, and every vertical pipe is ***plumb***.

The Spirit Level

The ***spirit level*** (Figure 51) is a glass vial that indicates level or plumb. Some models use four glass vials for the spirit levels, while others use three (horizontal, vertical/level, and 45°).

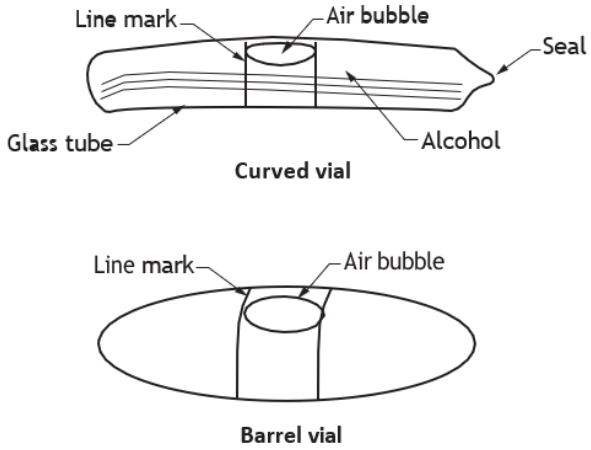

Figure 51 *Spirit level (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

When four vials are used, the vials are slightly curved and filled with alcohol containing a small air bubble. When three vials are used, they are barrel-shaped, that is, wider in the middle. These vials are also filled with alcohol. Some levels may have an additional fourth vial used to check the pitch or grade of drainage pipe.

Figure 52 *Four-vial and three-vial hand levels (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hand Levels

Popular hand levels are about 600 mm (24 in.) long, but there are 1200 mm (48 in.) and 1800 mm (72 in.) types. Modern models are made from aluminum or plastic; older types were made of wood.

Hand levels should be checked regularly for accuracy. Hand levels that are not accurate should be adjusted or repaired.

To check the hand level for straightness, sight along the edge or place the level on a known flat surface, such as the top of a table saw, to see if it is in full contact with the surface. Then turn the level over and check again.

When using the hand level, take care not to drop it or bang it about, as this can move the bubbles out of position and make readings inaccurate. Make a habit of hanging the level up when you are not using it.

Torpedo Level

The ***torpedo level*** is a small aluminum level 200 to 300 mm (6 in. to 9 in.) long. It has a bubble for level, a bubble for plumb, and a bubble for 45°. Plumbers commonly use this tool, but in the carpentry trade it is also handy for checking spaces too small to accommodate a long level.

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

Line Level

The line level is a very short level with hooks at each end that allow it to be attached to a string line. The line should be as tight as possible, and the level placed near the centre of the line. One end of the line should be attached at the height desired, and the other raised or lowered until the bubble is centred. The line level is good for approximate measures only, such as for excavations, fence posts, or building lines.

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

Optical Levels

The ***optical level*** (also called a *builders level* or *dumpy level*) is a high-powered telescope equipped with crosshairs (similar to a telescopic sight for a rifle) centrally mounted on a bearing so that it can rotate only horizontally. A very sensitive spirit bubble is mounted on the telescope. When this bubble is centred, the instrument is level with the line of sight.

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

When mounted on a tripod, the optical level is adjusted with foot screws to centre the spirit bubble. As the optical level is rotated through a horizontal circle, the bubble may or may not have to be reset to centre, depending on the type of optical level being used.

Optical levels are used to establish horizontal reference points and to determine elevations and benchmarks.

Optical levels used in the pipe trades are typically used with what is known as a ***level (or levelling rod)***.

There are many types of level rods. They can be made of wood, fibreglass, or aluminum alloy. They can be telescopic, or can come in sections that are bolted together or that fit one segment into the end of another. There are several different methods of displaying the scales. The type most suited to construction is the segmented type with a reflective face. These levels are easily dismantled for use in confined spaces, and a light source can be reflected on the scales for easy reading in poor light conditions.

Figure 56 *Imperial (left) and metric (right) levelling rods (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Laser Levels

Laser is a word derived from Light Amplification by Simulated Emission of Radiation (LASER). A mixture of helium and neon gases is used to emit a very narrow beam of light that does not grow larger as it moves away from the source, which in this case is the ***laser level***. The beam can be directed to any point, or it can be rotated continuously at various speeds. Laser beams used in these levels can be either red or green; red is most common but is harder to see than a green beam in bright environments. If used in very bright conditions, a sensor or detector may be required.

Figure 57 *Laser Level (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Do not look directly into a laser beam! Looking directly into the beam may be hazardous to your eyes. A quick flash of the beam is not a problem, but prolonged exposure should be avoided. The instrument must be positioned either above or below the worker's line of sight.

The instruments can be supported in several ways. The most usual supports are tripods of various heights. They can also be clamped to columns or have small feet attached so that they can be set into or on pipes. Suspension frames are available to hold the instruments and aim them into pipes.

Sensors or Receivers

Only one person is required when using a laser levelling instrument. When the instrument is set up and the beam is rotating, it creates a level reference plane that can be detected with the sensor or receiver.

The sensors or receivers operate on batteries and have a narrow window through which the beam can be detected. When the beam is sensed, the detector shows a small coloured light or emits a sound. Sensors or detectors can be attached to the levelling rod or used by themselves to locate instrument height on walls, forms, or pipe work.

Plumb Bob

The ***plumb bob*** is used to establish a vertical line or a point directly above or below another point. Most plumb bobs are made of steel or brass and have a small threaded point that can be replaced if it becomes damaged. Some plumb bobs are hollow and filled with mercury, which adds weight and helps dampen movement without increasing size.

Plumb bobs vary in size from 250 g (9 oz) to 500 g (18 oz). On very large jobs, plumb bobs can weigh as much as 30 kg (65 lbs). These are held by piano wire and suspended in a large pot of oil to dampen movement.

Nothing should be allowed to touch a plumb bob line when it is suspended. The string should be attached through the centre hole of the bob and tied with the knot underneath.

The plumb bob is useful for plumbing piping, walls, posts, concrete forms, and other vertical objects.

Plumb bobs that use lasers are also widely available to save time when laying out pipe runs. Laser plumb bobs can be rested on the floor to transfer marks upward to the ceiling, for example.

Figure 58 *Conventional and laser plumb bobs (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Layout and Marking Tools

Marking tools are used by tradespeople to indicate exact points of reference for various procedures such as cutting or drilling.

Soapstone

Soapstone is a chalk-like substance used to mark heat-resistant ***layout lines*** on steel. The disadvantage of soapstone is that it can wipe off easily. Because of its brittle nature, soapstone is best used in holders, which may be round or flat.

Figure 59 *Soapstone in a soapstone holder (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Scriber (or Awl)

The *scriber* is a marking tool made with a hardened, tempered steel point that scratches mild steel and other relatively soft metals. The scriber or awl is used to make layout lines that are accurate and that have greater permanence than lines made with soapstone. Scribers are precision tools and should not be used for any other purpose (for example, as a toothpick).

Figure 60 *Scribers (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Chalk Line

Chalk lines are used to lay out straight lines on a dry surface. A chalk line consists of a string on a retractable reel contained within a case. The case has a filler opening through which powdered chalk is poured. Every time the string is pulled from the case, it gets a coating of chalk, which is often red, yellow, or black.

The line is stretched tightly between two points on a surface, raised straight above the surface of the material at its centre, and then allowed to snap back. The snapping action deposits a straight line of chalk on the surface. The end of the line has a hooked eye that allows it to grip the edge of a surface such as plywood or hook over a nail driven into a structural member.

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

Divider and Trammel Points

Another tool used in connection with layout and metal fabrication is the ***divider***. You can use the divider to scribe circles and ***arcs*** or to locate one ***centre point*** in relation to another. As with the scriber, the hard, slender point must be ground frequently to keep it sharp, but the grinding should be done gently to avoid overheating and softening the metal.

Figure 62 *Divider (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Trammel points are attached to a length of scaled material and are used for marking large circles or arcs.

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

Centre Punch

The ***centre punch*** has a tapered bit with a broad, sharp point. Punches are ground to an angle of 90°, which makes them durable tools, but they are also somewhat difficult to position accurately on a smooth work surface such as plate. They are used chiefly for punching small indentations in metal as a guide for starting a drill bit. For this procedure, you first mark the material to be drilled with a scriber or pencil, place the centre punch directly on the mark, and strike the head of the punch with a sharp blow from a hammer. The indentation will prevents the drill tip from slipping or "walking" out of position.

Figure 64 *Centre punch (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Prick Punch

The ***prick punch*** has a bit that is tapered to a very narrow, sharp point. The point of a prick punch is ground to an angle of 30°. This gives the prick punch a very thin point that makes it easy to place accurately on the ***workpiece***. Often a prick punch is used to make the first indentation, then a centre punch is used to make a wider, deeper indentation. Although pipe trades workers do not make frequent use of a prick punch, it can be used in connection with drilling to make a small, accurate indentation at the intersection of two layout lines. Once this indentation is accurately located, the centre punch can be used to enlarge the indentation to a size that is suitable for the drill bit.

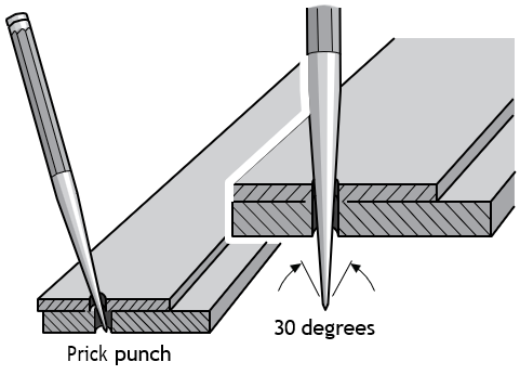

Figure 65 *Prick Punch (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The prick punch is occasionally used to align holes in two or more sheets or plates. By inserting the tapered end of the prick punch through the holes drilled into the metal and moving it back and forth, you can accurately line up the holes.

Punches become dull in time, and like scribers, they need to be ground gently on a grinding wheel. As with scribers, you must take care not to overheat punches, as this will remove the ***temper*** from the metal.

Check Your Knowledge: Blades and Measurement Tools

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Hammering and Prying Tools

Hammering tools are used in the pipe trades for striking and shaping materials, driving fasteners, and for hitting objects such as punches and pins. ***Prying*** tools assist the worker in removing unwanted fasteners or objects.

Claw Hammers

The head of a claw hammer is made of ***drop-forged steel***, which is heat-treated to make it strong and long-lasting. Claw hammers come in different weights:

- Light claw hammers, which weigh about 370 grams (13 oz.), are used for finishing.
- Heavy claw hammers, up to about 900 grams (32 oz.) in weight, are used for framing.

The average framing claw hammer weighs between 570 and 680 grams (20–24 oz.).

Claw hammers also come in two claw styles: The *straight (ripping) claw* is used most often for ripping apart wooden members. The curved claw is better suited for pulling nails.

Curved claw

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

Claw hammer handles are made of wood, fibreglass, or metal. The wood handle, usually fashioned from ***hickory***, absorbs shock better than a metal handle.

The metal or steel handle is either hollow or solid and extends into the hammer head. The end of the handle has either a rubber or leather grip. The advantage of the metal handle is that it almost never breaks; but, as mentioned, it is not a good shock absorber.

The fibreglass handle offers a compromise between the wood and steel types. It stands up to wear better than wood and has superior shock-absorbing qualities.

The head of the claw hammer should be securely fastened to the handle. A head that is loose should be re-tightened with metal wedges.

The most important feature of a hammer is its ***balance***. A hammer should feel comfortable in the hand, not head-heavy. The distribution of weight between the head and the handle, along with the length of the handle, determines the hammer's balance.

The hammer has two parts: the head and the handle. The head is made up of the following parts:

- face
- poll
- neck
- cheek
- claw
- *adze eye*

The face of the claw hammer is slightly curved and can be either smooth or *cross-hatched*. The cross-hatched hammer is usually used for framing because the hatch marks help prevent the hammer face from slipping off the nail. The cross-hatched hammer is not used for finishing because it can leave marks on the material.

Figure 67 *Parts of a hammer (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Ball-Peen Hammers

The heads of steel-face hammers, such as ***ball-peen hammers***, are made from high-grade alloy steel, ***drop-forged*** and *heat-treated* to the proper hardness. The ball-peen hammer (Figure 68) generally has a slightly rounded (***convex***) striking surface or face. The end opposite the face is shaped like a full half sphere and is called a ***peen***.

Figure 68 *Ball-peen hammer (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The size specification for a ball-peen hammer is determined by the weight of the head. Ball-peen hammers weigh from about 5.6 g to 1.35 kg (2 oz. to 3 lb.).

The ball-peen hammer can be used to set *soft* ***rivets*** or to strike chisels and punches. Small ball-peen hammers can be used to cut *gaskets*.

Sledgehammers

Sledgehammers are used for heavy work requiring significant force. They have longer handles than regular hammers and large rectangular heads. They weigh between 2.2 kg to 9 kg (5–20 lb.). Sledgehammers are also available for special applications, with soft heads or specially shaped heads. Handle length will vary with the weight of the head.

Figure 69 *Sledge hammer (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Soft-Face Hammers

Soft-face hammers have a surface that yields (or slightly compresses) when striking an object. Soft-face hammers are preferred when machined surfaces or precision parts are involved or when *marring* (damaging) a finished surface must be avoided. When working with parts that may be damaged by a metal hammer, the *plastic-tip hammers* or *composition plastic hammers* are good alternatives. You can also protect these parts by placing a piece of wood or brass over the surface before striking it with a hammer.

Figure 70 *Soft-face hammer (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

A plastic-tip hammer has a soft-face head and usually weighs between 225 g and 850 g (8 oz. to 2 lb.). Head diameters range from 18 mm to 32 mm ($\frac{3}{4}$ in. to 1 $\frac{1}{4}$ in.). Replaceable plastic tips are usually available in different levels of hardness.

Another type of soft-face hammer has a specially compounded *composition plastic tip* rather than a clear plastic tip. Replaceable tips made of extra-tough nylon are also available. This hammer is usually furnished with a fibreglass handle with a rubber handgrip.

A *brass-headed hammer* also has a relatively soft face. It typically weighs between 450 g and 850 g (1–2 lb.). A brass-headed hammer can be used for driving gears or shafts, or for tapping *shaft-mounted rocker arms*.

A *rubber mallet* has a high-grade rubber head moulded onto the handle. The handle may have ridges and grooves to retain the head. Rubber mallet heads are all about the same size, but weights vary from between 450 g and 850 g (1–2 lb.).

Figure 71 *Rubber mallet (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

A rubber mallet should be selected when it is important not to scratch or dent a nearby surface. However, this hammer should not be used on sharp or hardened work. Rubber mallets are often used for ***steam-tracing tubing***.

Lead hammers are used as "***dead-blow***" *hammers* because they don't bounce back when striking. They also don't mar or scratch delicate surfaces. Unfortunately, they tend to release and rub off bits of highly toxic lead dust and are no longer recommended. A safer alternative is a hammer with a hollow head filled with steel shot.

Chipping Hammers

Chipping hammers are a regular part of the pipefitter's or welder's tool set. They are used after every weld deposit to chip ***slag*** from the weld bead. The heads of chipping hammers are made of *forged alloy steel* that has been hardened and tempered for maximum strength. The types available differ only slightly in design, and the most common design is the cone point on one end and a straight chisel edge on the other. They may have either a wire or a hardwood handle. The pointed tip of the slender cone and the thin, tapered chisel edge can reach slag in even the most confined area.

Figure 72 *Chipping hammer (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Wrecking Bar

The ***wrecking bar***, also called a *gooseneck*, is from about 300 mm to 915 mm (12 in. to 36 in.) long, with the average length of about 600 mm (24 in.). It is made of heavy octagon-shaped steel with one end flattened and the other formed into a hook and claw for pulling nails. This bar is used for ***demolition***, removing or stripping concrete ***formwork***, and prying materials apart.

Figure 73 *Wrecking bar (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pry Bar

The ***pry bar*** (also called the *crowbar* or *long bar*) is made in two styles: a *pinch point* and a *wedge point*. A pry bar is typically 1200–1725 mm (5–6 ft.) long and weighs about 15 kg (33 lb.). It measures about 40 mm (1 $\frac{1}{2}$ in.) at the widest point. This bar is used for heavy work such as stripping concrete ***pipe sleeves*** and loosening compacted soil.

Wonder Bar

The ***wonder bar***, which is about 400 mm (16 in.) long and made from flat metal. It is used for light-duty prying and stripping work. There is a claw on either end. One end is bent to 90°, while the other end has a slight bend for leverage when prying. It's flat, wide surface area makes it a useful prying tool for general work.

Figure 74 *Wonder bar (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Nail Claw

The ***nail claw***, also called a *cat's paw*, is a short bar, about 30 cm (12 in.) long. At one end, there is a claw for pulling nails, while the other end has a slightly bent chisel point for prying.

This tool is very useful for wood frame construction when nails have to be pulled from lumber. The small claw is driven

under the nail head, and the tool is used to pull the nail free. Depending on the length, the nail is completely pulled or just started. A wrecking bar can be used to finish pulling larger nails.

Figure 75 *Nail claw (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Check Your Knowledge: Hammering and Prying Tools

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Bracing and Clamping Tools

Bracing and clamping tools allow the pipe trades person to secure material while it is being fabricated or manipulated. It is important to know the various types of tools available to make your job safer and less difficult.

Vises

A good-quality ***vise*** is a very rugged piece of equipment. Vises hold material or a part at a bench or stand while work such as assembly, disassembly, welding or filing is being performed.

Bench Vise

The standard metal or bench vise is available in many sizes and variations. Many include a flat anvil surface on the back so that the tradesperson can use this area for forming metal.

Figure 76 *Bench vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The size of a vise is usually measured by jaw width, but the maximum jaw opening should also be measured and considered when selecting a vise. Most good vises are available with a variety of jaw widths. Some vises have a set of curved, ***serrated jaws*** just above the winding screw, to hold pipe. The jaws on most styles may be replaceable.

The Machine Vise

This type of vise is used to hold a workpiece for a machining operation. For example, a ***machine vise*** is used to hold a workpiece for drilling with a drill press. The vise can be bolted to the drill press table. Machine vise jaws are replaceable. The jaw face is usually smooth, to prevent the workpiece from becoming marred. The jaws may also have vertical and horizontal machined grooves to provide a gripping surface for round or irregularly shaped objects.

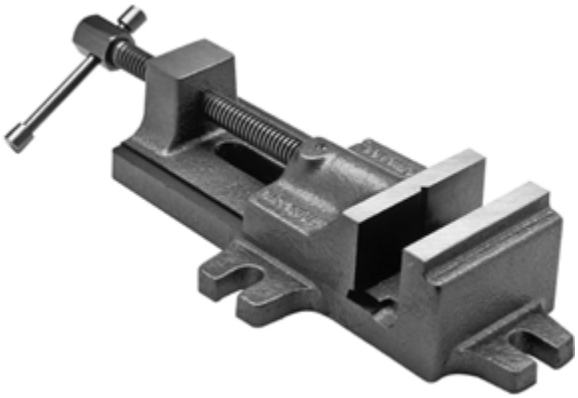

Figure 77 *Machine vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

C-clamps are available in many different sizes (the width they will open to) and throat depths (the distance they can reach over a piece of stock). They come in sizes ranging from 25 mm to 120 cm (1 in. to 24 in.).

C-clamps are used to clamp a work piece to a drill press table when the item is oddly shaped or too large to fit into a vise. They are also often used to hold a workpiece during welding or soldering operations. When welding, you must be careful to protect the screws of the clamp from weld spatter.

It is also important that C-clamps not be over-tightened, as this can damage both the clamp and the work

Figure 78 *C-clamps (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Wood Vises

Wood vises are used to hold a piece of wood while it is being worked on. By using a vise, you can use both hands on the tool, increasing your speed, accuracy and control.

The wood vise has two flat metal jaws that are opened or closed by the action of a screw thread. Wood pads are usually attached to the inner faces of the jaws to prevent marring the work piece held in the vise.

Wood vises are bolted to the front of a workbench to add to their stability. The vise has a small sliding lever near the handle that releases the screw thread and allows for rapid opening or closing of the vise.

Pipe Vises

Pipe vises are holding devices used to hold pipe stationary while you perform operations such as cutting, reaming and threading. Some are attached to portable stands for use at the job site; others are designed to be mounted on a workbench only.

Bench-mounted Pipe Vises

The following pipe vises are permanently mounted to shop benches:

Bench Yoke Vise

The iron yoke and base, and the addition of steel jaws make this yoke vise a sturdy tool; like other bench-mounted vises, it features a pipe rest. The disadvantage of this type of vise is the uneven pressure it distributes by gripping only part of the pipe wall. Too much pressure will result in a damaged or deformed pipe. The typical maximum pipe capacity is 15 cm (6 in.).

Figure 79 *Bench yoke vise (RIDGID/ Emerson Professional Tools). Used with permission.*

Top Screw Bench Chain Vise

The ***top screw chain vise*** is a popular bench-mounted type. Its main advantage lies with the holding chain, which distributes pressure evenly around the pipe. The crank handle is anchored to the base and can be swung freely and quickly in this top-mount position. The toothless jaws (chain) are sometimes specially coated with neoprene to avoid scoring the pipe. Pipe capacity is typically up to 20 cm (8 in.).

Figure 80 *Top screw bench chain vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Bottom Screw Chain Vise

This vise is no longer popular and is usually found in established fabrication shops only. The construction is similar to that of the top screw model, except for the position of the screw, which makes it slower to operate and provides for application of less force. The pipe capacity is usually up to 4 in.

Figure 81 *Bottom screw chain vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Open Side Vise

The ***open side vise*** is used for clamping a long length of pipe, but like the bench yoke vise, pressure is not distributed evenly around the pipe wall. It also maintains the disadvantage of only applying down forces from one side of the material. Pipe capacity is normally up to 10 cm (4 in.).

Portable Pipe Vises

The following pipe vices are portable for use on the job site:

Tri-stand Chain Vise

The ***tri-stand chain vise*** has a large base, hinged legs, and a folding tool tray, making it a complete, portable workbench. The chain type of vise is particularly popular because the chain holds a pipe quickly and securely, with uniform pressure. It is reasonably light and easily manoeuvrable to any area of a work site. To maintain stability it can be fastened with drop-in anchors or other appropriate fasteners to the floor, or it can be secured by the ceiling above with what is called the *ceiling brace screw*. This adjustable device allows the operator to quickly measure and cut a piece of 25 mm (1 in.) pipe to install plumb above the deck of the vise and tighten it against the ceiling for stability. Some models come equipped with a series of tubing benders formed into the deck of the unit. Pipe capacity is normally up to 125 mm (5 in.).

Figure 82 *Tri-stand chain vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Tri-stand Yoke Vise

The ***tri-stand yoke vise*** is similar to the tri-stand chain vise in most ways, except that the holding device is a pair of jaws rather than a chain. This vise is limited to holding pipe sizes up to an including 6 cm ($2\ \frac{1}{2}$ in.). As is with the bench yoke vise, pressure is not distributed evenly around the pipe.

Figure 83 *Tri-stand yoke vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Top Screw Stand Chain Vise

Two pairs of legs connected by a pipe make this vice handy for working on long lengths of pipe that require support. The legs and connecting pipe along the centre are fabricated onsite by the pipe trades worker to suit the height and length required. A ***top screw stand chain vise***, like most chain-style vises, will typically have a maximum pipe capacity of 13 cm (5 in.).

Figure 84 *Top screw stand chain vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Top Screw Post Chain Vise

This is a light but strong vise that fits any shape or kind of post to create an instant work platform. This vise might be

used on a job site where it is inconvenient to set up a tri-stand vise or when working on overhead piping. Pipe capacity is often 13 cm (5 in.) maximum.

Figure 85 *Top screw post chain vise* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Portable Kit Yoke Vise

Similar to the post chain vise in application, the vice clamps to a plank, a workbench, or a flat beam or post up to 10 cm (4 in.) thick. Maximum pipe capacity of this vise is normally up to 6 cm (2 $\frac{1}{2}$ in.).

Figure 86 *Portable kit yoke vise (RIDGID/ Emerson Professional Tools). Used with permission.*

Pipe Vises for Welding

Typically made of malleable iron, welding vises resist strain, heat, and distortion during welding tacking procedures (tack welding for fit-up of pipe). Screws and pins are used to hold the vise chains around the pipe.

Straight Pipe Welding Vise

Used on mains and risers, the straight pipe welding vise holds and aligns pipe to be tacked. Pipe capacity typically ranges from 13 mm to 21 cm ($\frac{1}{2}$ in. to 8 in.).

Figure 87 *Straight pipe welding vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Angle Pipe Welding Vise

The *angle pipe welding vise* is used on headers and branches. It holds a branch line at a right angle to a main or header while layout and cutting work is done. This type of vise can allow the pipe trades worker to work unassisted to fit up the joint. Pipe capacity typically ranges from 13 mm to 30 cm ($\frac{1}{2}$ in. to 12 in.).

Figure 88 *Angle pipe welding vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Elbow Pipe Welding Vise

The *elbow pipe welding vise* is used on horizontal mains, risers and other right angle changes of direction. It permits

lining up and holding of 90° elbows to the pipe until tacking is completed. Pipe capacity is often 6 cm to 21 cm (2 $\frac{1}{2}$ in. to 8 in.).

Figure 89 *Elbow pipe welding vise* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Flange Pipe Welding Vise

The *flange pipe welding vise* lines up the face of a flange at a right angle to the run of the pipe and holds it square for tacking. Pipe capacity is often 6 cm to 21 cm (2 $\frac{1}{2}$ in. to 8 in.).

Figure 90 *Flange pipe welding vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

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Wrenches

A wrench is a tool that is used to grip and turn a fastener or fitting. You will need a variety of different wrenches that come in both standard and metric measurements. When selecting a wrench to use, you must first know the size of the nut or bolt head and then find a corresponding wrench. Usually, but not always, each end of the wrench is a different size and is stamped accordingly. Wrenches are available with straight or offset heads.

Different styles include:

- Open-end wrench
- Box-end wrench
- Combination wrench
- Tubing nut (flare nut) wrench
- Adjustable wrench
- Ratchet wrench
- Slug wrench
- Hexagon key wrench (Allen key)
- Socket wrench
- Ratchet ***torque*** wrench
- Pipe wrench

Open-End Wrench

An open-end wrench has an open head on each end. It was designed to fit both square-headed (four corners) and hex-headed (six corners) nuts and bolts. Even though it has the advantage of being easy to position, this style of wrench can wear down corners on the nut or bolt head because it only makes contact at two points.

While the open-end wrench may not provide as good a grip as a box-end wrench, it can be used in situations where you cannot reach all the faces of the nut or bolt head.

Figure 91 *Open-end wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Box-End Wrench

The box-end wrench is an excellent tool for tightening and loosening nuts and bolts. Unlike the open-end wrench, the box-end wrench is made to grip the nut or bolt head on all sides. This prevents slipping and allows greater leverage.

The wrench must be slipped over the top of the nut or bolt head. The points around the inner circumference of the opening securely grip the bolt head or nut. These wrenches are available in either 6- or 12-point design. The 6-point wrench provides a more secure grip, but the wrench must be rotated further to achieve the next gripping location compared to the 12-point design.

Figure 92 *Box-end wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The two ends of the box-end wrench are usually different sizes. For example, a wrench with a $\frac{5}{8}$ in. opening on one end and an $\frac{11}{16}$ in. opening at the other end would be referred to as a $\frac{5}{8} \times \frac{11}{16}$ in. wrench. A metric wrench would have sizes such as 10 mm × 12 mm. The size of the wrench does not refer to the bolt diameter but rather to the distance across the flat of the nut or bolt head. Like the open-end wrench, the box-end wrench usually has the sizes stamped near the corresponding head.

Combination Wrench

The combination wrench is an open-end wrench and a box-end wrench, with both ends of the same size, combined into one tool. All the features of open-end and box-end wrenches apply also to a combination wrench. The combination wrench is available with 6- or 12-point box-end heads and in a wide selection of sizes and lengths.

Figure 93 *Combination wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Tubing Nut Wrench (Flare Nut Wrench)

The tubing nut or flare nut wrench is specially designed to provide a secure grip on line fittings. These wrenches have a slot through which the line or tube can be passed to allow a grip that is almost equal to a box-end wrench. This grip prevents wearing of the fitting hex nut corners during removal or installation, as might occur with an open-end wrench.

These wrenches are available in both imperial and metric, in a variety of sizes, and in both 6- and 12-point design.

Figure 94 *Flare nut wrench* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Adjustable Wrench

The adjustable wrench, often referred to as crescent wrenches has the provision for adjusting the opening to suit the nut or bolt being turned. The adjustable jaw is moved by a knurled nut. The size of all adjustable wrenches is designated by the wrench length, which varies from 10 cm to 61 cm (4 in. to 24 in.). For example, the 4 in. wrench has $\frac{1}{2}$ in. jaw capacity, while the 12 in. wrench has a $\frac{15}{16}$ in. capacity.

Figure 95 *Adjustable wrench* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Adjustable wrenches are useful but should never be used as a substitute for an open-end or box-end wrench. Adjustable wrenches can be pulled in either direction for light loads but develop their greatest strength when pressure is applied to the side of the wrench with the fixed jaw. Always be sure that the wrench is adjusted as tightly as possible against the nut or bolt head before attempting to turn it. This will act to avoid rounding the corners of fasteners when installing or removing them.

Ratchet Wrench

A ratchet wrench is a tool that is useful in tight places where it is impossible to reposition the wrench after each turn. Instead, you just move the handle back and forth once the box end is positioned over the fastener. It is not recommended for heavy applications.

Figure 96 *Ratchet wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Slug Wrench (Striking Wrench)

A ***slug wrench*** (or striking wrench) is a specialized thick, short, stocky wrench with a block at the end of the handle specifically designed for being struck with a hammer in order to add greater force. Used commonly with large fasteners, slug wrenches also provide shock and high force used to release large or stuck nuts and bolts, and are useful when space does not allow room for a large wrench.

Figure 97 *Slug wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hex Key Wrench (Allen Key)

The hex key or Allen key wrench is typically an L-shaped bar of hexagon-shaped tooled steel. It is made to fit the hexagon shaped hole found in some fasteners. Hex keys are classified by the size of their hexagonal stock measured across the hex flats. They come in either imperial or metric measurements, with the size usually stamped on the wrench. They are also available as a socket wrench, in a folding set, or as a series of T-handled drivers.

Figure 98 *Hex key wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Socket Wrenches

Socket wrenches are designed to be used for turning fasteners that cannot be easily accessed with a standard wrench. Socket wrenches may have 4, 6, 8, or 12 points. The 6- and 12-point sockets are most common. The 6-point socket is stronger and will do less damage to the fastener than a 12-point socket

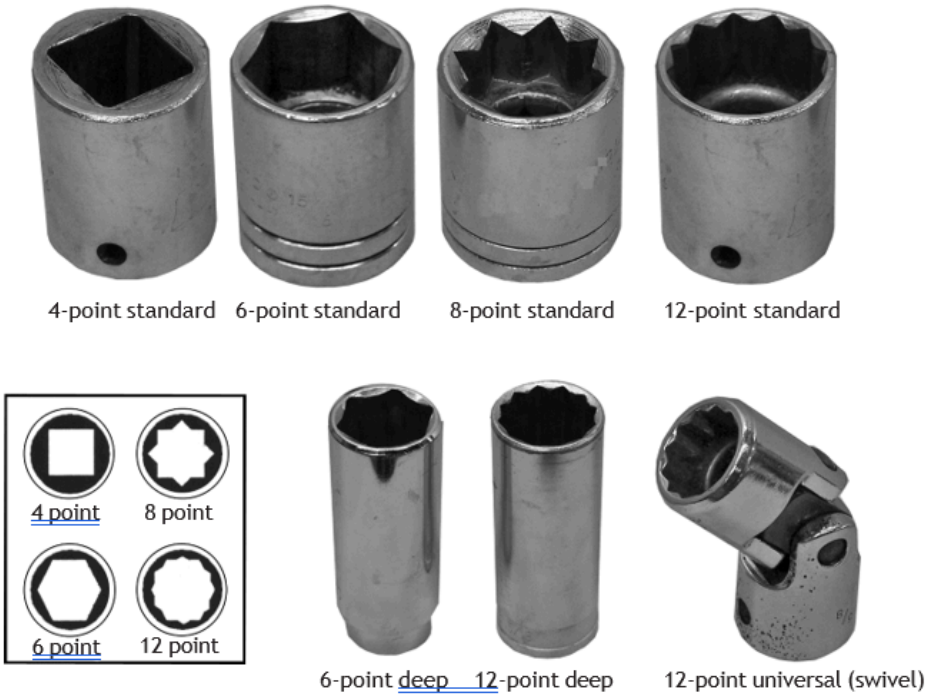

Figure 99 *Various sockets (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

A basic socket wrench set is made up of a handle and several barrel-shaped sockets. Each socket has a square hole on one end that fits directly into the drive lug on the socket wrench handle.

The other end of the socket looks like a box-end wrench and has 6, 8, or 12 points. With the socket firmly attached to the wrench handle, the socket is placed over the nut or bolt head and the handle is moved to loosen or tighten the fastener.

The universal flex or swivel socket permits the socket to be used at various angles by the swivelling action of the socket head. The deep socket allows you to loosen a nut on a stud or bolt that has a large number of threads showing when standard sockets would not be long enough to reach the nut.

Socket sizes are marked on the outside of the socket and indicate the head size of the fastener that they will fit. Other special sockets include those designed for removing and replacing oil pressure and temperature sending units, spark plugs, and sockets designed for use with impact wrenches.

Impact sockets have stronger construction and are not chrome plated, since the chrome would crack and flake off. The thick walls and heavy construction allow them to take the shock of the impact. For this reason, standard sockets should never be used with impact wrenches.

Figure 100 *Socket driver set (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The square drive is the end of the socket that attaches to the socket handle.

The square drives range in size from 6 mm ($\frac{1}{4}$ in.) to 5 cm (2 in.). The 6 mm ($\frac{1}{4}$ in.) through 19 mm ($\frac{3}{4}$ in.) sizes are most common. The drive size is measured in inches on both metric and imperial sockets.

Some socket handles have a small, half-exposed ball bearing centred on one side of the square drive. When the socket is fully pushed onto the socket handle, a machined groove or mating hole aligns with the recessed ball bearing to assist in retaining the socket.

Ratchet Torque Wrenches

Specifically useful for installing no-hub cast iron soil pipe couplings, ***ratchet torque wrenches*** tighten with a quick ratchet action and automatically release when they reach a pre-set amount of torque (twisting force). The $\frac{5}{16}$ in. driver model is common and is pre-set to 60 inch-pounds. The $\frac{3}{8}$ in. model is pre-set to 80 inch-pounds.

The click-type torque release function prevents over-tightening or damaging of gear clamps when installing no-hub couplings.

Figure 101 *Left: T-handle ratchet torque wrench; right: no-hub soil pipe coupling with [latex]\frac{5}{16} [/latex] in. gear clamps (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pipe Wrenches

A ***pipe wrench*** is used for turning pipe and other round objects. The sharp jaw teeth of the pipe wrench will dig in and mar (damage) the surface. A pipe wrench should not be used to turn bolts or nuts unless the head of the bolt has been damaged and will not accept a straight-faced wrench or socket.

Before using a pipe wrench, remove any grease or dirt from both the part to be turned and the pipe wrench jaws. A small wire brush or scribing tool is adequate. Adjust the movable jaw so that the work is gripped near the centre of the jaws. Pull carefully until the wrench has a good bite on the work. Then exert the force necessary to turn or tighten the work. Pipe wrenches should never be used on hardened surfaces since the jaw teeth may be dulled or chipped.

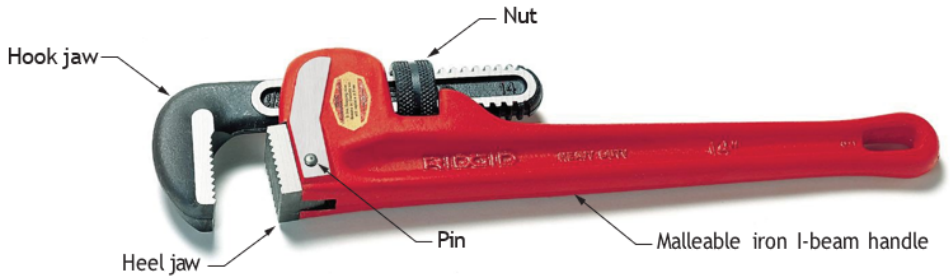

Figure 102 *Parts of a straight pipe wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

A variety of wrenches are used for gripping and turning pipe and fittings. The type of wrench selected for a job depends on pipe size, pipe material, and the amount of working space available.

The following wrenches are most common to the piping trade:

- Straight pattern pipe wrench
- End pattern pipe wrench
- Raprench

- Offset pattern pipe wrench
- Stillson pattern pipe wrenchs
- Vertical pipe wrench
- Rapidgrip wrench
- Spud wrench
- Hexagonal pipe wrench
- Compound leverage pipe wrench
- Chain wrench
- Chain tong
- Strap wrench
- Basin wrench
- Plastic nut basin wrench
- Internal wrench

The jaws of pipe wrenches have teeth for gripping round objects. The heel jaw is attached to the handle, while the hook jaw can be made to move in and out by adjusting the nut on the threaded section of the hook jaw. Both the shank of the hook jaw and the nut are held in position by the wrench housing.

Straight Pattern Pipe Wrench

Available in at least ten models, each is designed for a certain range of pipe sizes. The smallest is typically 150 mm (6 in.) long and has a pipe capacity of $\frac{3}{4}$ in.; the largest is 1500 mm (60 in.) long for use on 8 in. pipe. Pipe wrench sizes are designated by their length, measured from the tip of the handle to the inside of the hook jaw, when fully extended. Like the other standard wrenches shown here, this wrench comes with either an aluminum or cast iron handle.

Figure 103 *Straight pattern pipe wrench* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

End Pattern Pipe Wrench

These wrenches have a 45° opening and can be used when working in tight quarters or next to a wall or a corner.

Produced in about eight different sizes, the end pattern pipe wrench accepts pipe sizes ranging from 19 mm to 13 cm ($\frac{3}{4}$ in. to 5 in.).

Figure 104 *End pattern pipe wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Raprench (Rap-Wrench)

The ***Raprench*** has a pipe diameter scale on the hook jaw for size setting. It is available in several models with different pipe size capacities.

Figure 105 *Raprench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

This wrench has a deeper, broader hook jaw housing with a smooth, flat, hardened surface that is used like a hammer to jar loose pipes and fittings that have seized. The Raprench can usually accept pipe sizes up to 38 mm ($1\frac{1}{2}$ in.).

Offset Pattern Pipe Wrench

This unique pattern has the jaw open parallel to the direction of the handle. It also has a narrower hook jaw head.

These features allow easy entry to tight spots. Several models are marketed, with pipe capacities of 5 cm, 6 cm, and 8 cm (2 in., 2 $\frac{1}{2}$ in., and 3 in.).

Figure 106—*Offset pattern pipe wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Stillson Pattern Pipe Wrench

The forefather of the modern pipe wrench, the ***Stillson pattern pipe wrench***, has a pipe diameter scale on the hook jaw, for size setting. It is available in several models with different pipe size capacities, with the maximum pipe size 6 cm (2 $\frac{1}{2}$ in.).

Figure 107 *Stillson pattern pipe wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Vertical Pipe Wrench

This wrench is manufactured without a long handle and requires the user to insert a handle into the head assembly. It can be used on either vertical or horizontal pipe in closely confined areas and operates in a way similar to that of a basin wrench. It is especially useful for underground valve locations. Pipe capacity is typically 5 cm (2 in.) maximum.

RapidGrip Wrench

The ***rapidgrip wrench*** has a spring-loaded jaw designed for quick ratcheting action. It allows for one-handed operation while the worker uses the other hand to hold a backup wrench. It has a distinctive jaw designed to accept multiple sizes and shapes of material. Maximum jaw capacity is usually 5 cm (2 in.).

Figure 108 *RapidGrip wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Spud Wrench

This tool (also known as a ***monkey wrench***) utilizes smooth, flat, narrow jaws that are ideal for use on square or rectangular stock, such as a flat-edged fitting.

Figure 109—*Spud wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hexagonal Pipe Wrenches

The ***hexagonal wrench*** appears in two designs: straight and offset. Both types give a multi-sided grip, but the main difference between the two is the extra-wide opening of the offset, which is ideal for securing drain nuts on tubs and sinks. Thin, smooth jaws fit into tight spaces easily.

Figure 110 *Hexagonal pipe wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Compound Leverage Pipe Wrench

This wrench has the ability to multiply leverage numerous times. The chain wrench part attaches to the pipe adjacent to the fitting and imparts a holding force opposite in direction to the turning force of the hook jaw, which grasps the fitting. It is ideal for loosening seized joints.

Figure 111 *Compound leverage pipe wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

This wrench works on right- or left-hand threads and comes in several models, with pipe size capacities of 5 cm to 20 cm (2 in. to 8 in.).

Chain Wrenches

Chain wrenches and ***chain tongs*** provide another method of tightening threaded pipe and fittings. They have the advantage of distributing pressure evenly without crushing and work well in tight working areas, since the only clearance needed is sufficient space to wrap the chain around the pipe or fitting.

Figure 112 *Chain wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Chain Tongs

Tongs are manufactured in various sizes that can be used for pipe diameters from 6 mm to 30 cm ($\frac{1}{4}$ in. to 12 in.). When the teeth on one end of the double-ended Tongs jaw have become dull, the head can be unbolted and reversed. Single-ended Tongs (not shown) have a head that is non-reversible.

Figure 113 *Chain tong (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Strap Wrenches

Designed for polished or chrome pipe, the ***strap wrench*** has a woven nylon strap to give a tight grip. The various models have different strap lengths and widths, as well as different handle lengths. The two basic sizes have pipe capacities of 5 cm and 13 cm (2 in. and 5 in.), and handle lengths of 300 mm (11 $\frac{3}{4}$ in.) and 450 mm (18 in.). A powdered Rosin product can be applied to the strap for increased friction.

Figure 114 *Strap wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Basin Wrenches

The spring-loaded jaws of a ***basin wrench*** allow one-hand ratcheting on nuts in hard-to-reach areas. A tension plug holds the tool's head at any angle up to 90°. This wrench is particularly handy behind sinks and lavatories, where it is impossible to use a standard wrench.

The telescoping basin wrench can be adjusted for length. Its maximum capacity is 6 cm (2 $\frac{1}{2}$ in.). The non-telescoping model has a maximum capacity of 32 mm (1 $\frac{1}{4}$ in.).

Figure 115 *Telescoping basin wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Plastic Nut Basin Wrenches

Plastic nut basin wrenches are a type of basin wrench that is designed for turning plastic mounting nuts on faucets, sprayers and ballcocks. They often have a hole through the barrel to allow a screwdriver shaft to fit through and help increase torque.

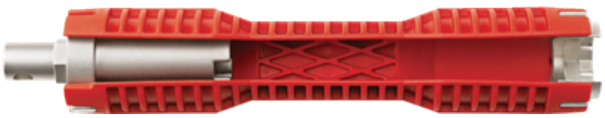

Figure 116 *Plastic nut basin wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Internal Wrench

The ***internal wrench*** is used to hold pipes, nipples, and fixture connections in place from the inside while a nut is tightened down. The knurled head of some types is reversible to accept sizes from 2.5 cm to 5 cm (1 in. to 2 in.).

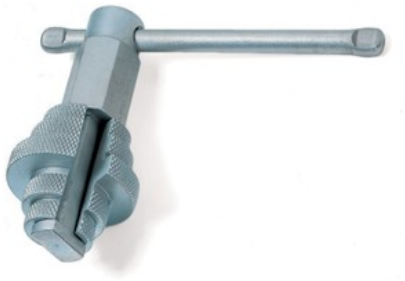

Figure 117—*Internal wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pliers

Pliers are used to increase gripping power when holding relatively small-diameter objects. Of the many types and designs that are produced, the three pliers illustrated below are the types most commonly used in the piping trades.

Never use pliers for turning nuts or bolts, as the sharp teeth will round off the corners and badly damage the nut or bolt.

Combination Slip-joint Pliers

Combination slip-joint pliers are the most common general-purpose pliers. They can be adjusted to two sizes by means of a sliding pivot that allows the jaws of the pliers to open widely for gripping larger items. The jaws have sharp, hardened cross teeth to grip the object on which you are working.

Figure 118 *Combination slip-joint pliers (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Arc-joint Pliers

Arc-joint pliers are made in various sizes with maximum capacities up to 10 cm (4 in.). The tongue and groove design provides maximum power at all openings. This type of joint design's advantage is that it is less prone to slipping under force due to increased surface area. Most piping trades people will refer to these simply as *Channellock pliers* (that manufacturer being the innovator of this product).

Figure 119 *Arc-joint pliers (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Water Pump Pliers

Water pump pliers have a maximum pipe capacity of 5 cm (2 in.). They are a style of slip-joint plier having multiple positions. The multiple slip-joint setup provides for rapid changes of jaw opening.

Figure 120 *Water pump pliers* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Linesman Pliers

Linesman pliers are non-adjustable, in that they have a fixed pivot point, and are easy to use for a multitude of tasks from bending metal to tying wire. Originally designed for the electrical field, their flat serrated jaws are equipped with cutters for snipping wires.

Figure 121 *Linesman pliers* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Needle-Nose Pliers

Needle-nose pliers come in a variety of sizes and styles, some incorporating a cutting surface. Many needle-nose pliers are useful in bending wire into curves or circles, and for retrieving small parts from equipment and hard to reach places.

Figure 122 *Needle-nose pliers (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Diagonal or Side-Cutting Pliers

Diagonal or side-cutting pliers are made with a diagonally cut head or face and a hard steel cutting edge to cut wire or other metal objects close to the surface. Diagonal cutters are especially useful for removing cotter pins (pins used for securing parts to equipment) and for trimming cotter pins to the desired length after installation.

Figure 123 *Side cutters (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Locking Pliers

Locking pliers are produced by several manufactures in a multitude of styles but are often referred to as *Vise-Grips* due to the popularity of that brand. They have a built-in spring-type mechanism which can be locked into position and released by pulling or squeezing a release lever. Locking pliers come in several sizes and styles and are available either with straight, cutting or curved jaws.

Figure 124 *Locking -pliers (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Wire Strippers/Crimpers

Wire strippers/crimpers are useful when making multiple wiring connections or splices. They include squared and rounded ***crimping*** heads, multi-gauge wire strippers, and a set of wire cutters. Most types also have small holes that enable smooth, quick cutting of small diameter machine bolts.

Figure 125 *Combination wire strippers/crimpers (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Screwdrivers

Screwdrivers are available in a variety of lengths and sizes. The length of a screwdriver is measured from the tip to where

the handle joins the blade. Lengths range from 38 mm to 60 cm (1 $\frac{1}{2}$ in. to 12 in.) or more, with the shorter lengths known as "*stubbies*." Stubbie screwdrivers are used only when space will not permit use of longer screwdrivers.

Some common screwdriver types include:

- Slotted
- Robertson
- Phillips
- Ratchet
- Stubby
- Offset
- Torx
- Clutch drive
- Allen

The parts of a screwdriver are the head, handle, ferrule, shank, blade, and tip. The length of the blade, as mentioned above, indicates the size of a screwdriver. Some screwdrivers may have square shanks that permit turning with a wrench, when required for extra torque.

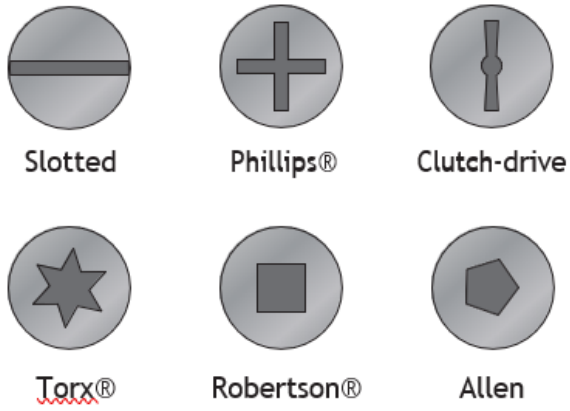

Figure 126 *(BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

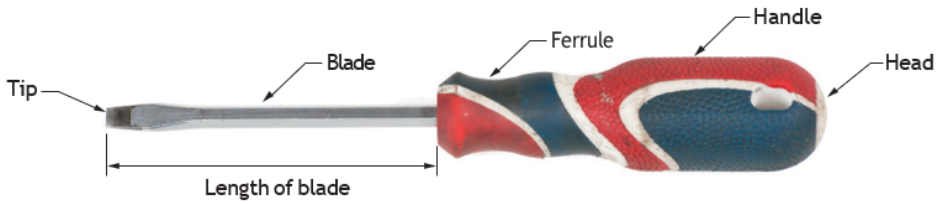

Figure 127 *Parts of a screwdriver (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Slotted Screwdriver

Although almost completely replaced by the Robertson head in modern construction, the slotted screwdriver was at one time the most commonly used screwdriver, and is still sometimes referred to as the "conventional" screwdriver. It comes in many lengths and tip sizes. When you select a screwdriver for slot screws, make sure that the tip is as wide as the diameter of the screw head and that it is as thick as the slot size. The figure below shows the correct fit for slot screwdrivers.

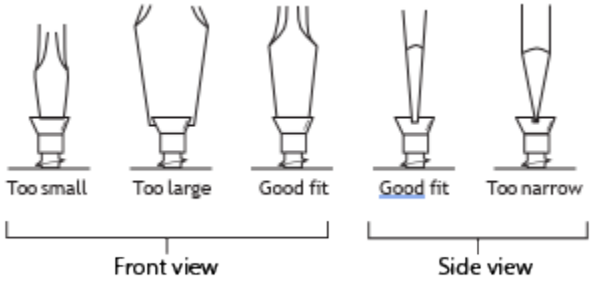

Figure 128 *Fitting for slotted screwdrivers (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

If the tip of the screwdriver becomes worn and rounded, reshape it by filing or grinding, often called dressing. Figure 129 shows correctly and incorrectly ground screwdriver tips.

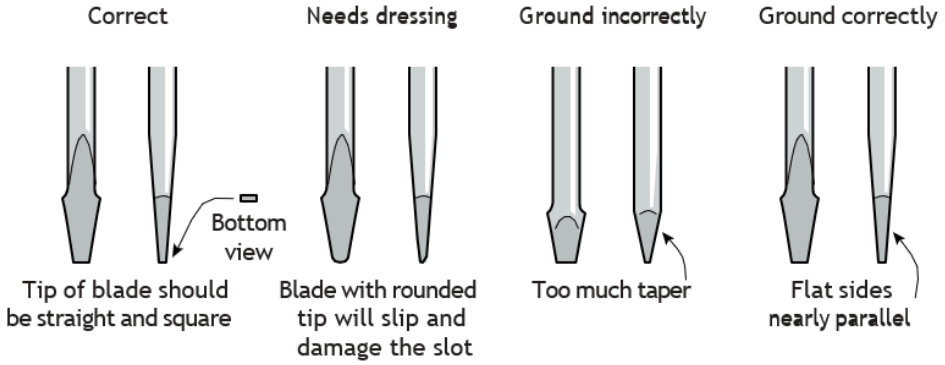

Figure 129 *Grinding slotted screwdriver blades (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Robertson Screwdriver

The advantage of the Robertson-head system is that it has a square-shaped socket in the screw head and a square protrusion on the tool. Both the tool and the socket have a taper, which makes inserting the driver easier and also tends to help keep the screw on the tool tip without the worker needing to hold it there.

Robertson screwdrivers are named after Canadian inventor P.L. Robertson, who invented the system in Milton, Ontario, in 1908.

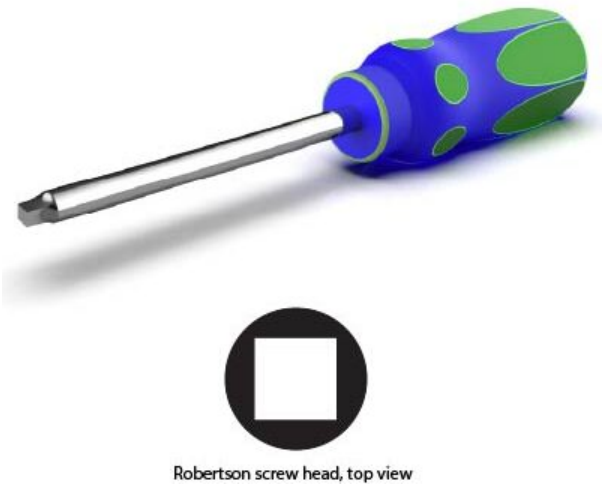

Figure 130 *Robertson screwdriver (Vijesh Panchal/ Pixabay) Pixabay Content License (https://pixabay.com/ service/license-summary/)*

Robertson-head screwdrivers are available in range of tip sizes. Robertson screwdrivers have a unique system of colour coding that are indicated on their handle according to the following colour and sizing system:

Table 1: ***Robertson Screw and Driver Classifications***

Colour	**Tip Size**	**Screw Sizes**
Orange	No. 00	#1 & #2
Yellow	No. 0	#3 & #4
Green	No. 1	#5, #6, #7
Red	No. 2	#8, #9, #10
Black	No. 3	#12 and larger

Phillips Screwdrivers

Phillips screws and drivers were known as “crossheads” when Henry Phillips first developed them in the early 1930s. The importance of the Phillips screw design lies in its self-centring property, useful on automated production lines that use powered screwdrivers. The Phillips screwdriver is available in the following sizes: No. 00, No. 0, No. 1, No. 2, No. 3, and No. 4, with No. 00 being the smallest and No. 4 the largest.

Figure 131 *Phillips screwdriver (kjpargeter/Freepik) Terms of Use (https://www.freepik.com/legal/terms-of-use)*

Ratchet Screwdrivers

The ratchet screwdriver typically has different tips for fitting into slotted, Robertson, and Phillips screws. To speed up a job, the ratchet on the ferrule of the driver can be set to install or remove a screw without the operator having to release the handle to regrip the driver. It can also be set to a locked position to permit the driver to be operated as an ordinary screwdriver.

Figure 132 *Ratchet screwdriver (Pittigrilli/Wikimedia commons) CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/)*

Stubby and Offset Screwdrivers

The stubby screwdriver is available in all sizes of slot, Robertson®, and Phillips® tips. The blade and handle are very short.

Another design is the ***offset screwdriver***, which enables the operator to reach into tight spaces. Most offset designs are Z-shaped, with the face of the tip at one end at right angles to the face of the tip at the other end.

Figure 133 *Stubby (top) and offset (bottom) screwdrivers (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Torx Screwdrivers

Torx is the trademark for a type of screw head characterized by a 6-point star-shaped pattern. By design, ***Torx head screwdrivers*** and screws resist ***cam-out*** (slipping out of the screw head) better than Phillips head or slot head screws. Where Phillips heads were designed to *cause* the driver to cam out, to prevent over-tightening, Torx heads were designed to *prevent* cam-out.

Torx screws are commonly found on automobiles, motorcycles, hard disk drives, and consumer electronics. Initially, they were sometimes used in applications requiring tamper-resistance, since the drive systems and screwdrivers were not initially widely available.

Figure 134 *Torx screwdriver (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Never use an Allen key wrench on a Torx screw. The head of the Torx screw may appear to fit an Allen key wrench, but you will find that as soon as force is applied, the corners of both the wrench and screw may be damaged.

Clutch Drive Screwdriver

The ***clutch drive screwdriver*** is used in the automotive and manufacturing industries. The driver tip must exactly match the size of the head. The head of the screw is held firmly by the driver tip; if a slot or Phillips driver were used with it, the screw might slip out.

Figure 135 *Clutch drive screwdriver (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Allen Head (Hex Head) Screwdrivers

Similar to the Allen key wrench, Allen head screwdrivers have a hexagonal head used to drive screws that have a matching hexagonal socket in the head.

Figure 136 *Allen screwdriver (Ralph/Pixabay) Pixabay Content License (https://pixabay.com/service/license-summary/)*

Check Your Knowledge: Pliers and Screwdrivers

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Tubing Benders

An ***annealed*** (softened by heating) copper tube can easily be bent across your knee, but its original circular cross section will be flattened in the process because the lateral forces across the part being bent haven't been contained. The use of ***tubing benders*** enables smooth corners to be formed in tubing while retaining the original profile. Tube benders range in styles from simple spring benders to complex mechanical benders that are used for larger bending operations.

Maximum capacities for tubing benders will be dictated by tubing diameter, wall thickness, style of benders and type and temper of the material.

Spring Tubing Benders

These types of benders form quick changes of direction in small-diameter soft-drawn copper and aluminum tubing.

Capacities range from 6 mm to 22 mm ($\frac{1}{4}$ in. to $\frac{7}{8}$ in.) OD.

Figure 137 *Spring tubing bender (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Compression Hand Lever Benders

This bender is designed for bending stainless steel, steel, copper, and aluminum tubes of several sizes.

It is equipped with a degree dial on the bending wheel allowing the user to easily read any angle of the bend.

Tube size dimensions for this type of bender usually range from 5 mm to 19 mm ($\frac{3}{16}$ in. to $\frac{3}{4}$ in.) OD.

Parts of the Compression Hand Lever Bender:

- **Bending Wheel**: provides the circular form that the tube rotates around during the actual bending process.
- **Placement Link**: has indicators that are used to correspond with measurements that are marked on the tubing.
- **Pull Handle**: assists to draw the tubing around the bending wheel to the desired bend required.
- **Tubing Fastener**: acts to lock the tubing in place during the bending process.
- **Stationary Handle**: supports the bending wheel while the bender is being use.

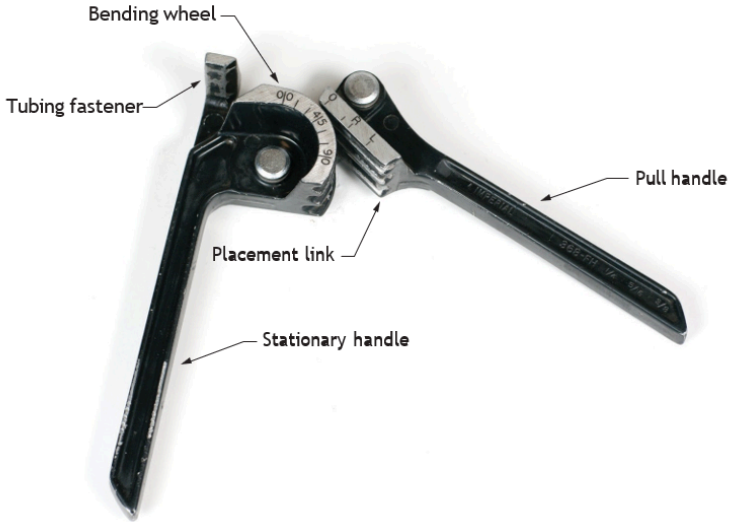

Figure 138 *Parts of the compression hand lever bender (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Swaging Tool

A ***swaging*** tool is sometimes used to join two lengths of tubing together. The tool is driven into the end of an annealed (softened by heat treating) tube. This forms a socket that will accept the end of the other piece of tube perfectly.

Figure 139 *Swaging tools (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Some swaging tools come in sets with a dedicated tool for each tube size, while others may have stepped formations to be used for multiple sizes.

Flaring Tool

Flaring tools are used to provide a mechanical joint in tubing systems. When flaring, the end of the tube is clamped into a flaring block to the correct height. The body of the tool is placed over the flaring block and a screw is turned to drive a steel cone toward the end of the tube. The better versions of flaring tools have the steel cone moving eccentrically, which sweeps the edge of the tube as it lowers forming a 45° flare.

Figure 140 *Flaring Tool (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

During tube installation, the flare is seated to a fitting with the inside of the flare against the cone-shaped end of the fitting, and the flare nut is screwed onto the fitting, pulling the inside of the flare against the seating surface of the fitting.

PEX Connecting Tools

Cross-linked Polyethylene (**PEX**) has become very popular for use in residential water plumbing because of its flexibility.

PEX tubing has also become the most popular material to transport water in hydronic radiant heating systems. Methods of joining the tubing include crimping, compressing, expanding and stainless steel clamping. It is unable to be welded with solvents.

Crimping Tools

The standard method for connecting PEX pipe to brass or plastic PEX insert fittings uses a copper crimp ring and a crimping tool. The copper crimp ring is placed over the pipe, the fitting is inserted inside the pipe, and the copper ring is crimped over the pipe and fitting using the crimping tool. The compression forces of the tool deform the ring to hold tightly against the tube and fitting, providing a reliable seal.

These tools are available in single size models, multiple size models, and a special style used for crimping in tight locations.

The Stainless Steel Clamp (SSC) method uses special clamps designed for PEX connections. The fittings used here are the same used in the standard connection method above, but in this method the SSC fastens the PEX tube to the fitting. A special SSC crimping tool is used to tighten the clamp around the tube and fitting.

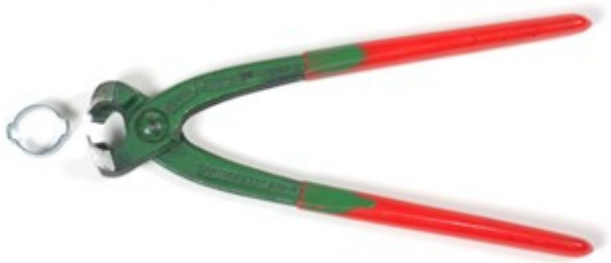

Figure 141 *Stainless steel clamp crimping tool and clamp (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Crimp Ring Removal Tool (Decrimper)

PEX crimp fittings can be reused after removal with the use of this crimp ring removal tool. Its jaws are set to a depth that will bite through the crimp ring and tubing, but won't damage the fitting. Some types will work on multiple sizes of tube, while others are size-specific.

Figure 142 *Crimp ring removal tool (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

PEX Expander Tools

The expansion method involves using an expander tool to increase the diameter of the PEX tube and a PEX collar, or ring. Special expansion fittings are inserted into the tube once expanded, which shrinks back to shape around the fitting. This method is unique and specific to one manufacturer's product

Figure 143 *PEX expander tool kit (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The shape memory capability of certain types of PEX tubing allows for this distinctive joining capability. Not all types of PEX tubing can be joined through the expansion process. The shape memory capability of PEX-A tubing (which is tubing that is manufactured using the Engel method) allows for this distinctive joining capability. PEX tubing types B and C, which are manufactured differently, must use crimp rings or SSCs.

Hand Threading Tools

The threaded piping used in some plumbing installations for the delivery of gases or fluids under pressure has a threaded section that narrows to create a seal (in contrast to the straight thread pattern commonly found on bolts). This is called ***tapered thread***.

Pipe 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 tape are applied to male (external) threads to lubricate the mating of the threads, thereby reducing friction and allowing the joint to be properly tightened to specifications without binding.

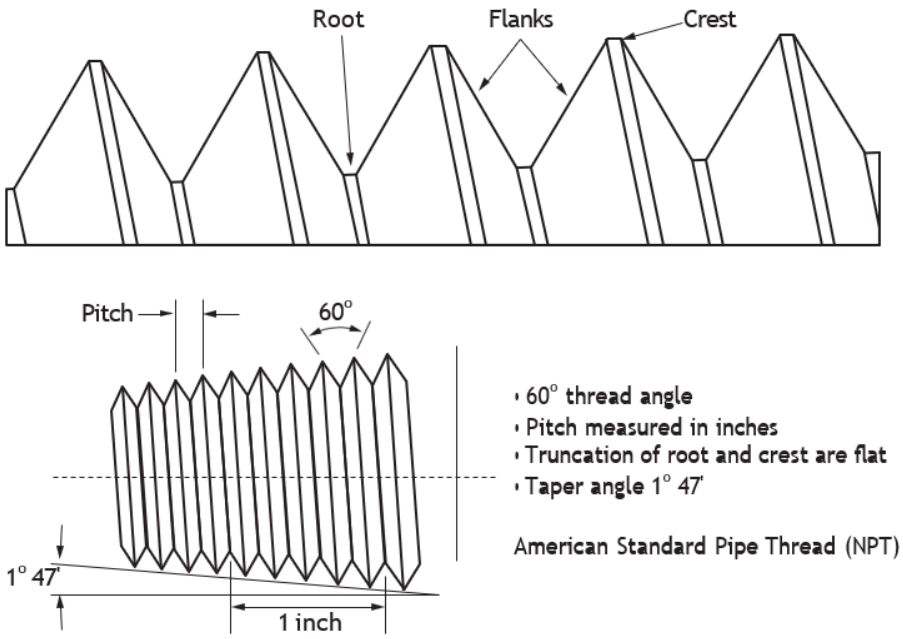

Figure 144 *National pipe thread (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

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

The rate of taper for all NPT threads is $\frac{1}{32}$ in. per inch (1° 47′) and the grooves that create the threads are formed at 60° angles.

Commonly used 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, appearing on pipes and fittings by most North American suppliers. Sizes smaller than $\frac{1}{8}$ in. are occasionally used for compressed air, while sizes larger than 2 in. are uncommon, due to the use of alternative methods of joining that are more common with these larger sizes.

European standard thread is known as ISO *Thread* or formally British Standard Pipe Thread (BSPT). In this system, there are two types of thread distinguished: *British Standard Pipe Parallel Thread* (BSPPT) which is a "running" thread with no taper—similar to bolt thread—in which the diameter of the threads is constant, and British Standard Pipe Taper Thread (BSPTT) in which the thread diameter increases or decreases along its length. Note that BSPT and NPT are not

interchangeable. BSPT and ISO use threads produced at an angle of 55° and the threads are rounded equally at crests and roots by circular arcs.

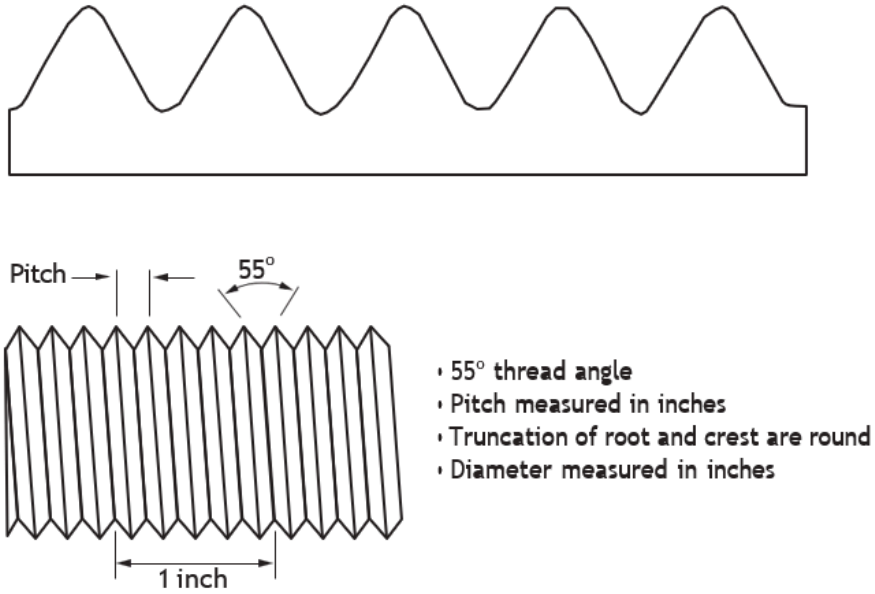

Figure 145 *ISO Thread (British Standard Thread) (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Especially precise threads are known as ***dry fit (or dry seal)*** meaning that no sealant is required for a gas-tight seal. Such threads are designed to ANSI/ASME standard B1.20.1 and are needed where a sealant would contaminate or react with the contents inside the piping (i.e., oxygen service).

Tapered threaded fittings are most commonly found in conjunction with carbon steel and other metallic pipe but are also used on plastic piping.

Due to the ***interference fit (wedging effect)*** of the tapered thread, extreme care must be used to avoid over-tightening a plastic joint. The over-stressed female fitting may split days, weeks or even years after initial installation.

Table 3: NPT and ISO Pipe Thread Sizes, Dimensions, and Thread Characteristics

Nominal Size	Threads Per Inch	Pipe OD	Pipe ID	Thread Angle	Pitch
$\frac{1}{8}$ **in.**	NPT **27**/ISO **28**	0.405 in.	0.269 in.	60°/55°	0.037 in./0.036 in.
0.25 in.	NPT **18**/ISO **19**	0.540 in.	0.364 in.	60°/55°	0.0556 in./0.053 in.
$\frac{3}{8}$ **in.**	NPT **18**/ISO **19**	0.675 in.	0.493 in.	60°/55°	0.0556 in./0.053 in.
0.5 in.	NPT **14**/ISO **14**	0.840 in.	0.622 in.	60°/55°	0.0714 in./0.071 in.
$\frac{3}{4}$ **in.**	NPT **14**/ISO **14**	1.050 in.	0.824 in.	60°/55°	0.0714 in./0.071 in.
1 in.	NPT **11.5**/ISO **11**	1.315 in.	1.049 in.	60°/55°	0.087 in./0.091 in.
1 $\frac{1}{4}$ **in.**	NPT **11.5**/ISO **11**	1.660 in.	1.380 in.	60°/55°	0.087 in./0.091 in.
1 $\frac{1}{2}$ **in.**	NPT **11.5**/ISO **11**	1.900 in.	1.610 in.	60°/55°	0.087 in./0.091 in.
2 in.	NPT **11.5**/ISO **11**	2.375 in.	2.067 in.	60°/55°	0.087 in./0.091 in.

Steel Pipe Nominal Dimensions for Standard Weight (Schedule 40) Pipe

Pipe size is specified with two non-dimensional numbers: Nominal Pipe Size (NPS) for diameter (based on inches) and pipe schedule (Sched. or Sch.) for wall thickness. ***Nominal Pipe Size (NPS)*** is loosely related to the inside diameter of

Schedule 40 pipe. NPS is used for referencing pipe sizes from 3 mm ($\frac{1}{8}$ in.) through 30 cm (12 in.), respectively.

Because of the pipe wall thickness, the actual diameter of the threads is larger than the NPS. Other schedules of pipe have different wall thickness, but the OD and thread profile remain the same, so the inside diameter of the pipe is therefore different from the "nominal" diameter.

Most threads are right hand, which means the fitting is screwed on to the threaded pipe in a clockwise motion. Other threads are left hand, in which case the fitting is screwed onto the threaded pipe with a counter-clockwise motion. Unless a thread is designated otherwise, it is assumed to be right hand.

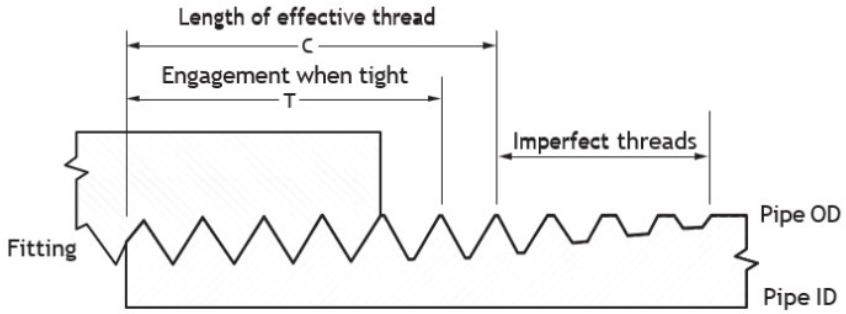

Figure 146 *Thread Engagement (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Considering that 7 to 8 threads are engaged when a pipe is screwed to a fitting (a few more for pipe sizes larger than 32 mm (1 $\frac{1}{4}$ in.), the approximate thread engagement can be measured or calculated for the various sizes of pipe. This will be useful in determining the length of pipe to cut when the centre-to-centre measurement between two fittings is known.

Pipe Taps

Pipe taps are used to cut or repair internal pipe threads. The process is called *tapping* and is usually done by hand, using a special wrench to hold and turn the tap.

Figure 147 *Pipe tap (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The pipe tap cuts standard tapered internal pipe threads. The diameter and pitch are usually stamped on the ***shank (shaft)*** of the tap.

The ***flutes (grooves)*** on a tap provide a space between the cutting edges to catch metal chips. The square end of the tap provides a sturdy grip for the tap wrench. Before attempting to tap new threads in a bare hole, taper the hole (with a taper pipe reamer) to properly shape the hole.

Pipe Dies

Dies are used to cut the *external* threads on pipe and fittings. The process is known simply as *threading*. A die head holds the cutting dies in place. A handle is mounted on the die head, often with a ratchet assembly for convenience and ease of operation and then turned to form the threads.

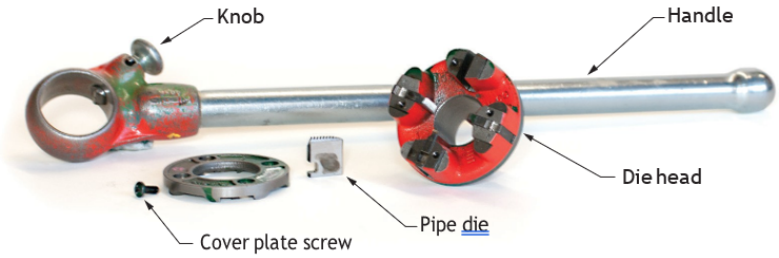

Figure 148 *Drop head threader with ratchet handle (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Dies have flutes or spaces between the cutting edges to provide space for metal chips to escape during the threading operation. They also have an angle notched into the front of the die, called the ***lead angle***, which allows the dies to start easily on the work piece.

There are two main types of dies, full width dies and receding

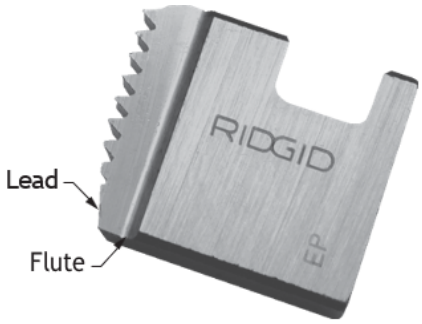

Figure 149 *Full width die (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Full Width Dies

Full width dies are equal to the length of the thread to be cut. The die moves along the pipe as it cuts the thread, and when the outer edge of the die is flush with the end of the pipe, the thread is complete. This applies to taper threads only. Full-width dies are used for threading smaller pipe sizes, where less effort is required.

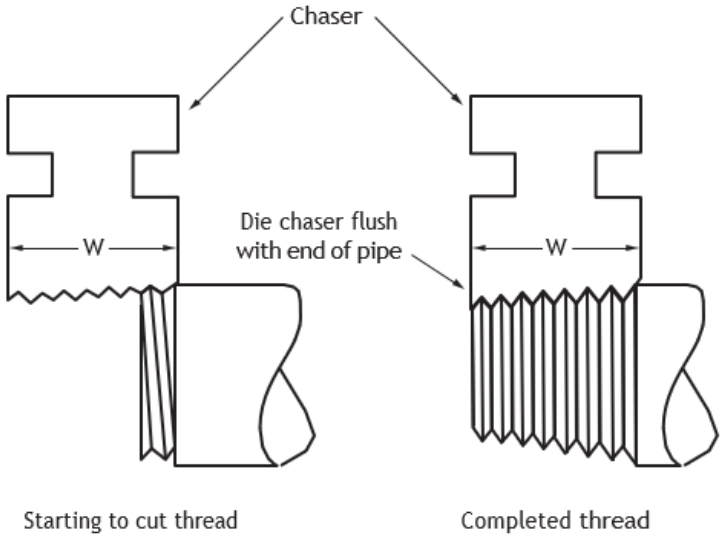

Figure 150 *Full width dies (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Receding Dies

Receding dies have considerably less width than the length of the thread to be cut. The die must travel along the pipe to cut the thread, and as the die moves along the pipe, it must recede from the centreline of the pipe in order to cut a tapered thread.

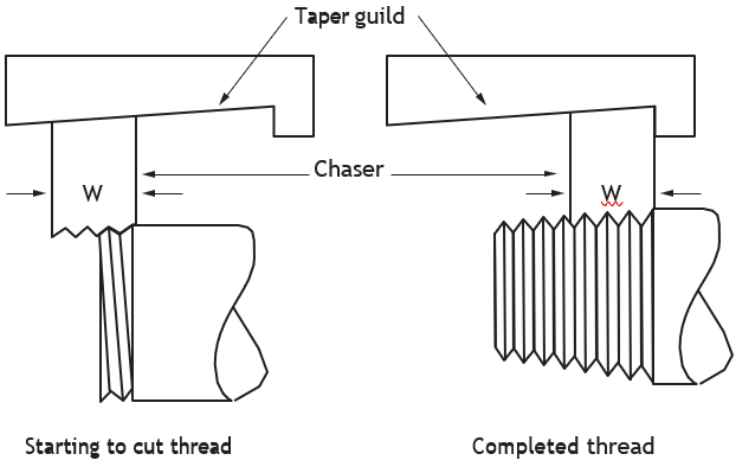

Figure 151 *Receding dies (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Receding dies are usually used to thread larger pipe where there is considerable surface area to cut.

Hand Threaders

The ratchet type of ***threader*** is preferred to other hand methods because the worker's body weight can be used to turn the full width dies while standing to one side of the pipe.

Drop head threaders are quick and easy to use for small jobs or in close quarters. The dies are interchangeable between similar pipe pitches.

Exposed Ratchet Drop Head Threader

The ***exposed ratchet drop head threader*** may be more widely used than the enclosed type. It is designed for pipe sizes ranging from 3 mm to 5 cm ($\frac{1}{8}$ in. to 2 in.). The die head locks into the ratchet and handle assembly and is removed by pulling out the reversible ratchet knob.

Enclosed Ratchet Drop Head Threader

With the enclosed ratchet drop head threader, the die head snaps into the ratchet from either side and is easily removed by pushing it out from the body. The ratchet is enclosed within the head of the ratchet handle. The pipe size capacity of this style is from 3 mm to 32 mm ($\frac{1}{8}$ in. to $1\frac{1}{4}$ in.).

Figure 152 *Exposed (left) versus enclosed (right) ratchet handles and drop head dies* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

In both the exposed and enclosed models, the dies can be reversed when threading in tight locations.

Drop head threaders can also be used with *power vises* (a machine used for turning pipe).

Jam-proof Ratchet Threader

The ***jam-proof ratchet threader*** uses receding dies and is useful for threading pipe between 2.5 cm to 5 cm (1 in. to 2 in.) in size. It uses one set of dies to thread different pipe sizes, and it is "jam-proof" (meaning that it will kick out automatically to prevent damage caused by dies receding past their limit after the thread is completely cut). This hand threader is often used as an attachment on power vises.

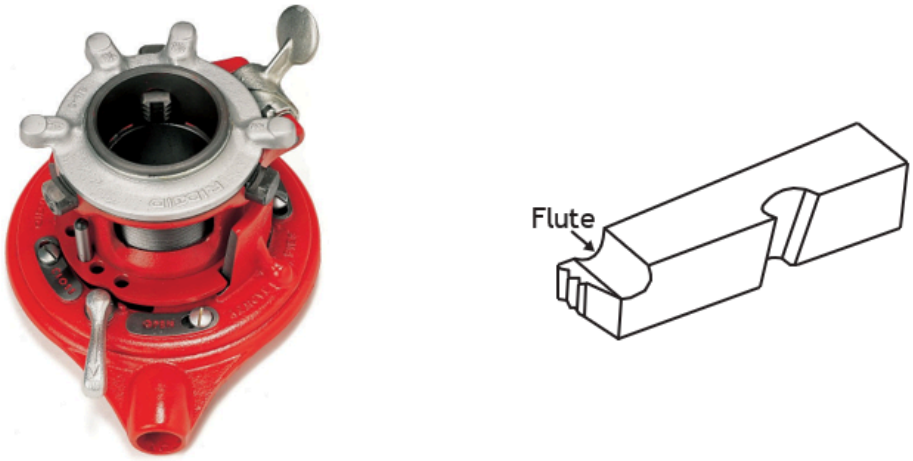

Figure 153 *Jam-proof ratchet threader and receding die* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Geared Pipe Threader

The ***geared pipe threader*** is mainly used with a power vise. It uses one set of high-speed dies for threading several sizes of pipe. A selector plate quickly sets the dies and work holder to the desired pipe size. By making adjustments, the geared threader can cut straight or tapered threads, as well as oversized or undersized threads.

The Model 141 geared threader cuts threads for pipe sizes 6 cm to 10 cm ($2\ \frac{1}{2}$ in. to 4 in.) and the Model 161 threads 10 cm to 15 cm (4 in. to 6 in.) steel pipe.

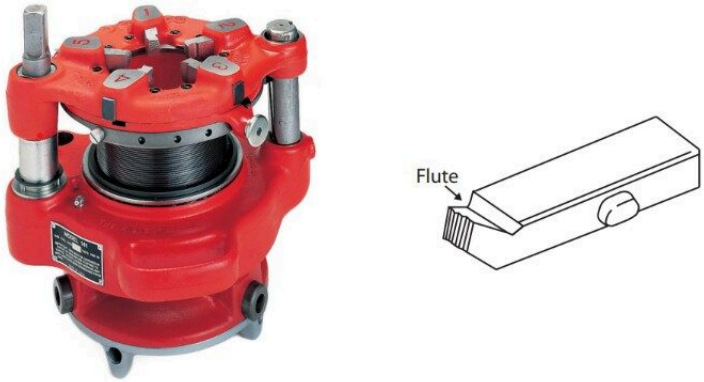

Figure 154 *Geared threader and receding die (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Geared threaders can be driven by hand with a ratchet handle (not recommended), or by power equipment.

Figure 155 *Ratchet handle for geared threader (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

A stationary power drive can be equipped with a drive shaft to power the geared threader, and there is also a hand-held power attachment available.

Thread Cutting Oil

To produce accurate work and smooth cuts, thread cutting oil (mineral oil) is used during a threading operation. The oil covers the pipe and the dies to reduce friction, cool both the chasers and the pipe, and flush away metal chips.

Thread cutting oils are either clear or dark and produce the same result when working with either power-driven or hand tools. The important ingredients include:

- Fatty oil to provide an even covering film on the workpiece
- Sulphur to supply a tough chemical film between the cutting edges and the threaded material
- Anti-foam agent to reduce surface tension and foam build-up
- Germicide to lessen the risk of infection should the operator be injured

Thread cutting oils should not be confused with the oils used to maintain the condition of tools. They are not meant to be used as lubricants for moving parts or machinery.

The hand-powered oiler provides the flow of oil to the workpiece and chasers during the threading operation. It contains a screened sump to receive oil, chips and materials, plus a hand-operated pistol-style pump to supply the oil as needed.

Occasionally the chip tray needs to be emptied of scrap material and the oil level should be maintained as directed by the manufacturer. Deal with the disposal of chips, metal scraps and used oil accordingly. Consult your site supervisor for an approved disposal location.

Figure 156 *Hand oiler (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Roll Groovers

Roll grooving is a piping connection method that continually grows more in popularity. Using pressure on a set of rollers that track the circumference of the pipe, grooves are formed to match strict specifications.

Using matching fittings and shoulder-style couplings with a gasket, grooved joints can be found in fire sprinkler systems, heating and cooling distribution, and water mains.

Figure 157 *Grooved joint (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hand-operated roll groovers are ideal for in-place field applications. Some models require only 89 mm (3 $\frac{1}{2}$ in.) of clearance to travel around a pipe and a minimum of only about 76 mm (3 in.) of exposed pipe for grooving. With the appropriate roll sets, they can form grooves in the walls of many types of metallic pipe up to 30 cm (12 in.) in diameter. A must when performing service work, the hand-operated groover is available in several different styles. Most employ the use of a ratchet handle and can be adapted for use on a power vise as well.

Figure 158 *Hand Operated Roll Groover (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Check Your Knowledge: Tubing Benders and Hand Threading Tools

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An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2725#h5p-30 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2725#h5p-30)

Electrical Testing Equipment

A technician is only as accurate as the measurement equipment being used. If the equipment is used incorrectly or is faulty, then the measurements will be inaccurate. If the measurements are inaccurate, then the technician will draw the wrong conclusions. To avoid getting inaccurate readings, you need to handle, use, and store meters properly.

The two major types of meters are digital and analog. Although both meters perform the same functions, they look different. As you can see, the difference is in the display unit.

Digital meters are usually simpler to use and are more accurate than analog meters and therefore have become more popular. We will focus on the ***digital multimeter* (DMM)**, as it is the most common type in use, although analog multimeters may still be preferable in some cases, for example when monitoring a rapidly varying value.

Figure 159 *Digital and analog multimeters (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Meter Safety Precautions

The proper care of test equipment and instruments is of utmost importance, whether they are analog or digital. The length of time an instrument retains its original usefulness, and accuracy depends largely on the care it receives in the hands of the user.

Improper connection can cause damage to the circuit or the test instrument and cause personal injury.

Precautions in Handling and Using a Meter

These precautions apply equally to digital and analog meters.

- Do not drop any meter.
- Do not overload any meter. When in doubt, use a high range that you know will not be overloaded. You can always switch to a lower range if necessary.
- Do not tamper with precision instruments. Let a competent instrument repair person service precision instruments.
- Before you connect a meter to a circuit, ensure that the range switch is set to an appropriate position.
- Carefully check circuit connections before applying power to meters.
- Be careful not to touch any other electronic components within the equipment.
- Be careful not to touch the probe tips to each other while connected to anything else.

Digital Multimeters

All ***digital multimeters*** combine the features of an ammeter, a voltmeter, and an ohmmeter. Figure 160 shows a typical DMM, although different models may have a different number of digits in the display unit and the input/output jacks may be in slightly different places. Since a DMM is an important tool, you will want to learn how to use one correctly

Figure 160 *Typical DMM (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The upper portion of the DMM houses the display unit. The middle portion of the DMM houses the function switch, and the bottom portion contains the jacks for test leads.

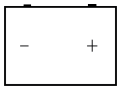
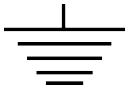
The function dial normally has positions that will allow a technician to measure AC volts, DC volts,

DC amps, and resistance. In addition, some DMMs have function switch positions that will allow a technician to measure AC amps and to test diodes and capacitors. Some DMMs require manual setting of ranges; others have an auto-ranging feature.

All DMMs may be used to measure voltage, current, and resistance. More advanced DMMs may measure frequency, relative power differences, or other important circuit parameters. Each measurement function has similarities and differences that you need to learn about.

Many meters will use symbols on the display, switch, and connections. Table 2 lists some of the common symbols you may see:

Table 2: ***Common DMM symbols***

AC	 Low Battery
DC	Manual range or automatic touch hold
Ohms	Continuity beeper
AC or DC	Diode
Hz Hertz	 Ground
+ Positive	Fuse
– Negative	Double Insulation
µF MicroFarad	Capacitor
m Milli	OL Overload
M Mega	

Mechanical Gauges

Analog Gauges

Gauges used for pressure testing may need to be of a type that can be calibrated—either by using a gauge tester or by comparison to a master gauge. These gauges are generally of the Bourdon tube type. The size of the dial face may be specified in the contract documents for the job. The accuracy of a manual reading increases with the size of the dial face.

The materials from which the gauge is constructed must be compatible with both the test fluid and the surrounding environment.

Bourdon Tube Gauges

The ***Bourdon pressure gauge*** uses the principle that a flattened tube tends to straighten or regain a more circular form in cross-section when pressurized (internally). Although this change in cross-section may be hardly noticeable, the strain of the material of the tube is magnified by forming the tube into a C-shape, so that the entire tube tends to straighten out or uncoil as it is pressurized. Eugene Bourdon patented his gauge in France in 1849, and it was widely adopted because of its superior sensitivity and accuracy.

Figure 161 *Pressure Gauge Measuring Psi and kPa (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Gauge stems (sockets) may be 6 mm or 13 mm ($\frac{1}{4}$ in. or $\frac{1}{2}$ in.) NPT, depending on the pressure range.

Figure 162 *Bourdon Tube Gauge (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Severe vibration or rapid fluctuations in pressure may cause gauges and recorders to give inaccurate readings. Circumstances may require the use of special devices or attachments to protect the gauge. Oil-filled gauges may be used on lines where vibration is not too severe. If pipe vibration is too severe, the gauge may have to be remotely mounted on a board and connected with a tube or hose to the test point.

Figure 163 *Oil-Filled Pressure Gauge (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pulsation dampeners and snubbers (Figure 164) are devices that can be installed immediately upstream of a gauge to prevent damage due to pressure pulsation or pressure surge.

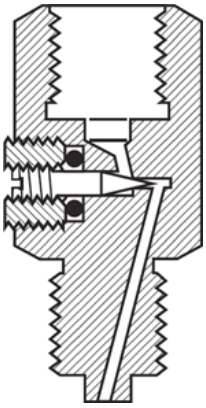


Figure 164 *Gauge Snubber* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Compound Gauges

A ***compound gauge*** indicates pressures above atmospheric (in psi) and vacuum pressures (inHg).

Figure 165 *Oil-Filled Compound Gauge* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Digital Gauges

Most digital gauges have precision within ±0.25% full scale accuracy and often measure positive, negative or differential pressures. The digital displays reduce the potential for errors in readings by eliminating errors commonly experienced with the inaccuracy of analog gages. Most units are powered by 12-24 DC and often have recharging capabilities as well. Keypads allow easy access to features including backlights, peak and valley readings, auto-zero and instant conversion of pressure units. Memory functions enable storage of multiple readings and often a HOLD key freezes the current pressure for situations where readings may fluctuate.

Figure 166 *Digital Pressure Gauge (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Manometers

The ***manometer*** is a measuring tool used to compare two different pressures, most commonly a system pressure and atmospheric pressure. There are two types of manometers, fluid-filled analog and digital. The analog manometer is simple, accurate, and reliable for measuring system fluid pressures. The analog manometer has no moving parts and does not require calibration. However, different fluids used such as mercury enable measurements of higher pressures but require further calculations.

Figure 167 *Fluid-Filled U-Tube Analog Manometer (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Typically, an analog manometer is a u-shaped tube partially filled with liquid, such as water or mercury. One end of the tube is open to atmosphere (P^2) while the other end of the tube connects to the system in question (P^1) (Figure 168). When the system pressure acts upon the fluid, this force causes the levels in the manometer to change, as seen in the image below. By measuring the difference in levels, the technician accurately measures the system's gauge pressure. For example, if 'h' was 3.0 inches in length, the system pressure is 3.0 in. of water column. If the fluid were mercury, with a specific gravity of 13.6, this measurement would read 40.8 in. of water column (1.46 psig), or 13.6 times the measurement with water.

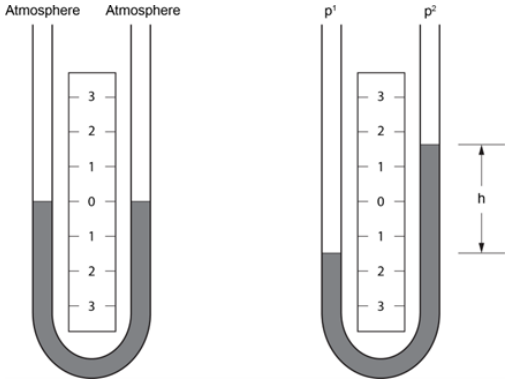


Figure 168 *Manometer basics (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The digital manometer has some advantages over the fluid-filled analog manometer: data storage to record multiple readings; multiple setting for higher pressures; technological compatibility for uploading data.

Supplementary Videos

The following BCcampus playlist includes short demonstrations of hand tools and equipment used in the trades. These videos were created by Camosun College to support the Trades Access Common Core – Tools and Equipment OER and provide practical examples of the tools discussed in this chapter.

Watch the playlist: Tools and Equipment Videos – BCcampus (https://media.bccampus.ca/playlist/details/0_3g8xp22x/categoryId/175673) [Playlist] by Camosun College

Self-Test B-1.1: Describe Hand Tools Used in the Pipe Trades

Complete Self-Test 1.1 and check your answers.

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2725#h5p-1 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2725#h5p-1)

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harmonized [Binder]. Crown Publications, Queen's Printer for British Columbia. https://www.crownpub.bc.ca/Product/Details/7960000261_S

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Camosun College. (2015). Trades Access Common Core Competency C-1: Describe Common Hand Tools and Their Uses. Victoria, B.C.: Crown Publications. Download for free from the B.C. Open Textbook Collection (https://open.bccampus.ca/browse-ourcollection/find-open-textbooks/).

Camosun College. (2022). Tools and Equipment Videos [Video playlist]. BCcampushttps://media.bccampus.ca/playlist/details/0_3g8xp22x/categoryId/175673

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All RIDGID tool images are used with permission from Emerson Professional Tools. Some of these images may have been carried forward from SkilledTradesBC learning resources; however, permission has been obtained directly from Emerson Professional Tools for their use here.

- **Figure 2** Compass saw (https://commons.wikimedia.org/wiki/File:Cassells_Carpentry.81-82_compass_n_pad_saws.png) is by Cassells' Carpentry and Joinery on Wikimedia and is in the Public Domain. (https://en.wikipedia.org/wiki/Public_domain)
- **Figure 130** Robertson screwdriver, (https://pixabay.com/photos/tool-screwdriver-manual-repair-7037516/) by Vijesh Panchal on Pixabay is used under the Pixabay Content License. (https://pixabay.com/service/license-summary/)
- **Figure 131** Phillips screwdriver, (https://www.freepik.com/free-photo/screwdriver_922730.htm) by kjpargeter on Freepik is used in alignment with the Freepik Terms of Use. (https://www.freepik.com/legal/terms-of-use)
- **Figure 132** Ratchet screwdriver (https://commons.wikimedia.org/wiki/File:Screwdriver_set_with_great_variety_of_bits_and_ratchet_screwdriver.jpg), by Pittigrilli on Wikimedia commons, is used under a CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/) license.
- **Figure 136** Allen screwdriver, (https://pixabay.com/photos/allen-wrench-tool-allen-key-allen-2134714/) by Ralph on Pixabay is used under the Pixabay Content License. (https://pixabay.com/service/license-summary/)

B-1.2 Use Hand Tools

While reading through the material, pay special attention to the safety precautions required when using hand tools.

Use Cutting Tools

Cutting tools have sharp edges that must be well maintained and handled carefully to avoid injury.

Hacksaws

When you attach a hacksaw blade to the frame, be sure the blade is placed on the pins with the arrow on the blade pointing forward, away from the handle. If the arrow is not visible, ensure that the teeth of the blade face forward because all cutting is done on the forward stroke.

There is no such thing as an all-purpose hacksaw blade. The right blade must be chosen for the specific job. The hardness and thickness of the material will determine the blade you should use.

A good rule to remember in choosing the right blade is to be sure that at least three teeth of the blade are in contact with the material being cut at all times. For materials such as wood, it would be recommended to use a 3-10 pitch blade (low TPI) Materials, such as copper may require an 18-24 pitch saw blade (high TPI).

Proper Use of a Hacksaw

Your technique is important when you use a hacksaw because the teeth are extremely fine, and the blade tends to be brittle.

1. Be sure the material to be cut is held securely in a vise or C-clamp. Secure the workpiece low in the vise. If the material shifts while you are attempting a cut, the blade may break or the material may be damaged. Be sure that the blade is held tightly in the hacksaw frame to prevent any wandering or warping of the blade during the cutting stroke.
2. Never start a cut with the saw held at a sharp angle to the material. This will break or dull the blade's teeth and also doesn't allow for at least two teeth contacting the material at all times.

Figure 1 *Left: Correct starting angle. right: incorrect starting angle (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

3. Grasp the hacksaw securely, with one hand on the grip or handle and one hand on the front of the frame. In starting the cut, guide the blade back toward you with your thumb guiding the side of the blade until the cutting slot is established (repeat this a few times). However, remember that, like a file, a hacksaw cuts only on the forward stroke—drawing the blade back is only done to accomplish a starting kerf.
4. Use a little downward pressure on the forward stroke but lift the saw slightly on the return stroke so that the teeth barely touch the material being cut.
5. The stroke should be long and steady, employing practically all the teeth on the blade. A lighter pressure should be used on soft metals and thin materials than that used on hard metals and heavier materials. Insufficient pressure on the forward stroke will dull the teeth by rubbing them against the metal without cutting it.
6. To ensure the saw blade moves in a straight line, keep your shoulder, elbow and forearm in line with the saw. This alignment is important to avoid any twisting or wobbling of the blade.
7. Do not rush when using a hacksaw. Most beginners saw too rapidly. Approximately 60 forward strokes per minute is a maximum. An ideal rate is 40 to 60 forward strokes per minute, with even pressure. If you rush the cut, you may damage the material or create injury to yourself or others.

Wood Handsaws

It is important to select the correct saw based on the direction of grain for the wood you intend to cut.

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

Using a Crosscut Saw

The following is the procedure for using a crosscut saw:

1. Mark the length of the board to be cut.
2. Square the line across the board, using a square.
3. Hold the saw at 90° to the board and about 45° from the floor.
4. Place the saw on the waste side of the line. Half the line should be left. Cutting on the wrong side will make the piece too short.

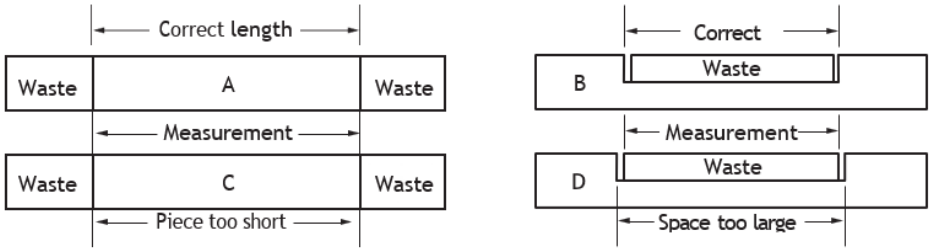


Figure 3 *Cutting on the Waste Side of the Line (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

5. Hold the knuckle of your thumb against the side of the blade. This helps to guide the first few strokes when you start a cut.
6. Start the cut gently and follow the line.
7. As you cut, keep your shoulder, elbow and wrist in line with the back of the saw blade.
8. Do not exert more pressure than you need. If too much is used, the saw may buckle, jump, and cut the operator's hand.
9. Use the full length of the blade to make the cut. Do not force the saw. Make long, smooth cuts.
10. Support the waste stock near the end of the cut. Slow down and shorten the length of the stroke. This prevents splitting the wood.

Using a Ripsaw

Using a ripsaw is similar to using a crosscut saw, except that the larger teeth can cause the saw to buckle more easily. As well, the wood may tend to bind the saw even though the saw has a good set.

The cause lies in the wood itself. When wood is split lengthwise, some of the tensions inside are released, and those remaining in the wood may make the edges want to move toward or away from each other. If the wood binds the saw in a cut, place a wedge at the start of the cut and move it as necessary.

Files

Different kinds of files are used to get the best results with different types of metal. All files are classified in two ways; by shape and by cutting face.

Shapes

The two commonly used shapes of files are the flat file and the half-round file.

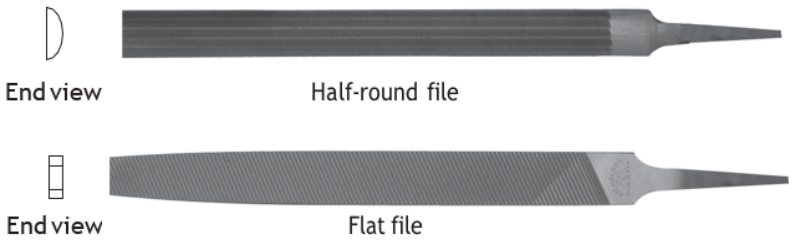


Figure 4 *File types (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The half-round file is used in pipe welding when putting the *landing* on the pipe and for removing slag and burrs. The flat file tapers at the point and generally has teeth on both edges. Flat files are used for general-purpose filing and for ***draw filing***.

Cutting Faces

Remember that ***cutting faces*** are classified according to the design of the cutting and according to the grade of their teeth. There are three designs of cutting face, the single-cut, the double-cut and the curved tooth.

These were covered in detail in Learning Task 1: Files.

File Handles

Files are sold without handles, so the first step in using a file is to fit it with the proper handle. Always select a handle that fits the file, neither too large nor too small for the file tang. File handles should have a strong *ferrule*, or metal collar.

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

There are two excellent reasons for using a file handle on all files. The first and most important is your safety. The tang

of a file is usually pointed. If you meet an obstruction while filing and the file stops suddenly, your hand could be severely punctured. Second, the handle helps guide the file and the work can be done more accurately and more quickly.

Filing Technique

If you are new to working with files, take your time and check your work frequently in order to do the job correctly. Some very common mistakes are:

1. Rocking the file from left to right as the material is being filed. This will create a curved rather than a flat surface.
2. Bearing down too hard in the middle of long cuts, thereby creating a dip in the middle of the material.
3. Filing for too long without checking the material. Frequent checks will help you detect incorrect filing methods and prevent you from removing too much material.
4. Filing with arm movement only. Your body should lean forward slightly during the forward stroke, then return to an upright position during the backward stroke.

Your workpiece should be placed in a bench vise. If it is a soft material such as aluminum, you should protect the workpiece by placing pieces of wood, plastic or soft metal between the vise jaws and the workpiece. Always wear eye protection during filing operations.

When moving the file across any work, hold the file as shown and move it straight ahead or at a slight angle. Hold it so that the handle end fits into the heel of your hand, with your thumb lying along the side of the file. Your forearm and the file should form a straight line.

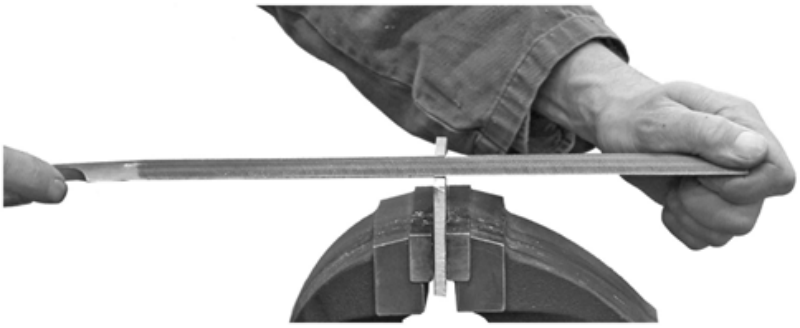


Figure 6 *Proper filing technique* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Hold the point of the file with your thumb and first two fingers of the other hand. For heavy filing strokes, the whole underside of your thumb should press down. On lighter strokes, place your thumb more at a right angle to the file.

When filing a piece of material, frequently stop and check your work for even cutting and squareness. If you are filing incorrectly or at the wrong angle, you will discover the problem before the material has been ruined.

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

An accurate method of checking your work for even cutting is by using a steel square. Hold the body of the square firmly against one edge of the material and check that no clearance is visible between the bottom of the blade and the top edge of the material. If clearance is visible, your filing methods are incorrect.

Draw Filing

Draw filing is used to finish a smooth surface by removing only small amounts of material at a time. Generally, a single-cut file is used for this operation. When filing pipe however, it may be preferable to use a double-cut file.

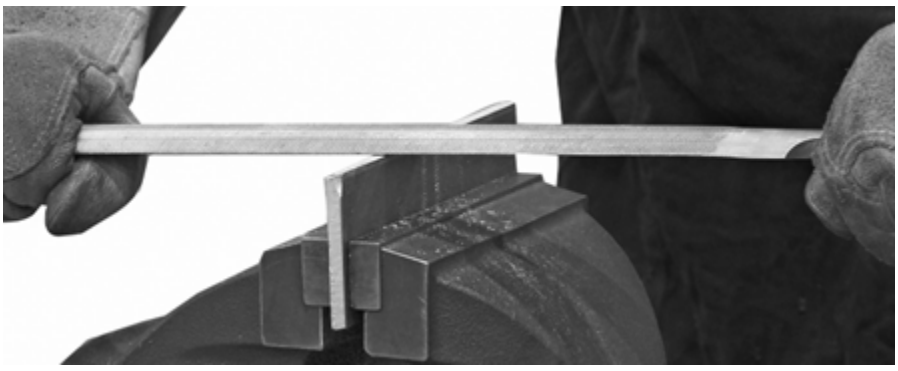


Figure 8 *Draw filing (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

To draw file, hold the file in both hands with your thumbs approximately 13 mm to 38 mm ($\frac{1}{2}$ in. to 1 $\frac{1}{2}$ in.) from each side of the material being cut. Then either push or pull the file straight across.

Raise the file slightly on the backstroke, as with ordinary filing. In the case of such soft metals as aluminum, brass, copper or lead, you can apply pressure on the backstroke without damaging the file.

With different grades of files, the angle at which the file is moved across the material will vary slightly, depending on the type of material being cut.

Maintenance of Files

Before starting any filing operation, especially the filing of mild steel or soft non-ferrous metals, coat the file with chalk. The chalk acts as a dry lubricant and prevents metal cuttings from becoming pinned or trapped in the teeth of the file.

Metal particles trapped in the teeth of a file not only reduce the file's ability to remove metal from the workpiece but may also cause damage to the surface of the workpiece.

As soon as you notice a build-up of particles on your file, brush them off with a file card. A file card has wire bristles on one side and fibre bristles on the other.

Figure 9 *File card (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Begin cleaning the file with the fibre bristles. If particles remain, remove them with the wire bristles.

Sometimes after filing soft metals such as aluminum, copper and lead, filings will remain stuck between the teeth even after you have used the file card. If this happens you should use a sharp, pointed piece of hard wood or soft iron to pick the remaining filings from between the teeth.

Never use a piece of hardened steel (such as a pointed punch or chisel) to pick file teeth clean as the tempered steel can damage the teeth.

Storing Files

More files wear out from abuse than from use. To maintain files while they are not being used, keep them separated from each other and from other tools to prevent damage to the file teeth.

A simple method for safely carrying your files in a tool box (or any place for that matter) is to fold a piece of cardboard into an accordion shape. Each fold should be just wide enough to entirely cover the file blade. Place a file in each

fold of the cardboard and fold the accordion together. Use heavy elastics or strips of inner-tubing to secure the file compartment.

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

Once your files have been securely wrapped, always store them in a dry place. Rust will adversely affect the cutting edge of file teeth.

Chisels

Select the appropriate chisel for the material being cut.

Cutting with Wood Chisels

Almost all wood chisels should be driven with a wooden mallet. The exception is the framing chisel, which can be driven with a steel hammer. All work should be held firmly in place, either in a vise or with a bench hook. All cuts should be with the grain of the wood, not against the grain. The blade should be angled for a slicing action instead of cutting square across.

Keep both hands back of the cutting edge. Do not cut toward yourself; always cut away from yourself. Never hold the work in one hand and the chisel with your other hand. Never chisel toward another person. Wear safety glasses when making heavy cuts with a hammer. Keep the chisel sharp at all times.

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

Cutting With Cold Chisels

Cutting with a cold chisel is a quick and efficient method of removing surplus metal on mild steel up to 3 mm ($\frac{1}{8}$ in.)

thick. In this type of cutting the workpiece is held in a vise, and the metal is sheared between the sharpened edge of the chisel and the edge of the stationary jaw of the vise.

It is important that the chisel be held correctly; otherwise, a rough or badly twisted job will result, and both the chisel and vise may be damaged. The bottom face of the chisel should be flat against the jaw of the vise, and the chisel must be angled to achieve a clean shearing action.

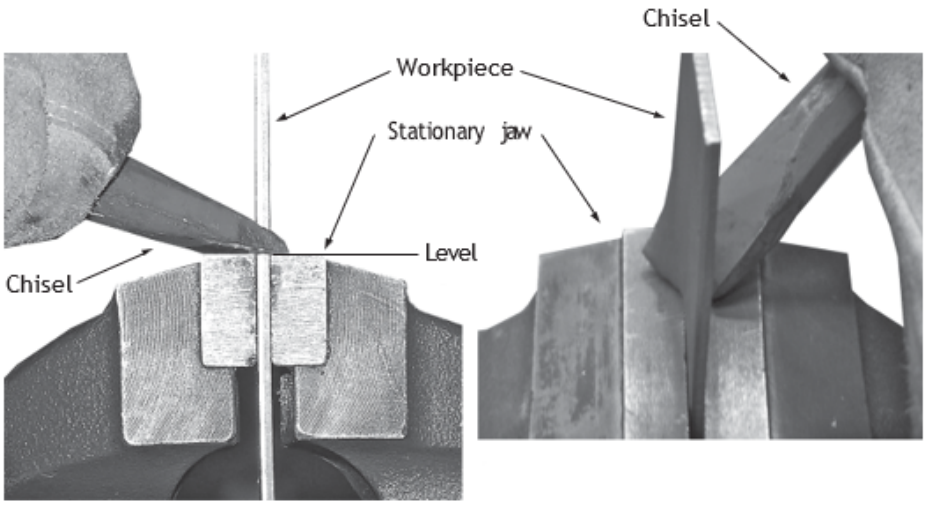


Figure 12 *Correct use of chisel (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Never try to cut from the end of the metal, as illustrated.

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

You can control the depth of the cut by raising or lowering the angle of the chisel. As you approach the end of a cut, strike the chisel lightly because a hard blow could cause the metal to fly off and injure someone nearby.

If you are right-handed, you should hold the chisel in your left hand and use your right hand to swing the hammer, or your left hand, if you are left-handed.

Never grip the chisel too tightly. A poorly aimed blow that misses the chisel could seriously injure your hand.

***A note about* PPE**: Always wear goggles or a face shield when you are using a chisel!

Always select a chisel large enough to do the required job. Chisels are usually struck with a hammer that weighs from 340 g to 900 g (3/4 lb. to 2 lbs.). A large hammer should be used with a large chisel.

Inspection, Maintenance and Storage of Chisels

Regularly inspect chisels for damage. Common conditions are shown here. The head of the damaged chisel, as compared to the undamaged chisel as shown has become mushroomed and the cutting edge has become nicked and dull with prolonged use. When this happens, the chisel must be dressed (cleaned up or repaired) before it can be used again. Mushroomed heads can be extremely hazardous.

Figure 14 *Damaged (left) and undamaged (right) chisel heads – can the right image's description be 'damaged chisel head'? (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Five basic rules for dressing chisels:

1. The tool must be returned to its original shape. Check an undamaged tool to determine the original shape.
2. All cracks and spalls (chipped areas) must be removed. Some cracks cannot be seen with the naked eye. If possible, use a magnifying glass for a closer look.
3. The grinding temperature must be kept low. The material should not turn yellow or a blue/purple colour. If the grinding temperature is not controlled, the hardness of the area that is being ground can be lost, making it hard,

brittle and easily fractured. Generally, chisels are heat-treated (hardened) approximately 38 mm (1 $\frac{1}{2}$ in.) back from the cutting edge. The grinding of the chisel should be kept well within these areas.
4. A medium or fine grit grinding wheel should be used.
5. The wheel rotation should always be away from the cutting edge, toward the body of the tool. This positioning of the tool directs heat away from the cutting edge.

When a tool has been damaged and redressed many times, it loses many of its original qualities and becomes unsafe.

Always store a chisel in a dry tool box or wrapped in a clean, dry rag. Protect the edge from damage; often manufacturers supply a protective cap to keep the chisel's edge, which is ideal.

Pipe Cutters

The following procedures for using different types of pipe cutters are general. In actual practice, you may find it difficult to follow these steps exactly. You should, however, aim to follow them as closely as possible.

Procedure for Cutting Steel Pipe

The following procedure describes cutting steel pipe:

1. Set the piece of pipe to be cut in a vise on a workbench or tri-stand.
2. Ensure the pipe end rests level in the vise. If necessary, use a pipe support stand to keep the pipe level and properly aligned.
3. Measure and mark the pipe to the desired length. (Use pencil, chalk or soapstone.)
4. Secure the pipe in the vise. The jaws of the vise should grip the pipe firmly, but not to the point where the teeth of the jaws dig excessively into the pipe. Too much pressure will result in a deformed, out-of-round pipe.
5. Select the correct type of cutter for the job. Inspect the cutter wheel to make sure it is:
    - Not damaged
    - Sharp
    - Designed both for the cutter and the material to be cut
6. Open the cutter jaws by turning the feed handle. Place the cutter on the pipe so that the rollers are in contact with the pipe.

It is important that the cutter rollers are against the pipe before you begin the cut. This ensures that the cutter will remain steady and square during the cutting operation.

Figure 15 *Position the pipe cutter (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

7. Turn the screw handle until the cutter wheel touches the pipe. Then gently engage the cutter wheel by turning the feed screw one-quarter of a turn.
8. Rotate the cutter a full 360° around the pipe so that the cutter wheel cuts a light groove.

Figure 16 *Lightly tighten and rotate pipe cutter (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

9. Check the groove to see if it *tracks* into the original starting groove. If it tracks, you will have a good cut. If it does not, the result will be a spiral groove on the pipe, not a cut.
10. When a true track is obtained, tighten the feed screw one-quarter of a turn and rotate the cutter around the pipe.

Continue to tighten the feed screw at each turn until the pipe is cut.

As well as steadying the cutter, the rollers "roll down" the burrs that the cutter wheel creates on the outside of the pipe.

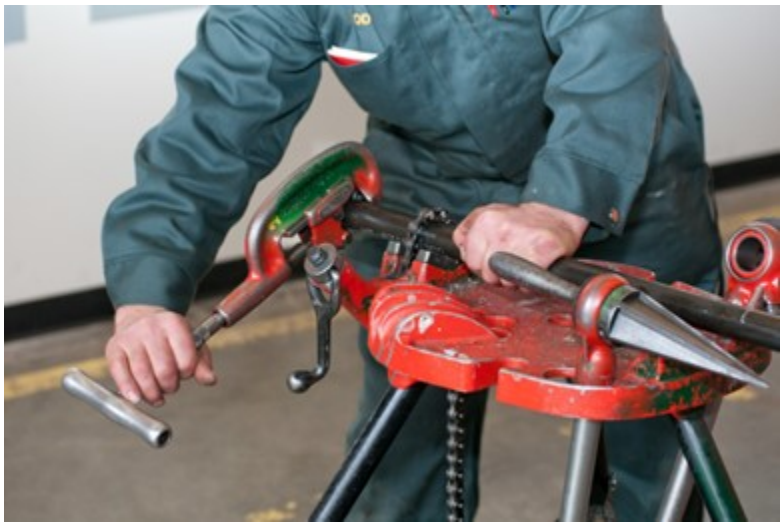


Figure 17 *Continue tightening and rotating (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Procedure for Cutting Copper Tube

The procedure for cutting copper tubing is similar to that of cutting steel pipe. Here are a few of the differences:

1. Some tubing cutters use a screw to anchor the rollers to the body of the cutters. When using these types of cutters, the rotation of the cut must be correct to ensure that the roller screw does not loosen and eventually fall out. Often, it is better to allow the handle of the cutter to *lead* the cut. Check the tension on any adjustable parts regularly.
2. When measuring tubing, it can sometimes be advantageous to quickly score the tubing at the required length with the back of a blade reamer (if the cutter being used is equipped with one), instead of using a marking pen each time. This can save a lot of time when taking multiple measurements.

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

Maintenance of Pipe Cutters

Follow these guidelines to ensure safe operation and a long life for pipe cutters:

- Periodically use a cleaning solution and a wire brush to clean the main parts of the cutter: the feed screw, the slide, the rollers and the cutter wheels.
- Use a suitable lubricating oil to thoroughly lubricate the feed screw, the slide, the rollers, and the cutter wheels. (Do not use thread cutting oil.)
- Inspect the cutter body, the feed screw, and the rollers for damage. Examine the tool for true tracking and sharpness of the cutter wheels. Replace any worn or damaged part of the tool, including the cutter wheels.
- Hang the cutters in a dry, warm place, if possible.

Using a Soil Pipe Cutter (scissor and ratchet)

No vise is required for cutting soil pipe, as cutting is usually done on the ground or on the shop floor.

1. Measure and mark the pipe to the length desired using chalk or soapstone.
2. Position the cutter on the mark.
3. Wrap the cutter's chain around the pipe. Tighten the chain using the hand wheel adjuster (Make sure the cutting chain is at right angles to the pipe.)

Figure 19 *Tighten the chain* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Figure 20 *Apply quick downward pressure* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

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

4. Pump the ratchet handle of the cutter until the pipe separates. If using the squeeze handle (scissor) type, squeeze the handles until the pipe separates.

Procedure for Cutting Glass Pipe (Internal Cutter)

The following procedure describes use of an internal glass pipe cutter:

1. Measure length of pipe required and mark glass with a pencil, grease crayon or felt marker.
2. Insert cutter head into pipe with the cutter wheel facing up.

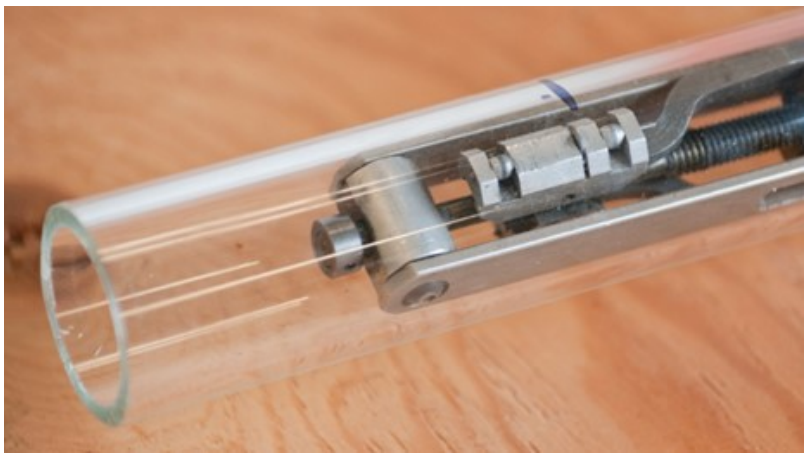


Figure 22 *Positioned in place (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

3. Slide the centring cone into the pipe until it seats against either the cut or beaded end.

4. Slide position collar against cone, align cutter wheel with distance mark on pipe and then lock ring stop using positioning thumb screw.

Figure 23 *Lock the position of the collar (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

5. Turn tension adjustment knob clockwise until cutter wheel contacts glass. Double check alignment of cutter wheel with mark on pipe. Note that the follower wheel does not assist in the scoring of the pipe, but it is required to assist in tensioning the cutter head.
6. Continue to turn tension knob clockwise to give sufficient pressure on cutting wheel to score the glass (a medium to light score is desirable on $1\frac{1}{2}$ in. to 3 in. pipe; use a heavy score on 4 in. pipe and larger).
7. With pipe firmly pressed against centring cone (and cone against position collar), make a test score about 4 mm ($\frac{1}{4}$ in.) long. Make final adjustments to tension knob, if required.

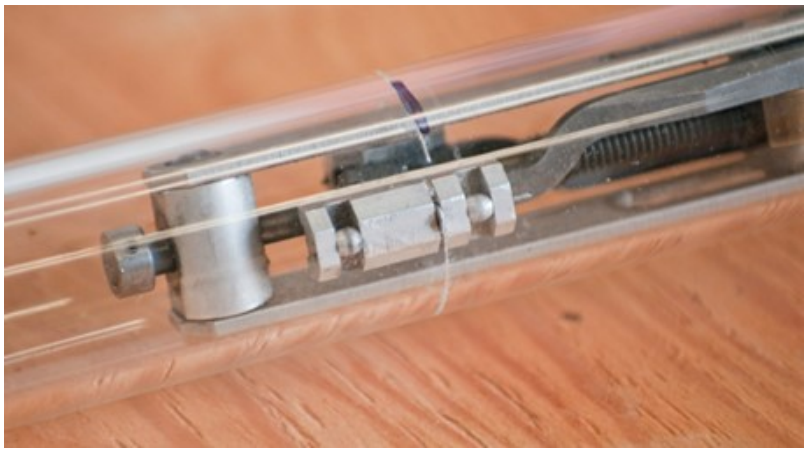


Figure 24 *Scoring the glass (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

8. Complete score around pipe by turning shaft one complete revolution—avoid scoring beyond the closing point of the circle of the cut.

9. Turn the tension knob counter-clockwise to draw the cutter wheel away from the inside wall of the pipe. DO NOT drag the scoring wheel against the pipe when removing the cutter.
10. Apply heat from a torch on score mark. As pipe begins to separate, follow score mark with flame. It may be necessary to tap the piece slightly to assist in separation of the two halves.

Figure 25 *Heat to separate (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 26 *Heat to separate (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

11. A plain-end coupling can now be used to transition the cut piece of pipe to a beaded fitting, a factory-beaded pipe, or another plain-cut end of pipe.

Reamers

As you learned in Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades), reamers are used for

deburring the inside of cut pipe to allow for full fluid flow. Reamers are made for pipe sizes from 3 mm to 10 cm ($\frac{1}{8}$ in. to 4 in.).

When using a reamer, the burr is only to the full bore of the pipe. Do not make the pipe wall thinner than it was manufactured.

To use either type of reamer as a hand tool, a ratchet handle is inserted onto the unit. To start the operation, centre and rotate the reamer slowly to allow it to align with the pipe's bore. Next, use the ratchet handle to apply pressure to the flutes and to turn the tool clockwise. The feed should be steady and rapid.

Pull back on the handle to remove the reamer. Inspect the interior pipe wall visually to determine if the burr has been removed.

Figure 27 *Using a hand reamer (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hand reamers can be used in conjunction with power vises, as seen below.

Never use a spiral hand reamer with a power vise, because it bites deep, and can jam.

Figure 28 *Using fluted hand reamer with power vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Maintaining Reamers

Follow these guidelines to ensure safe operation and a long life for the reamer:

- Clean the flutes of the reamer with a cloth or a wire brush.
- Inspect the edges and the grip for damage. If the flutes need regrinding, set the tool aside for professional repair.
- From time to time, feed lubricating oil into the ratchet mechanism in the handle.
- Store the reamer either in a toolbox or by hanging it up so that the flutes will not be damaged.

Chalk Lines

On a flat surface, a line can be marked using powdered chalk on a cotton cord. When the cord is "snapped" on the work surface, a dusting of chalk is left. Coloured or white chalk can be used.

The chalk line is fitted around a reel housed in a case. The powdered chalk is put into the case by removing a cap on the top face of the case. A metal ring with a hook is attached to the end of the line. The hook can be hooked over the end of a board or panel or onto a nail inserted for that purpose.

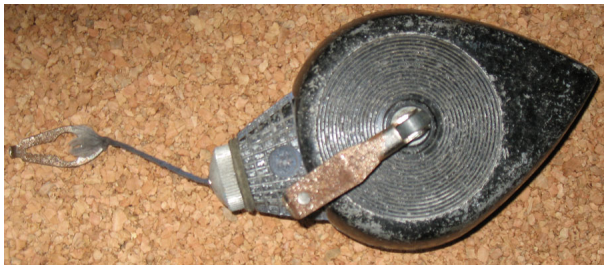


Figure 29 *Chalk Line (B. Askholm (https://commons.wikimedia.org/w/index.php?title=User:B._Askholm&action=edit&redlink=1), Wikipedia) CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0/)*

To use the chalk line, do the following:

1. On the work, mark the two points between which you want the line to be located.
2. Hook the ring over a nail or the end of the work, at the point where you want the line to start.
3. Pull the line horizontally out of the case, but do not allow it to touch the work.
4. Pull the line tight and place the end on the mark or past the point to be snapped.
5. With your other hand, lift the line straight up, about 100 to 150 mm; then allow it to snap down and a chalk mark will be left on the work.

Figure 30 *Lift the line* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

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

The following are other pointers on the use of a chalk line:

- If the line to be marked is very long, ask a fellow worker to hold down the line at the centre point, then snap the line on either side.
- When you chalk a line on a vertical surface, the line may sag. If so, use a nail to raise and support the line and ask a fellow worker to sight along the line to make sure it is straight.
- When the chalk line begins to fade, add more chalk powder to the case.

- Too much chalk in the case leaves a fuzzy line.
- Many chalk line tools have a shape that allows them to be suspended by their cord, thereby acting as a plumb bob.
- Some models have locking and quick release mechanisms as well as quick retrieve gear ratios to make them easier and quicker to use.

Wrap-around

When you have determined the length that a pipe is to be cut, a ***wrap-around*** can be used to make a straight, clean line around the pipe's circumference. This is especially beneficial if you aren't using a set of rotary cutters, but rather a high-speed cutting disk or an oxyacetylene cutting torch.

The following is a procedure for using the wrap-around:

1. Remove any varnish from the coating of steel pipe with a wire brush or a grinder equipped with a high-speed wire wheel.
2. Start by looping one end of the wrap-around around the pipe to one side of the mark and line up the edge of the short running end with edge of the longer rolled end.
3. Hold it snuggly between your hands as you slide it toward the mark on the pipe.

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

4. Holding the wrap tightly to the pipe, carefully tuck the short end on to the pipe and wrap the long end at least $1\frac{1}{4}$ times around the pipe in an over-lapping fashion.

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

5. With the wrap-around tightly in place, draw a line with a sharp piece of soapstone around the pipe, using the boundary of the wrap as a straight edge.

Figure 34 *Mark around the pipe (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hammers

Using a hammer correctly is important for reasons of safety. When using a hammer in conjunction with tools such as a cold chisel, incorrect usage could result in the cold chisel becoming a dangerous projectile.

The correct way to hold and use a hammer is illustrated below. To strike a heavy blow with the least effort, grip the hammer firmly, but not rigidly, near the end of the handle. Gripping the handle near the head reduces the force of the blow. Always strike the object with the centre of the face of the hammer. That way, you will protect the face edge from chipping as the blow is distributed over a larger area. All hammering should be started with light blows, followed by heavy blows, if necessary.

Figure 35 *Correct (left) and incorrect (right) use of a hammer (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

General Rules for Nailing Wood

Nail thinner pieces of wood to thicker pieces of wood. This provides more holding power. Stagger the nails so that they are not in line with the grain of the wood (to prevent splitting).

Do not drive nails too close to the edge of the wood. Keep them back a minimum of 20 mm, or a distance equal to the thickness of the material, whichever is less.

If the wood is very hard, and you encounter difficulty in driving nails, or if the wood is very narrow and tends to split, drill pilot holes that are slightly smaller than the nails being used.

Place the chisel point of the nail across the grain so that it will cut the wood fibres as it is driven in.

When nailing into the end grain of wood, drive the nails at an angle to provide more holding power. Provide solid support for the members. Members without proper support tend to bounce and cause nailing problems.

Do not use a hammer to strike the face of another hammer. This could cause a fragment of hardened steel to fly off and injure the operator or others. Use a small pry bar or nail puller to pull hard-to-remove nails.

Always wear eye protection equipment when using a hammer. Never use a hammer that has a loose head or a damaged handle. Injury can result if the head flies off or if the handle breaks.

Follow these guidelines to ensure safe operation and a long life of hammers:

- Keep your hammer clean at all times. A greasy or dirty hammer can be dangerous.
- Always use a hammer of the correct size and weight for the job.
- Never strike an object with the side of a hammer.
- Never strike hardened steel objects with a hammer, as this may cause chips to fly.
- Use wire brush to clean textured face.
- Regularly inspect handle for damage.

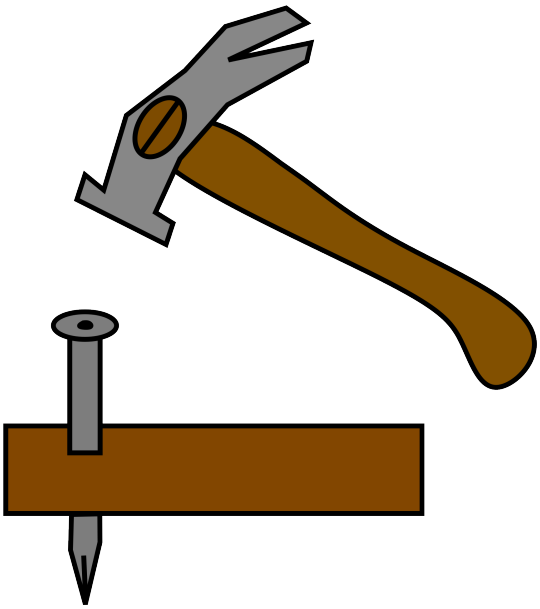


Figure 36 *Image by Bill Shortridge (https://pixabay.com/users/carvit56-9226797/?utm_source=link-attribution&utm_medium=referral&utm_campaign=image&utm_content=7333333) from Pixabay (https://pixabay.com//?utm_source=link-attribution&utm_medium=referral&utm_campaign=image&utm_content=7333333)*

Vises

To use a vise, simply rotate the handle to the desired opening. Place the work piece in the vise and tighten it just enough to hold it in place. If the part being held is soft or brittle, it may be broken or compressed by too much pressure.

Soft vise jaw-caps are available to protect the workpiece. They come in pairs and slip over the jaw facings. The tabs are bent around the front and back jaws to hold them in place.

Know the type of material being clamped in the vise. Be sure the jaw facings are of the type that will not damage the material. If jaw-caps are not available, use two strips of aluminum, copper, brass or wood to protect the material.

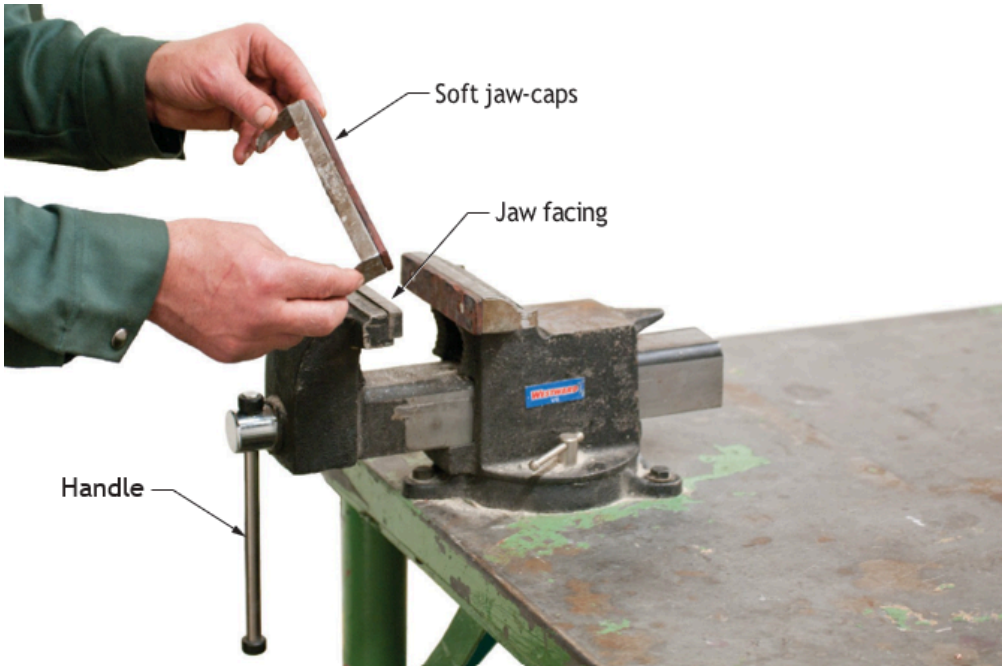


Figure 37 *Bench Vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

For a hard or tough work piece that is to be hammered or chiselled, you must ensure that the vise is tight enough to prevent the workpiece from slipping. You should also place the workpiece in such a position that you will be hammering or chiselling toward the stationary jaw.

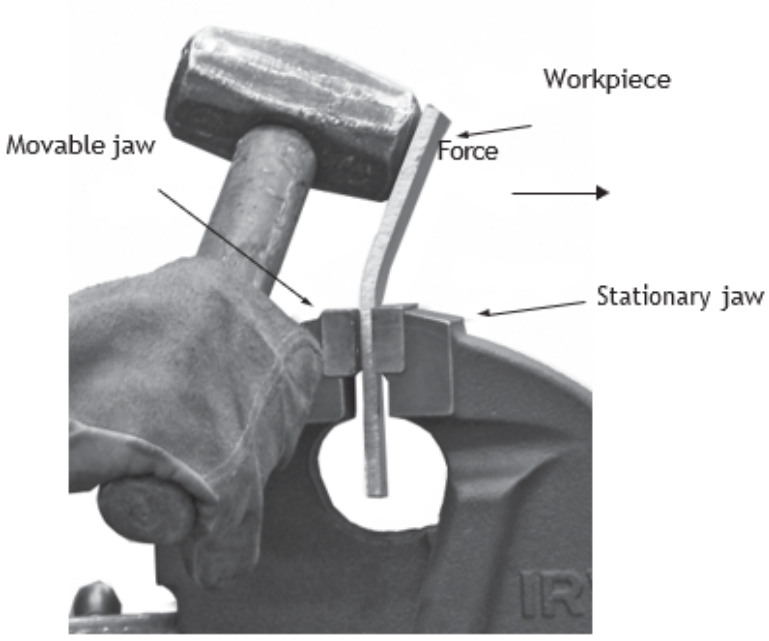


Figure 38 *Correct way to use a vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Never hammer on the vise unless there is an anvil built on the vise for that purpose. Remove the screw periodically for cleaning and lubrication. When the jaw facings wear out or lose their gripping power, replace them. Never over-tighten the vise handle by using an extension bar over the handle ends or by hammering on the handle.

Follow these guidelines to ensure safe operation and a long life for the vise:

- Clean the housing of the vise with a solvent as the need arises.
- After using the vise, clean the gripping surfaces with a wire brush.
- Use a good grade of lubricating oil to clean and lubricate the screw spindles and any hinged joint.
- Inspect the gripping devices for damage or excessive wear, and replace if necessary.
- Keep the surfaces of the vise and work area free of grease, dirt, and other tools.
- If the vise is portable, hang it up in a clean, dry area when it is not in use.

Wrenches

Keep your wrenches clean. Working with greasy, dirty tools can be dangerous, as your hands can slip, causing injury. The dirt can also damage the component on which you are working. Adjustable wrenches and pipe wrenches should be cleaned and lightly oiled periodically.

Make sure the wrench is the correct size for the job. Loose-fitting wrenches can damage both the workpiece and the jaws of the wrench.

Do not abuse the wrench by driving on it with a hammer or by adding leverage with a piece of pipe. Do not use any wrench as a hammer and do not use socket handles for any purpose other than driving sockets. Do not use a socket wrench as a bushing or seal driver or for any other purpose. Check socket wrenches for chipping and cracking or other damage. Do not use them if they are damaged.

Hex key wrenches can be reconditioned if the end of the key becomes worn and slips in the socket head screw. Grind the end back to a point where the hexagon shape is true. Be careful that you keep the tool cool during the grinding operation to avoid affecting the hardened metal.

Pipe Wrenches

The following procedure describes the use of pipe wrenches:

1. Select the correct wrench type and size for the job. (A loose-fitting wrench will slip and very possibly cause hand injuries.) A pipe wrench is designed for round stock. It should never be used on square or hexagonal material. The following list shows the correct pipe wrench to use for various common pipe sizes:

Table 1: Pipe Wrench Sizes and Their Corresponding Pipe Sizes

Wrench size (inches)	Pipe size (inches)
8	$\frac{1}{8}$ and $\frac{1}{4}$
10	$\frac{3}{8}$ and $\frac{1}{2}$
14	$\frac{3}{4}$ and 1
18	$1\frac{1}{4}$ and $1\frac{1}{2}$
24	2

2. Inspect the wrench for damage. Jaws that are sprung or teeth that are dull, for example, can cause the tool to slip.
3. Mount the pipe wrench correctly on the work piece. Regardless of the size of the wrench, there must be a gap between the shank of the hook jaw and the pipe. This permits the pressure of the two gripping surfaces (the heel jaw and the teeth of the hook jaw) to firmly grip the pipe for full turning force.

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

4. With a grip on the pipe, push or pull on the wrench in the direction it is intended to move.
5. To obtain a new grip on the pipe, move the handle in the reverse direction. This will release the workpiece, and the handle can then be moved to its original position and a new grip obtained. Follow this procedure until the workpiece has been given as many turns as required.

- Do not use a wrench to lift or bend pipe.
- Do not use a substitute device or “cheater” to increase the leverage of a wrench.

- Valves, regulators and controls are not designed to withstand the torque across their body that is necessary to tighten or loosen them. Grasp the valve on the same end as the pipe on which you are working.
- Never grasp the open end of a fitting with a wrench. A pipe, nipple or adapter screwed in a few turns will prevent bending the open end of the fitting.

Maintaining the Condition of Pipe Wrenches

Follow these guidelines to ensure safe operation and a long life for the pipe wrenches:

- To prevent rust, apply oil at regular intervals to nuts, springs, jaws and other moving parts.
- Inspect the wrench before and after use for worn or broken parts. Pay particular attention to the heel and hook jaw or clasping device. If the teeth are worn, the wrench can sometimes be restored to usefulness by filing the teeth with a triangular file.
- Store the wrench properly. Use the hole in the handle to hang it up or hang it in a slotted holder designed for tools.

Pliers

When using pliers, observe the following:

- Pliers are not made to withstand any pressure in excess of normal hand squeezing.
- Never attempt to cut large screws or bolts with a pair of cutting pliers.
- Never put excessive side pressure on needle-nose pliers.
- Never expose pliers to a direct flame.
- Do not use pliers on nut or bolt heads.
- Wear safety glasses when cutting wire.
- Cut at right angles.
- Use the right tool for the job.

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

Screwdrivers

Screwdrivers should be kept clean and free of grease, oil and dirt. The handle should be intact and well secured, and the tip should not be worn. When a tip becomes worn, the slot screwdriver can be filed to shape, but other types must be replaced.

Figure 41 *Flat head Screwdriver (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Screwdrivers should never be used as prying tools, punches, hammers or chisels.

Tubing Spring Benders

The following procedure describes using ***tubing spring bender***s:

1. Select bending spring that just fits over the tube to be bent.
2. Slip the centre of the spring over the centre of the area to be bent.
3. Hold bender in both hands, with thumbs supporting the back of the curve and slowly make the bend.
4. Grasp flanged end of the spring and remove from the tubing.

Figure 42 *Bending soft tubing with a spring bender (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Tubing Compression Hand Benders

The following procedure describes using a ***compression hand bender*** to form a 90-degree bend:

1. Measure tubing to the desired length at the centre of the 90° bend. Mark all the way around the tube with a pencil or felt marker. (If more than one bend is required on the tube, measure from the centre of the previously completed bend to the centre of the new bend to be formed.)
2. Place the tubing in the bender with the measured end of the tubing along the stationary handle of the bender. (The critical measurement is to the left of the mark.)
3. Position the measured mark directly in line with either the 90 or L notch on the placement link (manufactures vary in their design). Secure the tubing fastener onto the tube (making sure the 0 notch on the bending wheel and placement link are in line).

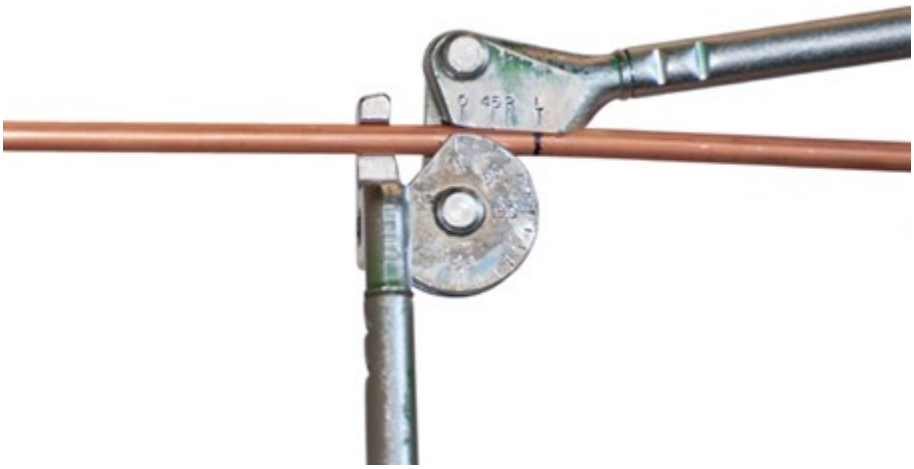
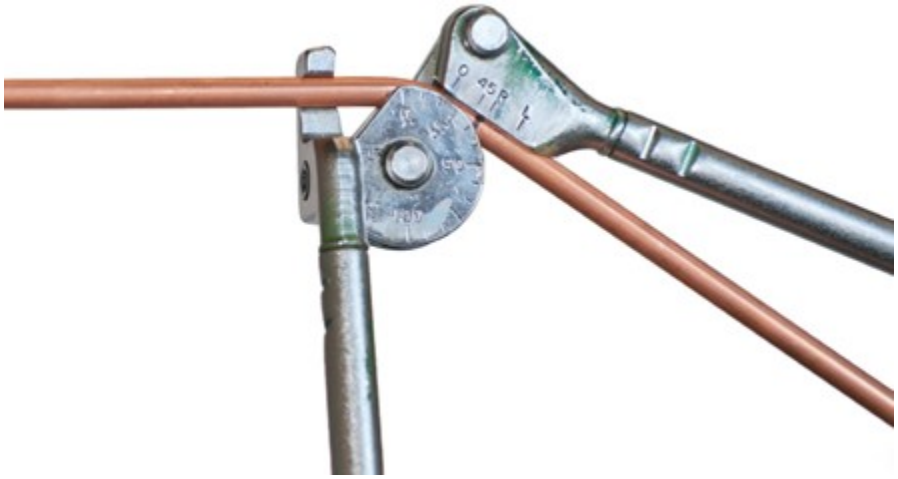


Figure 43 *Position the bender (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

4. While moving the pull handle toward the stationary handle, pull down smoothly and evenly until the 0 notch on the placement link lines up with the 90° mark on the bending wheel.



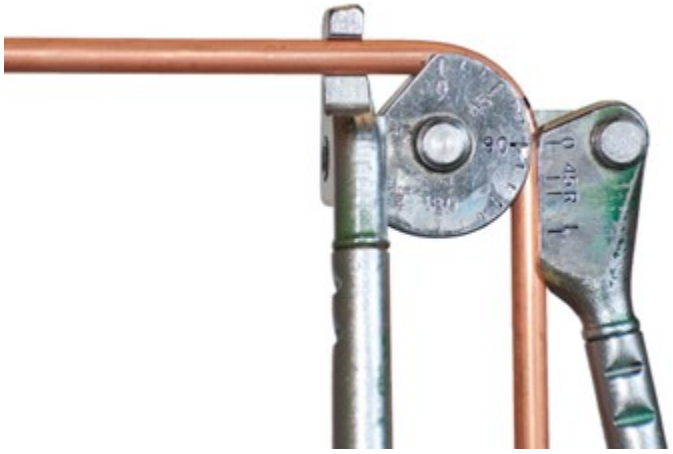


Figure 44 *Bending the tubing* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

90-Degree Reverse-bend

The R indicator notch on the placement link is used when the end of the tube from which the dimension is measured is reversed from what is described above. (In other words, the critical measurement is to the *right* of the bender.)

45-Degree Bend

The following procedure describes using a compression hand bender to form a 90-degree bend:

1. Measure tubing to the desired length at the centre of the 45° bend. Mark all the way around the tube with a pencil or felt marker. (If more than one bend is required on the tube, measure from the centre of the previously completed bend to the centre of the new bend to be formed.)
2. Tubing can be placed in either direction from the bending wheel.
3. Position the measured mark directly in line with the 45 notch on the placement link. Secure the tubing fastener onto the tube (making sure the 0 notch on the bending wheel and placement link are in line).
4. While moving the pull handle toward the stationary handle, pull down smoothly and evenly until the 0 notch on the placement link lines up with the 45° mark on the bending wheel.

Tubing Gain (Bend Length Increase)

When bending tubing, the actual bend made does not follow the absolute profile of a straight line layout. Realistically, the bend made in a tube will short-cut the angle slightly on each bend.

This short-cutting of the corners gives “additional length” to the remaining section of straight tube.

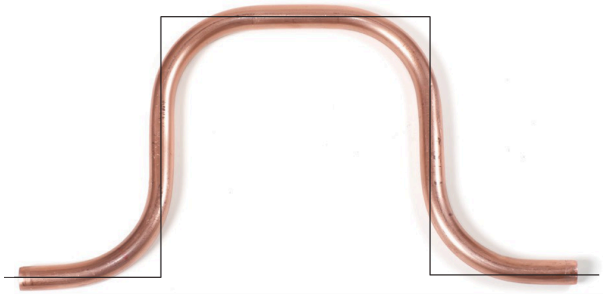


Figure 45 *Tubing gain (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The additional length is commonly referred to as ***gain***.

Gain for 90-degree bends is approximately equal to the OD of the tube being bent. Tables are available that provide the exact gain lengths for various sizes of tube and different bending radii.

If bending is performed correctly by proper positioning of the measurement mark on the placement link (and in multi-bending operations, measuring each bend from the previous bend), the gain will appear correctly on the straight length of the tube opposite the measured length.

Bending in this manner will ensure correct end-to-centre and centre-to-centre measurements when bending tubing.

Flaring Tools

Tube flaring is a method of forming the end of a tube into a funnel shape so it can be held by a threaded fitting. When a flared tube is prepared, a flare nut is slipped onto the tube, and the end of the tube is flared.

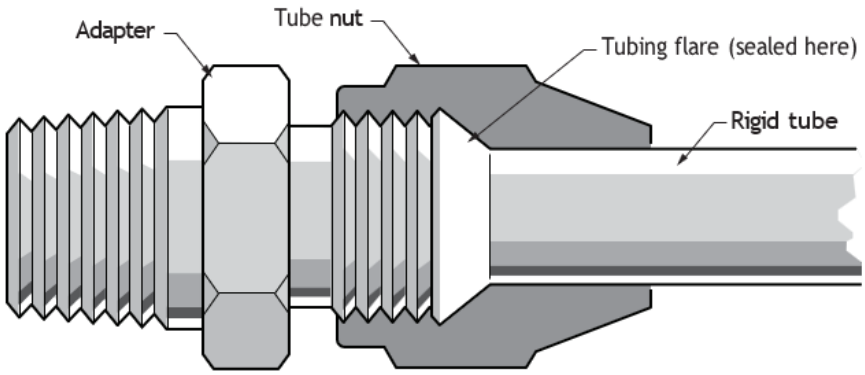


Figure 46 *Flared tubing connection (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

During tube installation, the flare is seated to a fitting with the inside of the flare against the cone- shaped end of the fitting, and the flare nut is screwed onto the fitting, pulling the inside of the flare against the seating surface of the fitting.

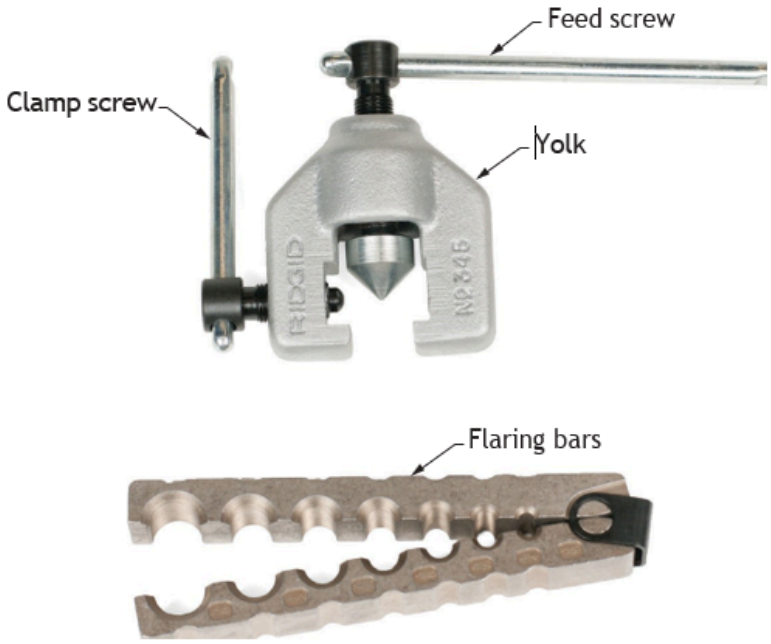


Figure 47 *Parts of a flaring tool (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The following procedure describes the use of a flaring tool:

1. Cut and ream tubing.
2. Slide flare nut over tubing.
3. Back off feed screw handle and clamp screw to permit flaring bars to slide freely through the yoke. Slide yoke to the hinged end of the flaring bars.
4. Insert tube into proper size opening and close flaring bars. Push tube up from bottom of the tool until it is even with top of flaring bars.
   Note: *Oversize or undersize flares can be made by adjusting tube position slightly above or below the top of the flaring bars.*
5. Slide yoke forward over tube until arrow or indicator on yoke meets line on flaring bars.
6. Turn feed screw handle clockwise until pressure kick-out releases. A few additional turns before backing off will *burnish* (polish) the flare.
7. Back off feed screw handle as far as it will travel. Release clamp screw and slide the yoke back. The completed flare should be slightly visible above the face of the flaring bars.
8. Remove tube. If the tube tends to stick, tighten clamp screw while against tapered end of flaring bars. This action will force the bars open.The flare must be large enough to seat properly against the fitting, but small enough that the threads of the flare nut will slide over it.

Crimpers

PEX fittings are installed in PEX tubing using crimp rings and a crimping tool. The crimping tool compresses the crimp rings over the PEX tubing with a fitting inside of the tubing to create a watertight seal in the joint.

Figure 48 *PEX crimping tool and fittings (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The following procedure describes the use of a PEX crimping tool:

1. Square-cut the PEX tubing perpendicular to the length of the tubing. Remove all excess material or burrs that might affect the fitting connection.
2. Slip one crimp ring over the end of the tubing. The ring has to be in place before the fitting is inserted into the tubing.
3. Push a PEX fitting into the tubing. The fitting should be inserted into the tubing as far as is it is designed to travel.

Figure 49 *Insert PEX fitting (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

4. Slide the crimp ring so that it sits 3 mm ($\frac{1}{8}$ in.) from the end of the tubing. Pull the handles of the crimping tool apart to open the jaws of the crimper. Place the open jaws over one crimp ring at a time. Press the crimper handles together to force the jaws together over the crimp ring.

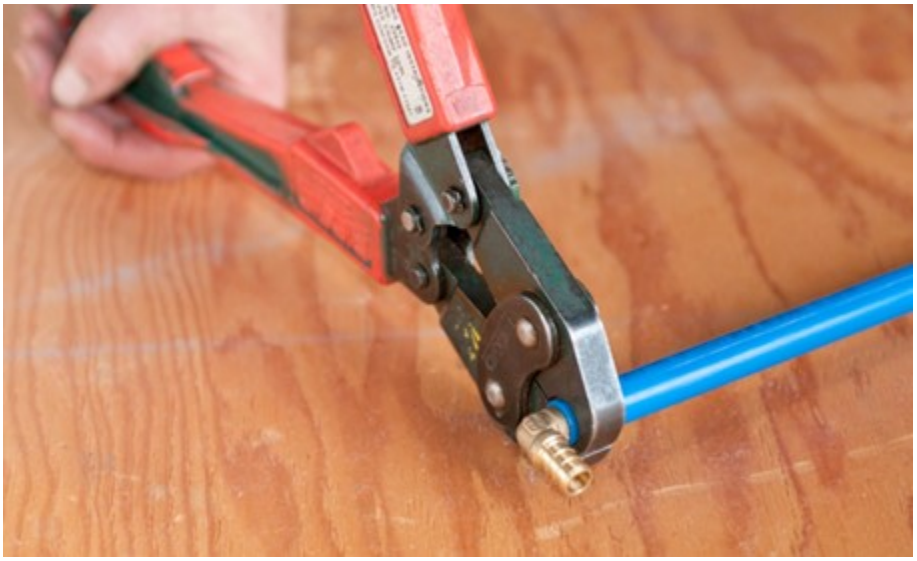


Figure 50 *Compress crimp ring (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

All crimps should be tested with a ***GO/NO-GO gauge***. If the crimp is perfect, the gauge marked GO will slide onto the crimped ring. The gauge marked NO-GO will not slide onto the crimped ring.

Figure 51 *Use the GO/NO-GO gauge (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The GO/NO-GO gauge performs two tests. The crimped ring must pass the GO test and fail the NO- GO test.

If both, gauges slide onto the crimped ring, then the crimp is too tight and the pipe or fitting could be damaged. If both gauges will not slide on, then the ring is not crimped enough and could leak.

Refer to manufacturer's literature for calibration instructions. As well, store your tool with care. It is vital for calibration that the tool be stored with the jaws just touching – the tool should NOT be under tension.

Hand PEX Expander Tool

Expanded PEX fittings make solid, permanent connections without torches, glues or gauges. The unique shape memory of quality PEX-A tubing forms a tight seal around the fitting, creating a strong, reliable connection. Note that fittings used for this system are not interchangeable with other joining methods (i.e., not to be used with crimp rings, or vice versa).

1. Square-cut the PEX tubing perpendicular to the length of the tubing. Remove all excess material or burrs that might affect the fitting connection.
2. Slide the PEX ring over the end of the tubing. Extend the end of the ring over the end of the tubing no more than 1 mm ($\frac{1}{16}$ in.). Manufacturers have added an internal ridge on one end of the ring to ensure proper amount of overhang.
3. When using the hand expander tool, brace the free handle of the tool against your hip or place one hand on each handle. Fully separate the handles and slide the expander head into the tubing until it stops.

Figure 52 *Insert expander tool (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

4. Full expansions are necessary to make a proper connection. Bring the handles together to expand.

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

5. Separate the handles, remove the head from the tubing, and rotate it one-eighth of a turn. Slide the tool head into the tubing in the newly rotated position and expand again. (Some tools have a head with a self-rotating feature.)

Figure 54 *Rotate tubing one-eighth of a turn (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

If the head is not rotated after each expansion, the segments on the tool head may cause deep grooves in the tubing. These grooves can result in potential leak paths.

6. Repeat the expansion process until the tubing and ring are snug against the shoulder on the expander head (usually about 3 or 4 expansions, depending on tubing size).

7. Immediately remove the PEX expander tool. As you slide the tubing over the fitting, you should feel some resistance. If the tubing reaches the shoulder of the fitting without any resistance, the tubing may be over-expanded and may require additional time to fully shrink over the fitting. The tubing and PEX ring should seat against the shoulder of the fitting for a proper connection.

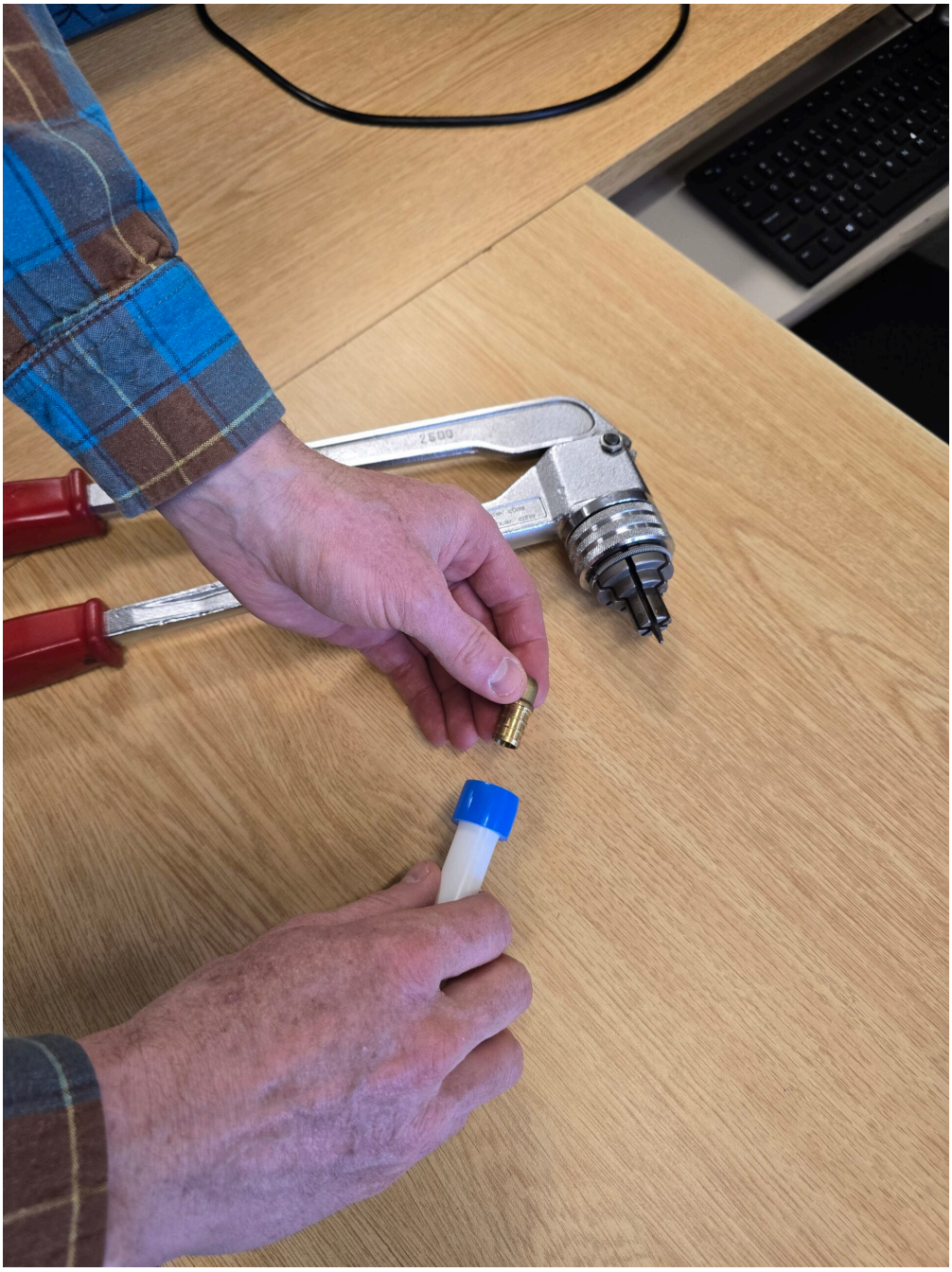


Figure 55 *Insert PEX fitting (Audrey Curran/ TRU Open Press)* CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Important tips for proper PEX expanded connections:

- If the fitting does not slide into the tubing all the way to the stop, immediately remove it from the tubing and expand the tubing one final time.

Note: To avoid over-expanding the tubing, do not hold the tubing in the expanded position for an extended period of time.

- The manufacturer will recommend the appropriate number of expansions required for each size of tubing. Experience, technique and weather conditions influence the actual number of expansions (PEX becomes less flexible when cold, for example). Greater or fewer expansions may be necessary under certain conditions. The correct number of expansions is the amount necessary for the tubing and the shoulder of the fitting to fit snugly together.
- Good connections result when the PEX ring rests snugly against the stop of the fitting's shoulder. If there is more than 1 mm ($\frac{1}{16}$ in.) between the ring and the shoulder of the fitting, squarely cut the tubing 5 cm (2 in.) away from the fitting, and make another connection using a new PEX ring.

Disconnecting a Brass PEX Fitting from an Expanded Joint

Brass PEX fittings are manufactured connections and can be concealed in walls, ceilings and floors. However, when necessary, brass fittings can be disconnected (plastic fittings cannot be reclaimed or reused).

1. Make sure the system is not pressurized.
2. Use a heat gun to heat one side of the PEX ring. When the ring is a clear colour, use a utility knife to carefully cut through the ring. Take care to cut only the ring and not the tubing. This will protect the fitting from being damaged by the knife. Remove the PEX ring from the tubing with pliers to avoid touching the hot ring. ***Note***: *Do not gouge the fitting when cutting the ProPEX Ring. Nicks and gouges in the fitting may result in leaks. If nicked, discard the fitting.*
3. Remove the PEX ring and apply heat directly around the fitting and tubing connection. Gently work the tubing back and forth while pulling slightly away from the fitting until the tubing separates from the fitting.

Maintenance and Troubleshooting of PEX Expanded Joints

Trouble-free installations begin with a PEX expander tool that is maintained in proper working condition. If the tool or segment fingers are damaged, it is very difficult to make a proper connection.

The following troubleshooting suggestions are designed to assist with problems in the field.

For fittings that will not seal:

- Ensure that the expander head is securely screwed onto the tool (hand-tightened). Make sure the segment fingers are not bent. If the head does not completely close when the tool's handles are open, replace the head.
- Examine the tool for excess grease on the segment fingers. Remove excess grease prior to making ProPEX connections.
- Examine the fitting for any damage. Nicks and gouges on the fitting will cause the fitting to leak.
- Make sure the internal driver cone is not damaged or bent. Make sure the last expansion is not held in the expanded position before the fitting is inserted. The longer the tubing and *ProPEX Ring* are held in the expanded position, the greater the chance for a leak.

- Be sure to rotate the tool one-eighth of a turn after each expansion.

If expansion is difficult:

- Make sure the internal cone is properly greased.

If the expansion head slips out of the tubing when making expansions:

- Ensure the tubing and PEX ring are dry.
- Make sure that grease is not getting into the tubing.
- Examine the segment fingers to make sure that none are bent.

If the PEX ring slides down the tubing during expansion:

***Note*:** this is no longer common since the manufacturers have added an internal ridge to the PEX rings.

- Ensure your hands are clean while handling the tubing. Any sweat or oils on your hands can act as a lubricant. Due to the smooth finish of PEX, any form of lubricant can cause the PEX ring to slide across the tubing during expansion.
- If you anticipate that the PEX ring may possibly slide down, position the ring slightly farther over the end of the tubing and make the first couple of expansions slowly, holding your closed hand tightly under the ring and tube. Once the ring and the tubing begin to expand together, you can continue with the normal number and type of expansions.
- Occasionally, a light amount of abrasion applied to the outer surface of the end of the PEX tube can assist in stopping the ring from sliding.

If more than the recommended number of expansions are needed to make a connection:

- Make sure that the head is hand tightened to the expander tool.
- Examine the segment fingers to make sure that none are bent.
- Be sure to completely cycle the full range of the tool on each expansion.

Cold-weather expansions:

- Temperatures affect the time required for the tubing and ring to shrink onto the fitting. Colder *ambient* (surrounding) temperatures will require longer contraction times.
- Warming fittings and PEX rings reduces contraction time. Put fittings and rings in your pockets prior to installation to keep them warm.
- Make expanded PEX connections at temperatures above –15°C (5°F).
- Fewer expansions are necessary in temperatures below 4°C (40°F).

Hand Threading Tools

There are many different types of hand threading tools. The choice of tool may be based on the size of pipe and/or location as well as ease of use.

Ratchet Drop Head Threader

The following describes the procedure for a ratchet drop head threader:

1. Be sure the end of the pipe has been cleanly and squarely cut.
2. Be sure that the end of the pipe has been thoroughly reamed to remove any burrs from the internal surface.
3. Mount the pipe firmly in a suitable vise. Use a pipe support stand, if necessary, to keep the pipe aligned and level.
4. Select the die head that is appropriate for both the thread form desired and the size of the pipe to be threaded. Make sure the dies are designed for that particular die head.

Figure 56 *Enclosed ratchet drop head threader (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

5. Slip the pipe guide at the rear of the threader over the pipe

Figure 57 *Slide threader on to pipe (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

6. Gently apply pressure to the front of the die head, and move the handle down while holding the die head. This will start the thread.

Figure 58 *Start the thread (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

7. To ensure maximum leverage, keep your weight above the handle. Do not raise the handle above the level of your waist, as this will reduce leverage. Do not let your arms do all of the work. Use the weight of your body.
8. While cutting the thread, generously apply thread cutting oil with a pumping action of the oiler pistol.

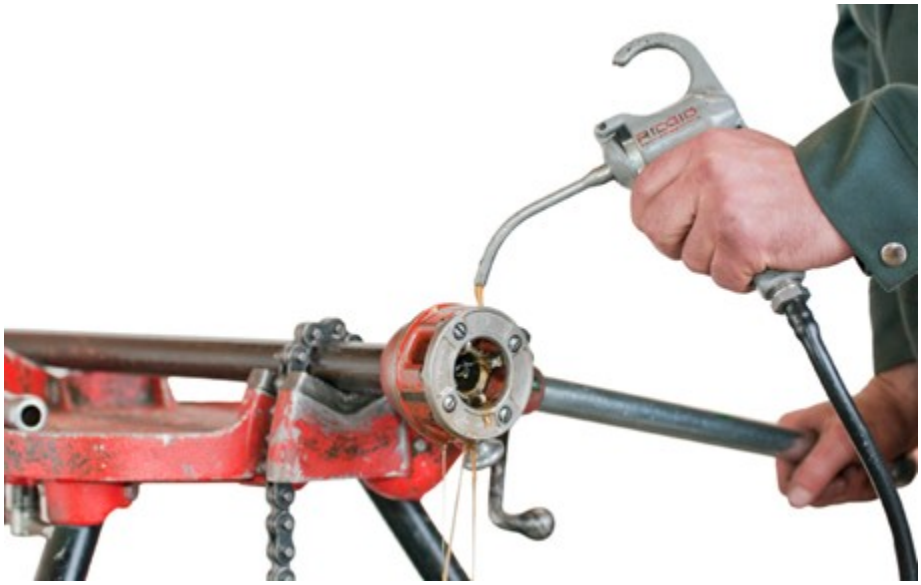


Figure 59 *Oil as you turn (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

9. Stop threading when the outer ends of the dies are flush with the end of the pipe. (You have now made the correct length of thread. To continue threading beyond this point would make a straight or running thread and produce an improper joint.)

Figure 60 *Stop when flush (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

10. Back off the die head from the completed thread. To do this, reverse the ratchet mechanism and turn the die head in the opposite direction to that used during the threading operation. When the dies are nearly removed from the thread, stop for a moment to be sure that you will have control over the unit when the die head is finally removed from the completed thread. In this way, neither the thread nor the threader will be damaged.

Always check a threaded pipe visually. Do not use your fingers to check a freshly cut thread because the threads are very sharp and will cut skin easily.

Jam-proof Ratchet Threader

The following describes the procedure for using a jam-proof ratchet threader:

Adjusting the Threader for Size

1. Place the threader in the position as shown above.
2. Unscrew the work holder by turning it counter-clockwise until the change plate is clear of the posts.
3. Move the post to the pipe size desired.
4. Screw the work holder clockwise until the change plate slides over the post.
5. For standard thread, set the change plate between the two standard (ST'D) marks. For undersize or deep threads, set the change plate slightly above the standard (ST'D) marks.

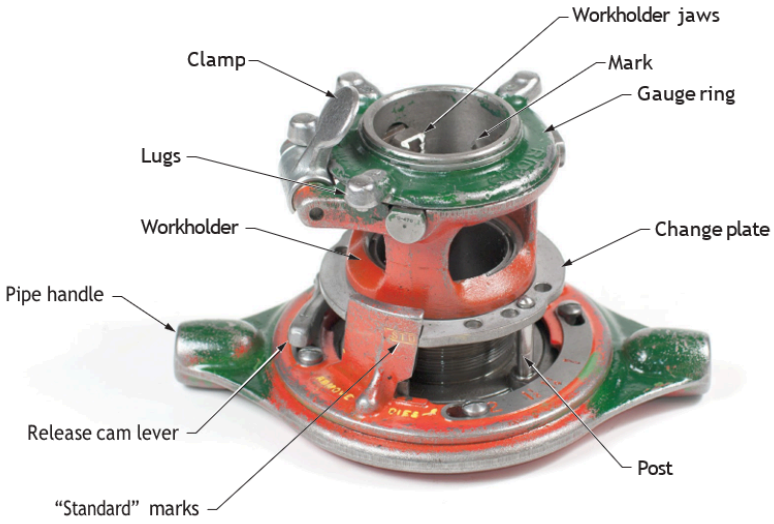


Figure 61 *Parts of the jam-proof ratchet threader* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Setting the Work Holder

Turn the gauge ring until the desired size lines up with the mark on the top of the work holder.

Figure 62 *Jam-proof ratchet threader* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Threading the Pipe

1. Be sure the release cam lever is at the close position for cutting threads.
2. Making sure the pipe is held securely in the vise, slide the threader onto the pipe, work holder end first.

3. Centre the end of the pipe in the dies.
4. Firmly tighten the clamp screw of the work holder.

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

5. To thread, pump the threader handle while applying thread cutting oil to the dies.

Figure 64 *Oil as you turn (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

6. The threader automatically releases when the change plate reaches the point shown in the following figure.

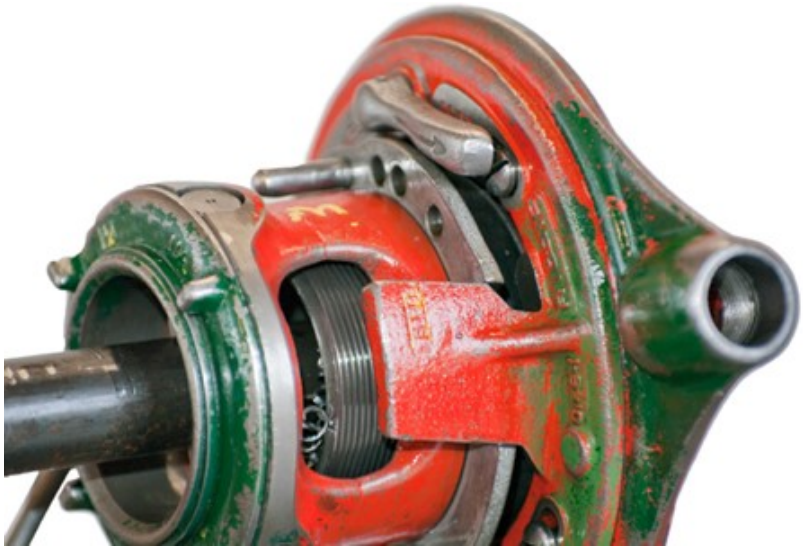


Figure 65 *Threader release point (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Removing the Jam-Proof Ratchet Threader from the Finished Thread

1. Turn the release cam lever to the open position and spin the threader back to the standard position. Loosen the clamp screw and slide the threader off.
   OR
2. Turn the release cam lever to the open position and loosen the clamp screw. Pull the threader straight off the pipe. No spinning off is necessary for this method of removal, but it does help prepare the tool for the next thread.

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

Geared Threader

The geared threader is used for threading pipe larger than 5 cm (2 in.) in diameter. The gears give a mechanical advantage, resulting in the drive shaft turning a number of times for a complete turn of the threader.

Once set up and mounted on the pipe, the geared threader can be turned with a hand ratchet, or any of the power drives using various accessories and hook-up methods.

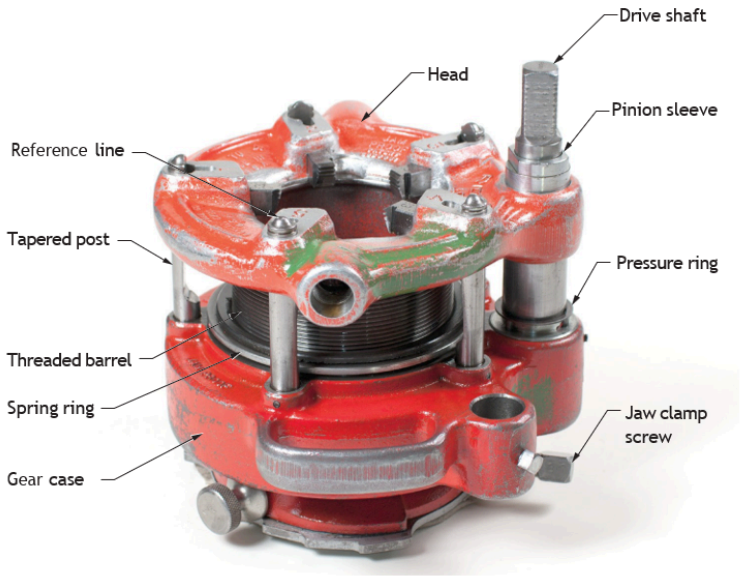


Figure 67 *Geared threader with drive shaft up* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

The jam-proof threader and the geared threader are similar in the fact that they use receding dies. Both have a base that clamps on the pipe with the dies set in to cut threads deepest at the end of the pipe. As threading continues, the die head turns on threads relative to the stationary base, and the dies recede to form tapered threads. Depending on how "open" the dies are at the beginning of threading, oversized and undersized threads can be cut. Other adjustments can be made to make straight (untapered) threads.

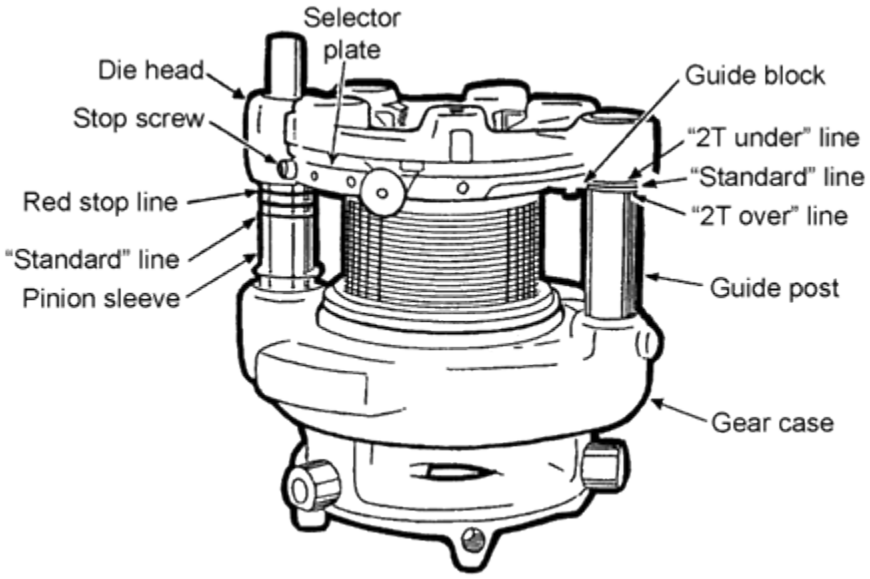


Figure 68 *Geared threader showing pinion sleeve and guide post reference lines (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

To adjust the geared threader for size:

1. Place the threader on the floor or the workbench with the driveshaft up.
2. Pull the knobs of the cam plate, and rotate the cam plate to the desired pipe size marking on top of the die head. Release the knobs when the locating pins drop into the holes of the selector plate. For some types of geared threaders, the size is adjusted by replacing the dies.
3. Grasp the work holder and turn the square end of the driveshaft (or turn the gear case by hand) to the reference line on the guide post.

To set for standard size thread, either one of the following two reference lines may be used depending on the type of geared threader:

- Reference Line 1—Set the bottom surface of the die head at the red "Standard" line on the pinion sleeve.
- Reference Line 2—Set the upper surface of the die head, which houses the guide post, even with the centerline at the top end of the guide post.

Cleaning and Storing Threaders

Follow these guidelines to ensure safe operation and a long life for the pipe threaders:

1. Clean and wipe down threaders at the end of each job.
2. Take the pipe threader apart periodically to ensure through cleaning.
3. Submerge the threader parts in a cleaning solution designed for the purpose and scrub with a wire brush.
4. Because cleaning agents cause tools to become dry, lubricate as necessary after cleaning. Use good quality lubricating oil. **Do not use thread cutting oil** (which is not a lubricant for servicing threaders).

Figure 69 *Exposed ratchet threader and drop head die set (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

5. Inspect dies for damage or wear. First, examine the dies visually. Next, perform a test cut. If you suspect the cutting edges need regrinding, set the die aside for professional repair.
6. Store dies and die heads separately on a rack in a clean, dry area. Careful storage helps prevent damage.

Pipe Taps

Tapered pipe taps can be used for making internal threads into ferrous and non-ferrous materials to connect pipe or fittings. A pipe tap resembles a shortened bolt with a slotted or squared head on one end and threads on the other end, interspersed with sharp fins. Pipe taps come in various sizes and configurations.

Figure 70 *Pipe taps (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The following procedure describes the use of pipe taps:

1. Apply cutting oil to the drill and drill a hole in the material that needs threads. Proper hole size is very important.
2. Clean the hole with a wire brush. Remove any loose chips or pieces of metal that can result from drilling.
3. Apply oil to the pipe tap. Insert the threaded end onto the hole and grasp it with a tap wrench.
4. Turn the pipe tap clockwise one half of a turn, then turn the pipe tape counterclockwise one half of a turn.

Continue this process slowly and carefully until you have advanced approximately ten tap threads into the hole. Check your fitting. If you find that it is too tight, you can run the tap through deeper.

Follow these guidelines to ensure safe operation and a long life for the pipe taps:

- Each time after use, clean off the pipe taps with a file card (a wire brush with short bristles).
- Inspect the cutting edges for wear or damage. If the edges need regrinding, set the tap aside for professional repair. Do not attempt to regrind them yourself.
- Store the pipe tap in its original container, in a toolbox, or on a rack.

Figure 71 *Adjustable tap wrench (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Maintaining and Storing Oilers

Follow these guidelines to ensure proper operation and a long life for the oilers:

- Metal chips and filings should be removed from the chip pan after each job and disposed of in an approved and responsible manner (ex. cleaned/drained, placed in a labelled container, and taken to a metal recycling centre) as to not contaminate soil and water.
- Periodically clean the screen with a cleaning solvent.
- Check to make sure that the level of the oil in the can is above the suction line.
- Remove the oil when the deposit in the can becomes heavy. Clean out the can with a solvent and pour in fresh thread cutting oil, making sure that the oil level is above the suction line.
- Store the full oiler in a safe, dry location away from flammables.

Figure 72 *Hand operated oiler and various threading oils (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hand Operated Roll Groover

The hand roll groover is designed to groove schedule 10 and 40 steel, aluminum and PVC pipe in 32 mm to 15 cm (1 $\frac{1}{4}$ in. to 6 in.) sizes. It is also designed to groove 32 mm to 150 mm (1 $\frac{1}{4}$ to 6 in.) schedule 10 and 32 mm to 50 mm (1 $\frac{1}{4}$ in. to 2 in.) schedule 40 stainless steel pipe. With a roll set change, it can be used to groove 5 cm to 20 cm (2 in. to 8 in.) Type K, L, M and DWV copper tube.

Table 2: Hand Operated Roll Groovers – Specifications

Material	Schedule/Type	Size Range (mm)	Size Range (inches)	Notes
Steel, Aluminum & PVC	Schedule 10 & 40	32 mm to 150 mm	1¼ in. to 6 in.	–
Stainless Steel	Schedule 10	32 mm to 150 mm	1¼ in. to 6 in.	–
Stainless Steel	Schedule 40	32 mm to 50 mm	1¼ in. to 2 in.	–
Copper	Type K, L, M & DWV	50 mm to 200 mm	2 in. to 8 in.	Requires roll set change

The hand roll groover can be used for in-place applications (pipe that is in place or mounted in a vise) or with a power drive for powered applications on the job site. The hand roll groover is not intended for production type applications.

Figure 73 *Hand operated combination roll groover (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

When grooving in place, make sure that there will be enough space for the hand roll groover to fit and be operated. The roll groover will orbit around the solidly mounted pipe and requires:

- A minimum of 16.5 cm (6 $\frac{1}{2}$ in.) clearance around the pipe to be grooved
- A minimum of 6 cm (2 $\frac{1}{2}$ in.) pipe extending past an obstruction (such as a wall)

Figure 74 *Grooved pipe end (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Note: the use of roll sets (groove roll and driveshaft) on both carbon and stainless steel pipe can lead to contamination of the stainless steel material from carbon steel (ferrous) particles. This contamination could cause corrosion and premature pipe failure. To prevent ferrous contamination of stainless steel pipe, use roll sets dedicated for stainless steel roll grooving only. Alternately, a stainless steel wire brush may be used to thoroughly clean the roll set when switching between materials.

The following procedure describes the preparation for roll grooving:

1. Inspect the pipe to be grooved and confirm that the hand roll groover is the correct tool for the job.

2. If grooving in place on existing piping, make sure that the system has been depressurized and emptied of contents. Know what the contents are and any hazards associated with them.
3. Cut pipe to proper length. Make sure pipe end is cut square and free of burrs. Burrs can catch or cut gloves or fingers during grooving. Large burrs and the method of pipe cutting can affect the quality of the groove made and the tracking of the groove. Do not attempt to groove pipe that has been cut with a torch.
4. All internal/external weld beads or seams must be ground flush at least 5 cm (2 in.) back from the end of the pipe. Do not cut flats into gasket seat area, this could cause leaks.
5. Remove all scale, dirt, rust and other contaminants at least 5 cm (2 in.) back from the end of the pipe. Contaminants can clog the drive *knurls* (ridges) and prevent proper driving and tracking of the pipe while grooving.
6. Make sure that the pipe to be grooved is solidly mounted. The pipe must be able to withstand the weight of the roll groover (approximately 13.6 kg or 30 lbs.), and the force and torque required for grooving without moving.

Always follow grooved coupling manufacturers' specific recommendations for pipe end preparation. Failure to follow the grooved coupling manufacturer's recommendations may lead to an improper connection and cause leaks.

For pipe that is in-place, remove the pipe, if possible, and groove at a pipe vise. In other cases, it may be necessary to add other temporary or permanent pipe supports. When using a pipe vise, make sure that it is secure and will not tip during use. For longer lengths of pipe, use appropriate pipe stands to support the extra length.

Mounting the hand roll groover to the pipe:

1. Confirm that the hand roll groover has been inspected and has the appropriate roll set installed.
2. Make sure that the support arms are tight in the body of the roll groover or remove them completely for better access in tight spaces. Next, install the ratchet into the feedscrew and install the extension into the manual drive square at the back of the roll groover. Make sure both the ratchet and extension are securely installed.
3. Make sure that there is enough space between the groove roll and driveshaft for the pipe wall. If needed, turn the feedscrew counter-clockwise to retract the groove roll.
4. Securely grasp the roll groover. Do not lift with the ratchet. Place the driveshaft into the pipe and make sure that the cover plate is tight to the end of the pipe. Tighten the feedscrew to bring the groove roll into contact with the outside of the pipe. Once the feedscrew is hand tight, use the ratchet to tighten the feedscrew an additional $\frac{1}{4}$ turn. Confirm that the roll groover is securely attached to the pipe and the cover plate is flush to the end of the pipe. If not, repeat the procedure. Always make sure groover is secure when used in place to prevent it from falling.

Figure 75 *Holding the hand roll groover in place while tightening the feedscrew (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Precautions When Grooving Pipe "In Position" (in-place)

- Only drive manually for in-place applications. Do not use powered devices (such as drills or impact tools) to drive the roll groover when used in place. Use of powered devices can damage the groover and increase the risk of injury.
- Do not wear loose clothing when operating the roll groover. Keep sleeves and jackets buttoned. Do not reach across the machine or pipe. Loose clothing can become entangled in rotating parts and cause crushing injuries.
- Keep hands away from grooving rolls. Do not groove pipes shorter than specified. Do not wear loose fitting gloves. Fingers can be crushed between groove rolls or between groove roll and pipe.
- Keep hands away from ends of pipe. Do not reach inside pipe. Burrs and sharp edges can catch and cut. Fingers can be crushed between groove rolls or between groove roll and pipe.
- Always wear eye protection to protect your eyes against dirt and foreign objects. Wear steel toe footwear to protect feet from tipping tools and falling pipe. When working in place, wear a hard hat.

Follow operating instructions to reduce the risk of injury from crushing, tipping, striking and other causes.

Setting/Measuring the Groove Diameter

Note: These instructions are derived specifically from one manufacturer.

1. Confirm that the equipment and pipe are properly set up. Improper pipe preparation can affect the accurate set up of the groove depth gauge. The groove roll should be touching the pipe.
2. Adjust the groove depth gauge so that the correct step of the gauge is under the head of the adjusting screw. The groove depth gauge is designed for use with pipe.
3. Turn the adjusting screw clockwise until the head touches the step of the depth gauge. Turn the groove depth gauge to the grooving position. If gauge is not in the grooving position, it will prevent grooving and may be damaged.
4. Prepare a test groove (follow the steps for *forming the roll groove*, below).
5. Measure the groove diameter. The best method for measuring groove diameter is the use of a pipe tape (diameter tape). Snugly wrap the pipe tape around the pipe in the groove. Make sure that the tape sits flat in the bottom of the groove, and read the groove diameter.

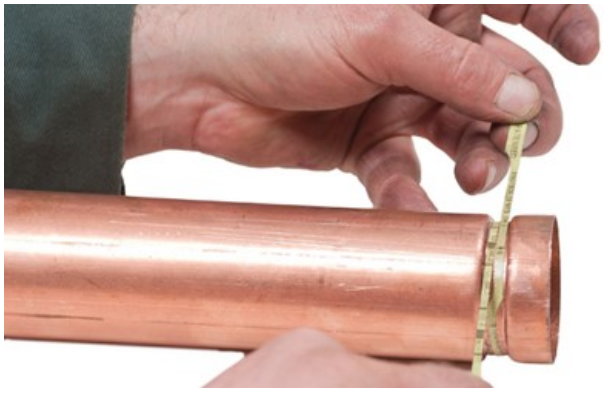


Figure 76 *Using the pipe tape (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

6. Compare the measured groove diameter to the required groove diameter (this may be specified by the groove fitting manufacturer). If the measured groove is outside of the required groove diameter, the adjusting screw must be repositioned to give the correct groove diameter.

    - To increase groove diameter, turn the adjusting screw clockwise.
    - To decrease groove diameter, turn the adjusting screw counter-clockwise.

    - Each $\frac{1}{4}$ turn of the adjusting screw changes the groove diameter approximately 0.5 mm (0.02 in.).

7. Repeat steps 4–6 until the groove diameter is within specifications. If the first groove is too large, the groove can be adjusted and the groove made smaller.
   If the groove is too small, another groove will need to be made. *Proper groove diameter is important to insure connection performance.* Grooves made out of specification could cause joint failure.

Due to differing pipe characteristics, a test groove should always be performed before the first groove of the day, or when changing pipe size, schedule or material. *Groove diameter setting gauges are approximate only and the groove diameter must be measured to confirm proper size.*

Forming the Roll Groove

1. Confirm that the equipment and pipe are properly set up.
2. Assume a proper operating position. Make sure that your footing is good and you are well balanced.
3. Make sure that the feedscrew has been tightened $\frac{1}{4}$ turn.
4. Remove the ratchet from the feedscrew, and securely install in the extension. (In close quarters applications, the extension does not need to be used.)
5. Turn the ratchet clockwise as viewed from the back of the roll groover (this will match the arrows cast into the back of the roll groover). Watch the groover rotate and be sure that the cover plate of the roll groover stays in contact with the end of the pipe.
6. If the roll groover starts to move away from the pipe end, stop rotating the ratchet to prevent the roll groover from spiraling off the pipe end and falling.
7. The roll groover support arms can be pushed on to help bring the cover plate back in contact with the pipe end. If needed, remount the roll groover to the pipe.
8. (See Mounting the Hand Roll Groover to Pipe.) If the pipe end is deformed, it will need to be cut off and a new groove prepared.
9. Continue rotating the ratchet until the roll groover completes at least a full rotation around the pipe.

10. Remove the ratchet from the extension and attach to the feedscrew. Tighten the feedscrew another $\frac{1}{4}$ turn. Remove the ratchet from the feedscrew and securely attach to the extension. Do not tighten the feedscrew more than $\frac{1}{4}$ turn per pipe rotation. Aggressive tightening of the feedscrew can cause excessive groove flare and can cause the roll groover to walk off the pipe. Continue rotating the ratchet to drive the roll groover around the pipe while monitoring the position of the cover plate to the end of the pipe.

Figure 77 *Turn the ratchet handle clockwise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

11. Continue tightening the feedscrew $\frac{1}{4}$ turn per groove revolution around pipe until the head of the adjusting screw stops against the top of the roll groover. Do not continue tightening the feedscrew after the adjusting screw reaches the top of the roll groover; this can damage the adjusting screw. Rotate the roll groover at least two more full rotations around the pipe after the adjusting screw reaches the top of the roll groover to insure uniform groove depth.
12. Move the ratchet to the feedscrew. Securely grasp the roll groover. Turn the feedscrew counter- clockwise and retract the groove roll so that the roll groover can be removed from the pipe. *Do not drop the roll groover.*
13. Inspect the groove.

- Make sure that the groove is fully formed.
- Check the groove diameter and make sure it is within specification.
- Check any other items required by the fitting manufacturer. If any problems are found, the groove cannot be used.

Changing Groover Roll Sets

When changing roll sets for grooving different types of pipe, refer to and follow manufacturer's instructions carefully. Mismatched parts or rollers will cause improper grooves, which can lead to leaks and possible injury.

Figure 78 *Roll groover gear case* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Hand Roll Groover Maintenance

Follow these guidelines to ensure safe operation and a long life for hand roll groovers:

- Lubricate the hand roll groover with good general purpose grease once a month.
- (Grease fittings are located on the side of the operator's side of the base, the front of the slide block, and the end of the groove roll shaft.)
- Add grease until a small amount is pushed out. Apply a light coat of grease to the feedscrew.

Figure 79 *Location of grease fittings* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

- The gear box of many hand roll groovers has adequate grease for its service life and does not require the addition

of any grease unless the gear box is opened.
- Clean the driveshaft knurls with a wire brush on a daily basis or more often, if needed.

Self-Test B-1.2: Use Hand Tools

Complete Self-Test 1.2 and check your answers.

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2732#h5p-2 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2732#h5p-2)

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B-1.3 Use Levelling Equipment

Levels Used to Establish Elevations

Levels are instruments used to project a level line 360° around their axis in order to transfer, measure or set elevations. There are two broad categories of levels: optical and electronic. ***Optical levels***, also known as ***builder's levels***, generally need two people to operate them. One person looks through a telescope and interprets the reading of a sighting from a levelling rod, which is held by the other person. ***Electronic levels*** rotate a light beam and only require one operator, who uses the rod along with a sensor that picks up the light beam.

Optical Level Electronic Level With a Sensor

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

Types of Builder's (optical) levels

Optical levels are high-powered telescopes equipped with crosshairs and centrally mounted on a bearing so that they can rotate *only* horizontally. They are different from ***transits*** or ***theodolite levels***. Transits and theodolites (Figure 2) can measure horizontal *and* vertical angles and are used as surveying tools.

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

Builder's levels are designed for horizontal rotation only and therefore are only used for horizontal leveling. This learning resource will not cover transits or theodolites.

An optical level can be used to perform the following tasks:

1. Find the elevation of selected locations. Given a benchmark location and elevation, you can find the elevations of a series of other given locations.
2. Establish the elevation of an object. Blueprints provide the information needed to do the following:

    - Set the elevation of a slab
    - Set the height of a wall
    - Set the invert (lowest inside point of a pipe's inner surface) elevation and slope of a pipe

Optical levels can be categorized as manual or automatic, according to the way they are set up. There are two types of manual levels: "dumpy" and tilting.

"Dumpy" Levels (also known as 4-pin levels)

Although no one seems to know for certain where the term ***dumpy*** came from, it's widely accepted as the most rudimentary of all the builder's levels. It consists of a short telescope mounted to a table that is adjustable using thumbscrews or "pins." A ***spirit vial*** mounted below the telescope contains an air bubble in a small amount of alcohol, which is used instead of water so that freezing isn't a problem. The vial is similar to those found in ***carpenter***'s or "***torpedo***" levels. Dumpy levels are the least expensive and least sensitive of all the builder's levels and are generally known as being the hardest to correctly set up. They traditionally have four pins, while the others typically have only three.

Figure 3 A *"dumpy" level* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Tilting Levels

A ***tilting level*** (also known as *split-bubble* or *engineer's levels*) is so named because the horizontal plane of the telescope can be raised or lowered very slightly through a limited arc without impairing the accuracy of the reading. This is done to ensure that the reading taken is precisely level.

A fish-eye bubble provides for general levelling, and a bubble tube is usually mounted alongside the telescope and is viewed through a separate eyepiece for fine-tuning. For example, an optical sighting arrangement that brings opposite halves of a bubble image (split bubble) into alignment. Illustrated later in this section.

Tilting levels are generally more compact, more sensitive and more expensive than dumpy levels. They usually have only three pins for levelling the table, which makes them easier to set up than the dumpy, although some are made in a 4-pin configuration.

Figure 4 A *tilting level* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Automatic Levels

Automatic levels (also known as self-levelling levels) have only a fish-eye bubble that needs manual centring. Inside the instrument is a prism, also known as a ***compensator***, suspended by very fine wires. An automatic level, if shaken lightly, will make a slight "jangling" sound from within, evidence of the prism and wires. The prism fine-tunes the levelling, which makes setting up the automatic level very quick and easy. Once the fish-eye bubble is centred, the telescope can be rotated through 360˚ without the need for any further adjustment.

Optical instruments share a number of features:

- ***crosshairs*** and ***stadia*** lines inside the viewfinder
- an eyepiece focus (for the crosshairs)
- field-of-view focus (for the levelling rod)
- a $\frac{5}{8}$„ female thread connection on the footplate (for attachment to the tripod)
- an ***azimuth adjustment*** (for precise sideways movement)

Some varieties may or may not have an azimuth clamp and screw for moving the telescope sideways.

Figure 5 *Automatic level and levelling rod* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Types of Electronic Laser Levels

The use of laser and electronic levels has now become very commonplace on the job site. They are easy to use and have a distinct advantage over optical levels because they require only one operator. One worker using a laser or electronic level can perform the same job as two workers using an optical level. Electronic levels also allow many workers on large jobs to use the same instrument setup at one time with different receivers. They are ideal for setting suspended ceilings, levelling concrete floors, setting drainpipes, grading roads and building lots, and performing other tasks that are usually

done with a standard optical level. It is important to read the manufacturer's instructions before using these levels. Do not exceed the maximum range of the instrument and complete an accuracy check on a regular basis.

Laser levels

The word *laser* is an acronym for "Light Amplification by Stimulated Emission of Radiation." A mixture of helium and neon gases is used to emit a very narrow beam of light that does not grow larger as it moves away from the source, which in this case is the laser level (Figure 6). In low light conditions the laser beam can be seen as bright red. Some manufacturers use a green laser beam, which is easier to see in daylight conditions. In bright sunlight, a sensor or detector is required in order to read the beam.

Never look directly into a laser beam! Looking directly into the beam may be hazardous to your eyes. A quick flash of the beam is not a problem, but avoid prolonged contact with your eyes. The instrument must be positioned either above or below the line of sight of the average worker.

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

Electronic Laser Levels

With electronic levels (Figure 7) the beam can be directed to any point, or it can be rotated continuously at various speeds and controlled remotely. A beam detector or sensor must be used to locate this infrared laser beam.

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

Using Electronic Laser Levels

Electronic laser levels depend on an electrical power source such as batteries, a 12-volt source from a truck or car, or a 110 VAC adapter. Set-up is very easy. A bubble level or fish-eye is used to rough- level the instrument. When the bubble is in the ring, the instrument levels itself with its motor- driven levelling system. If, during operation, the instrument is knocked and moved beyond the limits of self-levelling, the beam shuts off.

The instruments can be supported in several ways. The most usual supports are tripods of various heights. They can also be clamped to columns, or have small feet attached so that they can be set into or on drainage pipes. Suspension frames are available to hold the instruments and aim them into pipes.

Sensors or Detectors

Electronic laser levelling instruments can be operated by a single person. When the instrument is set up and running, a level reference plane is created that can be seen by eye or detected with the sensor or detector (Figure 8).

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

The sensors or detectors operate on batteries and have a narrow window through which the beam can be detected. When the beam is sensed, the detector shows a small, colored light or emits a sound. Sensors or detectors can be attached to the levelling rod or can be used by themselves to locate instrument height on walls or forms.

Targets

Targets (Figure 9) are made of clear plastic with a cross marked on them. They are used to set levels with a laser level for items such as ceiling T-bars, concrete screeds or drainage pipes, using a direct or rotating beam. The object (with target attached) is lowered, raised or moved sideways until the beam is located at the target cross.

Figure 9 *Target (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Checking Laser Level Accuracy

Many laser levels are designed to allow the operator to calibrate the unit. The manufacturer's instructions will include the method. Often it is as simple as setting up 50 meters from a wall, marking the location, and then rotating the instrument 360° and marking again. If the two marks are not within tolerance of each other, then turn the instrument on by pushing two buttons at once and adjust the beam up or down by pushing buttons. Then rotate the instrument 90° and make a third mark. Rotate the instrument another 180° and make a fourth mark. The instrument is turned on by pushing another combination of buttons, and then the beam is adjusted. In this way, both the X and Y axes are recalibrated.

Pipe Laser Levels

Pipe laser levels (Figure 10) are specially designed for installing pipes requiring a constant grade and for setting grades for areas requiring drainage. When laying pipe, the laser is set up at the end of the pipe (either inside or on top) and set to the desired slope of the pipe. The target is located at the end of the pipe and the pipe is moved until the target is centered to the beam. Pipe laying can continue until a change of direction is required or the maximum range of the beam has been reached.

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

Five-Way Laser Levels

A *five-way laser level* is used mainly for laying out 90° corners, for levelling and for plumbing up or down. It can also be used as an electronic chalk line. There are five laser beams (Figure 11); one shoots down, one shoots up, one shoots straight forward. The last two are at 90° on both sides to the forward beam.

Figure 11 *Five-way laser level (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The unit self-levels, and the beams are bright enough that a sensor is not required. Most five-way levels are accurate only up to between 10 and 30 meters, as the laser beam becomes too wide past that point.

Five-way laser levels can be set on the floor, mounted on a tripod or clamped to an object. Follow the manufacturer's instructions; be careful not to exceed the rated distance. As the laser beams are quite bright, extra care should be taken not look into the beams.

Parts of a Tilting Level

Figures 12 to 15 identify the major working parts of a tilting level. Note that a tilting level has some parts that are not found on either a "dumpy" or an automatic level. The functions of these parts and some others are described on the following pages.

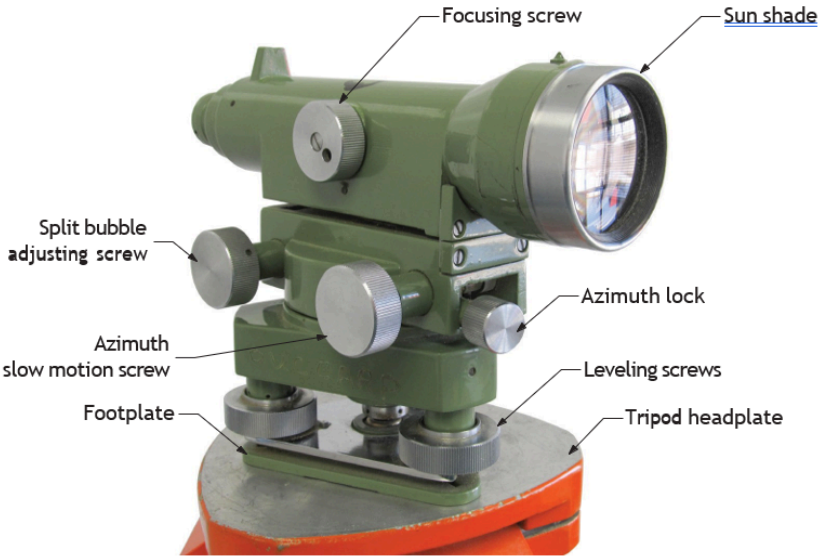


Figure 12 *Tilting level (front view)* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

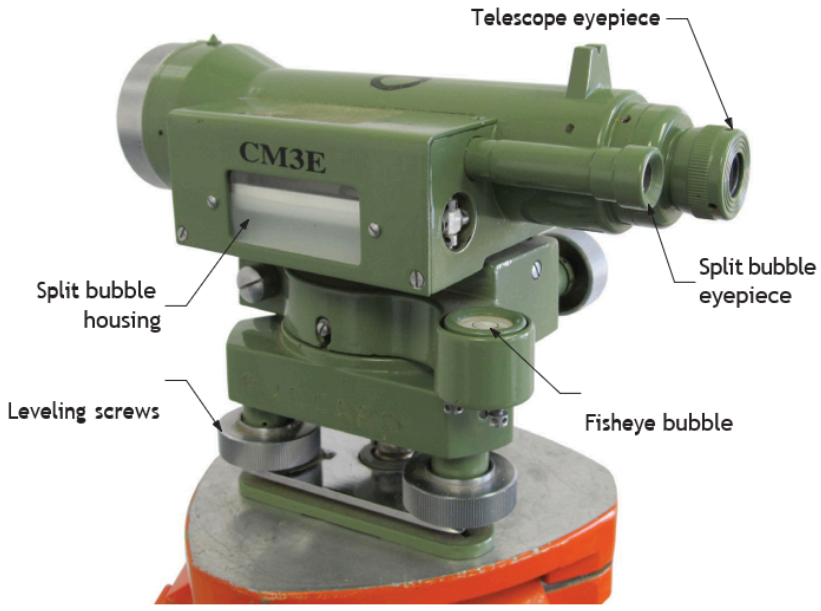


Figure 13 *Tilting level (rear view)* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

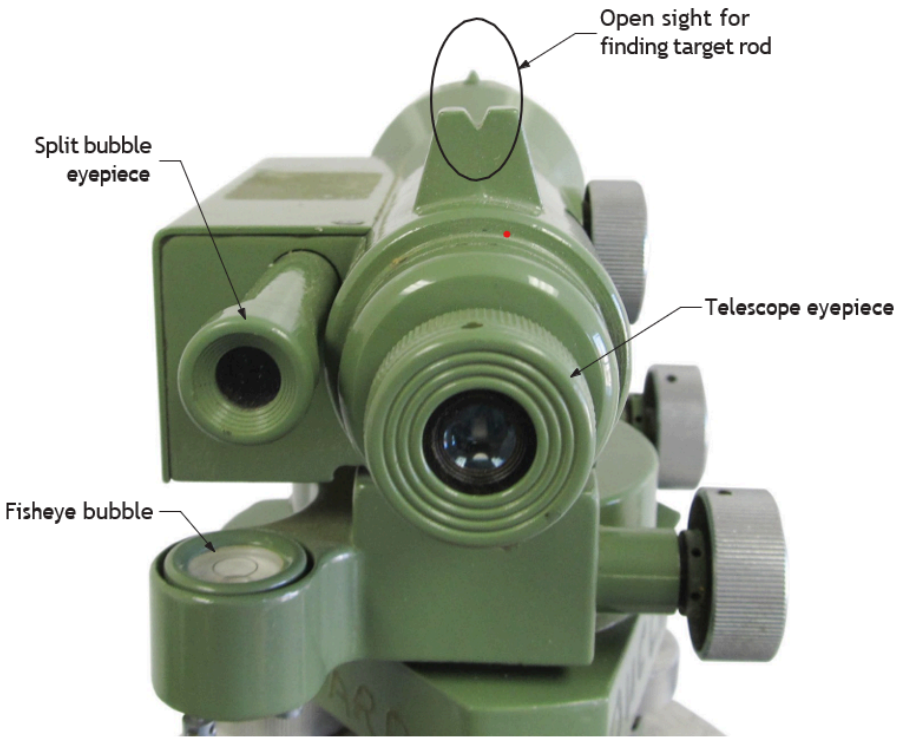


Figure 14 *Tilting level (back view)* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

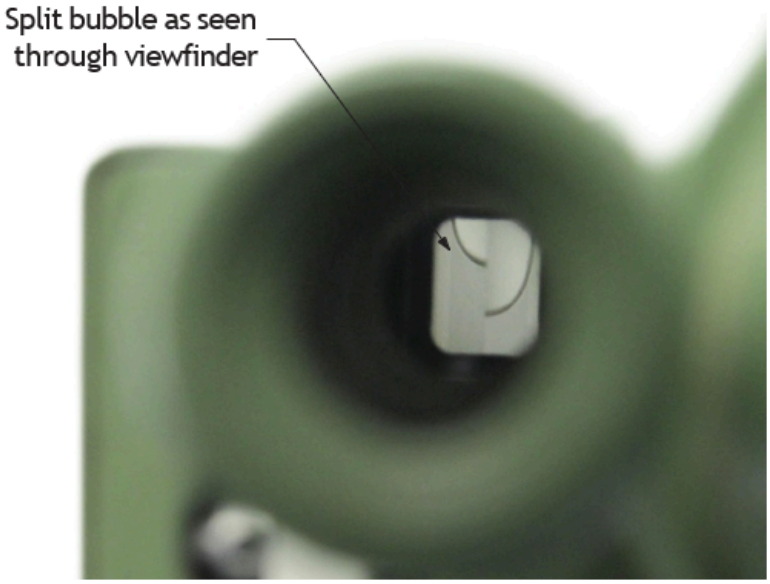


Figure 15 *View of split bubble* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Telescope Eyepiece

The eye is positioned at the telescopic eyepiece when a reading is being taken. The eyepiece has a knurled adjustment ring for focusing the crosshairs.

Crosshairs/Stadia Hairs

The crosshairs are lines that are etched on a piece of glass, sometimes called the fixed reticle. The crosshairs are a pair of vertical and horizontal lines (Figure 16). Readings are taken at the horizontal crosshair. The rod can be lined up plumb in one direction using the vertical hair. The vertical hair is further divided by lines above and below the horizontal crosshair, called stadia lines, which are used to measure distance.

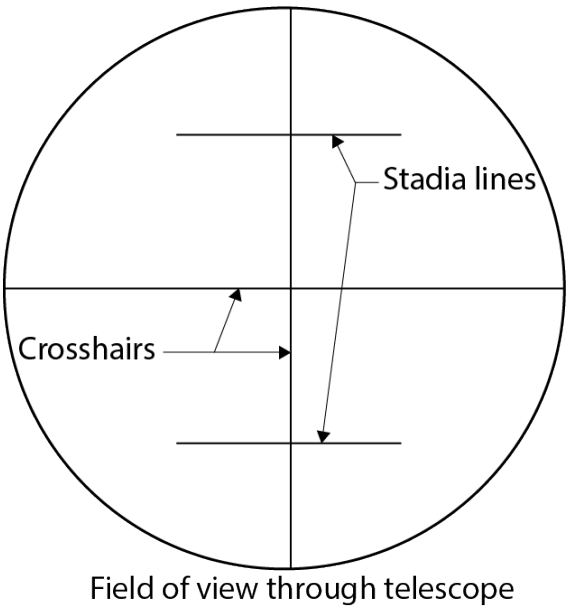


Figure 16 *Field of view through an optical level (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Telescopic Barrel

The telescopic barrel contains the lenses and focusing ratchet mechanism. The lens at the front, or the end opposite the eyepiece, is called the objective lens.

Focusing Screw

The focusing screw brings the object seen through the eyepiece into sharp focus by moving the lenses inside the barrel.

Levelling Split Bubble

The levelling split bubble (Figure 17) can be located above or below the barrel, as on a dumpy level, or alongside it, as on a tilting level. The length of the bubble expands and contracts with changes in temperature.

Figure 17 *Split bubble level as seen through side of instrument (original image) (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Fish-Eye Bubble

The fish-eye bubble is used to roughly set to level the line of sight of a tilting level, or to accurately set up an automatic level. It is attached to the levelling head.

Horizontal Tangent Screw

This screw is also referred to as the slow motion or azimuth screw. It is used to slowly rotate and accurately aim the telescope horizontally. Usually it is located just below the objective lens. It will only operate if the horizontal (azimuth) clamp is tightened.

Horizontal Tangent Screw Clamp (Azimuth Lock)

This clamp can be loosened to allow the barrel of the instrument to be freely swung horizontally, and to roughly aim the instrument. Once the instrument is roughly aimed, the clamp is then tightened, and the fine horizontal sighting is done with the slow-motion screw.

Levelling Screw / Tilting Screw

The levelling screw is used to bring the instrument perfectly horizontal, parallel to the line of sight. It is usually located just below the eyepiece and is activated by turning in direction to center the bubble in the level vial. Sometimes it is aided by a coincidence optical mechanism, known as a split bubble. You must line up both halves of the bubble in the mirror to level the instrument (Figure 18).

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

The sunshade is a short tube attached to the objective lens end of the barrel to eliminate sun glare.

Tripod

The footplate of a builder's level is fastened to the headplate of a three-legged stand known as a tripod by a $\frac{5}{8}$" NC bolt fixed to the underside of the tripod's headplate. The tripod has three extendable legs with feet that are pointed and have a horizontal peg that allows for them to be firmly pressed by foot into soft ground (Figure 19).

Figure 19 *Tripod pegs pushed into the ground* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

There are also rubber tips and suction cups available for use on smooth floors. The top pivot pin of each leg can be tightened or loosened to create more or less resistance to opening or closing the legs. When used on fairly rough terrain, a light closing force would be adequate, whereas on smooth, slippery surfaces a more positive force would

be advantageous in order to keep the tripod legs from splaying outward. If the tripod does not have rubber feet or suction cups, a triangle of 1×4 wood can be used, with the tripod feet pushed into the corners (Figure 20). It is of utmost importance to not move the tripod at all once it is set in position; to do so would necessitate a re- setting of the level.

Figure 20 *Tripod on smooth surface (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Levelling Rods

Levelling or *target rods* (Figure 21) also known as *Philadelphia rods*, are used to take readings on sights. They can be either hinged or telescopic and can be made of wood, fibreglass or aluminum alloy. The units of measure (scales) can be metric or imperial.

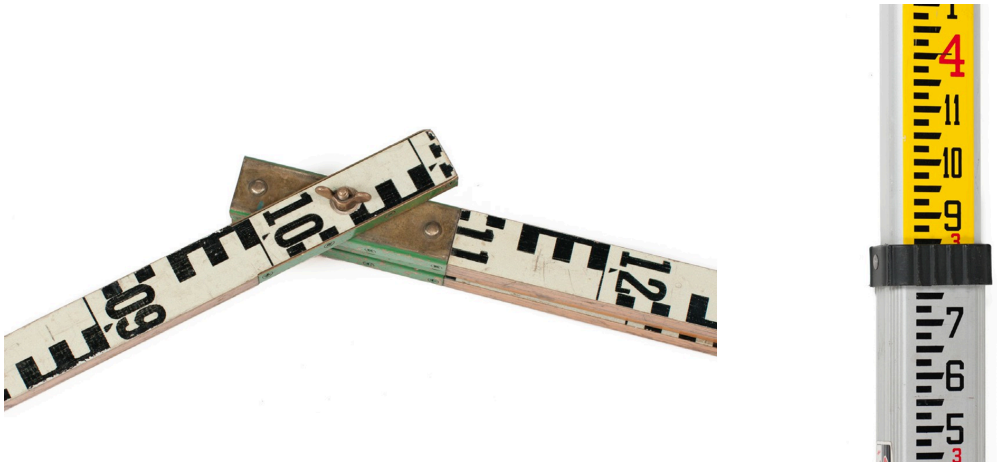


Figure 21 *Levelling rods (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

There are several methods of displaying the scales. The type suited to construction could be the segmented type with a Scotchlite face as they are easily collapsed for use in confined spaces, and a light source can be shone on the scales for easy reading in poor light conditions.

Metric Rods

Scales in the metric system are generally shown in 10-mm (1-cm) divisions (Figure 22). It has been the practice when using metric rods to visually break down the 10-mm divisions. With a bit of practice one should have no difficulty in making rough estimates to the closest millimeter (±1 mm), which is considered an acceptable tolerance. For more accurate readings, a target that has the 1-cm scale divided up into millimeters can be fitted on the rod, or a portion of a metric tape measure can be held with the rod.

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

Imperial Rods

The imperial system of measurement, which uses inches and feet, is used on both the architect's rod and the engineer's rod The architect's rod is broken into feet, inches and fractions of an inch, whereas the engineer's rod is divided into feet and hundredths of a foot. You can quickly tell if it is an architect's or engineer's rod by looking for the 11-inch marking. The engineer's rod does not show the 11-inch mark, while the architectural rod does.

Architect's rod readings (Figure 23) are divided into $\frac{1}{8}$" increments, which are generally considered to be the accepted tolerance for field readings. The marks with the point at the end are at the 0″ mark and the $\frac{1}{2}$" mark.

Engineer's rod readings (Figure 23) are divided into 0.01′ ($\frac{1}{100}$,) increments. The marks with the point at the end are at the 0.1′ ($\frac{1}{10}$, or $\frac{10}{100}$,) mark and the 0.05′ ($\frac{5}{100}$,) mark.

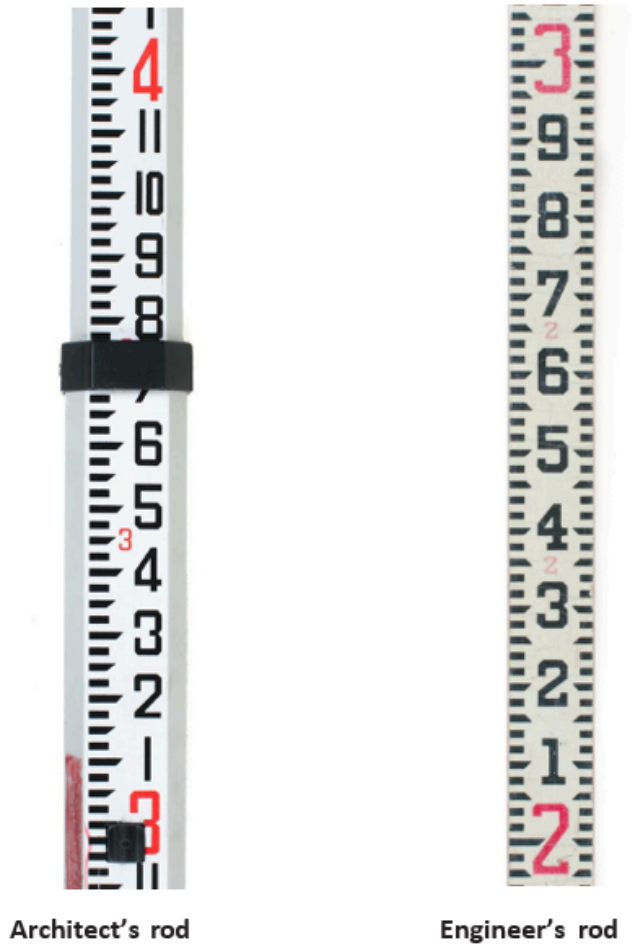


Figure 23 *Imperial target rods (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Care should be taken when reading the engineer's rod: a reading of 0.6′ would be 7.2″ or 7 3/16″ , not 6″!

Note – When geodetic (accurate measurements of the earth) elevations are needed, either the metric or engineer's scales is used.

Stadia Lines

Stadia lines (or hairs) (Figure 24) are used to find the distance from the instrument to the rod.

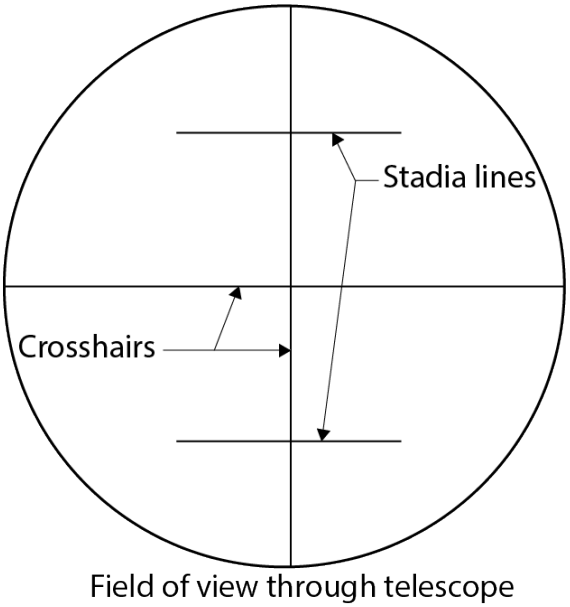


Figure 24 *Stadia lines (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The accuracy of the stadia line distance is totally dependent upon how accurate the rod readings are. For example, if the stadia line reading was accurate to 1 millimeter, then the resulting distance would be accurate to ±100 mm. The stadia line ratio is 1:100, no matter what the rod units are.

To find the distance:

- Take the readings of the top stadia line and of the bottom stadia line.
- Subtract the smaller from the larger.
- Multiply the answer by 100.

The result is the distance from the instrument to the rod. See examples 1 and 2 below. The concept will work with an architect's, engineer's or metric rod.

Example 1

Top stadia line reading = 1.500 m

Bottom stadia line reading = 1.345 m

Difference between readings = 0.155 m

Distance to the rod = 0.155 × 100 = 15.5 m

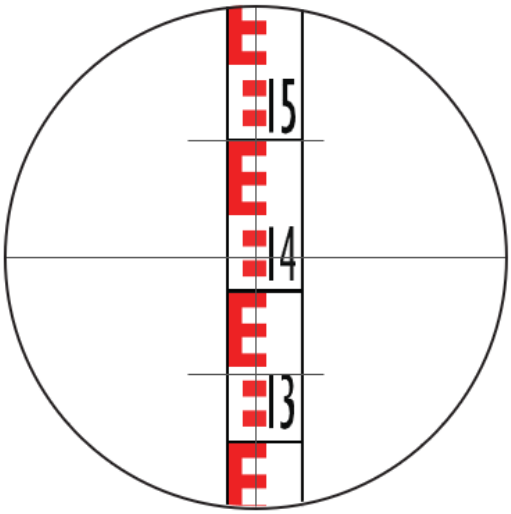


Figure 25 *Illustration for Example 1 (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Example 2

Top stadia line reading = 3.74′

Bottom stadia line reading = 3.51′

Difference between readings = 0.23′

Distance to the rod = 0.23′ × 100 = 23′

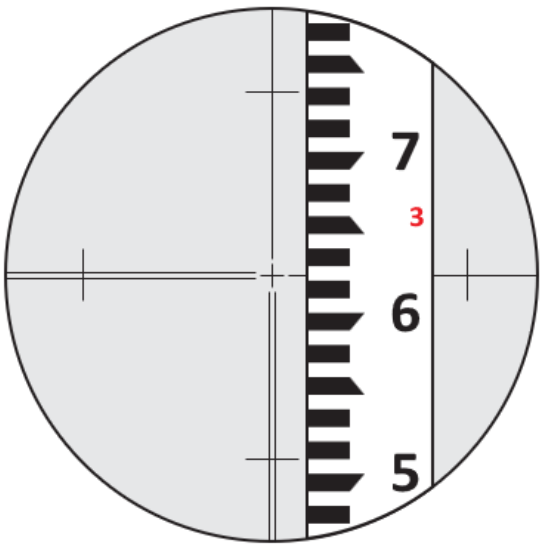


Figure 26 *Illustration for Example 2 (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Using the Level Rod

To ensure that accurate information is obtained, the level rod must be held plumb whenever a reading is taken. The instrument operator can see through the telescope whether the rod is being held plumb in one direction only. To obtain plumb in the other direction, the instrument operator must give a signal to the rod person to slowly move the rod through a small arc forward and backward, so that the lowest reading can be taken if the rod is being held erect, or the lowest reading if the rod is inverted. The illustration in Figure 103 should help in understanding this.

Figure 27 *Moving the rod through a small arc, forward and backward (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The device shown in Figure 28 contains a fish-eye bubble and can be used by the rod person to plumb the rod.

Figure 28 *Fish eye attached to rod (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

A pointed target (like a sharp pencil) is moved up and down on the rod by the rod person as directed by the instrument-person. The rod reading is taken by the rod person and relayed to the instrument person.

Hand Signals

Hand signals should be used for communication between the instrument person and rod person. These are necessary so that the work can be done efficiently, without yelling or shouting to each other. Sometimes the distance between the instrument person and the rod person is too great or it is too noisy for verbal communication.

Figure 29 shows the hand signals that should be used.

Figure 29 *Hand signals (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Set-up and Care of Optical Levels

Tripod Set-Up

If possible, set up midway between the backsight and foresight locations.

Using the leg thumbscrews or cam locks, extend the legs enough so that, when set up, the instrument will be at a comfortable height for readings. A good suggestion is to have all three legs closed and in contact with the ground, and the tripod top plate at chin level. This will put the mounted instrument at a comfortable height. Snug their locking screws up, but do not over tighten the screws. Grasp two of the legs and plant the third out in front of you into the ground. Spread the tripod legs about 900 mm (3 ft.) apart, draw the two legs back and set the feet firmly into the ground (farther apart if windy).

If the ground is sloping, put two legs on the downhill side and the other one uphill. Use a triangular wooden frame if setting up on a floor with a smooth surface such as concrete, where the feet of the tripod cannot dig in. Once the feet are set, adjust the leg lengths so that the top plate of the tripod is level by eye.

Make sure the tripod is secure against any movement by grasping the head and gently trying to move it in a horizontal circle. If there is any movement, then something is loose and all connections should be tightened up before proceeding to mount the instrument. If possible, try to stand between two of the legs when sighting, rather than straddling one of the legs and bumping the instrument. Attach the instrument to the tripod. Tighten the locking screw firmly, but do not over tighten.

Levelling the Instrument

Levelling instruments are used to set, transfer and measure elevations. Levelling the instrument so that the line of sight is in a level position is the most important procedure to obtain accurate levelling work. There are different methods for instruments with four or three levelling screws, and for the quick-set type of instrument. Each will be described separately.

If the instrument goes out of level for any reason, it must be readjusted to a level position before continuing to take readings.

Levelling Instruments with Four Levelling Screws (Pins)

Most instruments with four levelling pins use a tubular level vial. A tubular level vial is a curved glass tube filled with alcohol that has a bubble of air trapped inside. The amount of curve in the vial is very slight, sometimes not even able to be seen by eye. The air bubble will move to the highest point of the curve; if the vial is tipped either left or right, the air bubble will move toward the higher end.

To level the instrument, follow these steps:

1. Make sure all the levelling screws are loose and equally set for height.
2. Position the telescope barrel over a diagonal pair of levelling screws and take up any slack on these screws so the instrument will not wobble horizontally.
3. Turn the levelling screws in opposite directions, using the direction of the left thumb to guide the level bubble roughly to centre. This is referred to as the “rule of the left thumb,” which states that the level bubble will always travel in the same direction as that of the left thumb (Figure 30).
4. Rotate the telescope 90˚ so it is directly over the other two pins, and repeat the process in step 3.

Continue to repeat steps 3 and 4 until the bubble does not move when the telescope is slowly rotated 360 degrees.

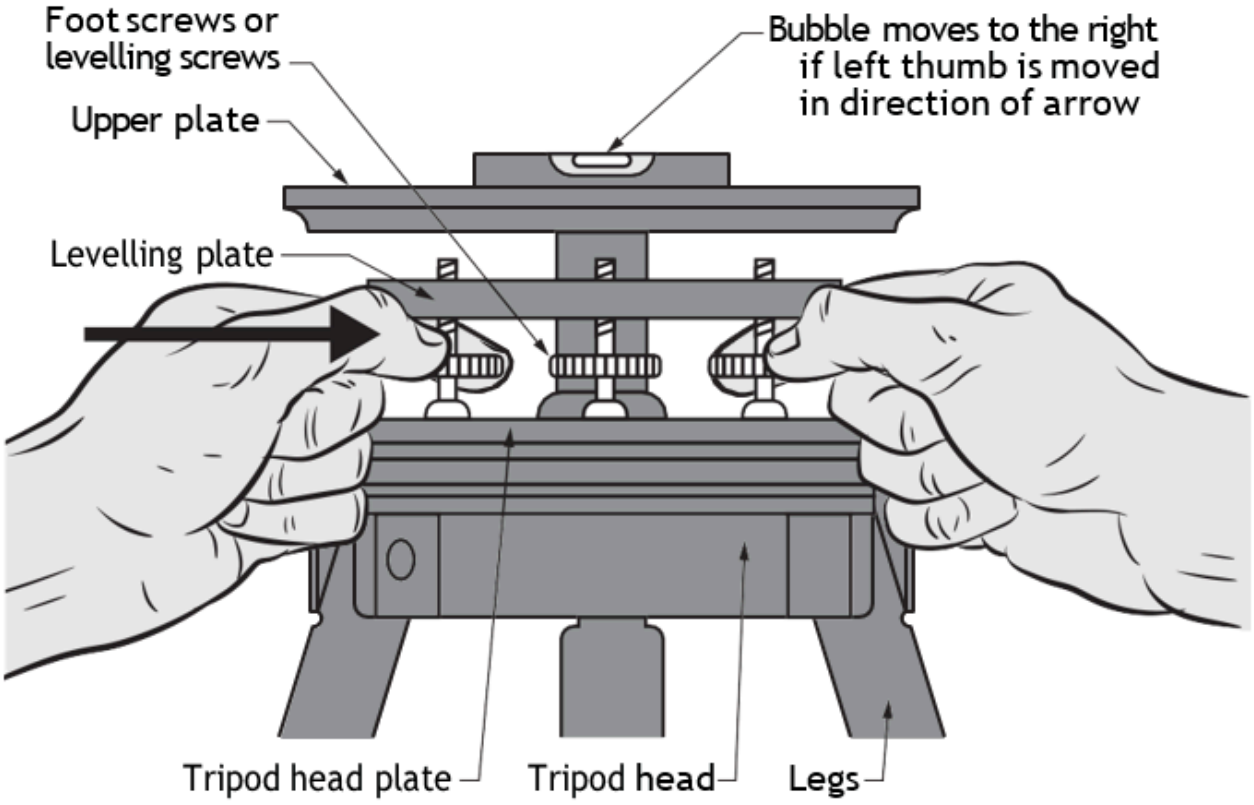


Figure 30 *Bubble moves in the same direction as the left thumb (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Levelling Instruments with Three Levelling Screws (pins)

Instruments with three pins are quite different from those with four pins. The pins on a three-pin instrument always hold the instrument from rocking, so they do not need to be tightened up to take out any slack.

Instruments with three pins usually have two levelling devices: a rough levelling device, which is usually a fish-eye bubble, and a fine levelling device, which could be either a split-bubble or an automatically-adjusting hanging prism.

The foot screws on three-pin levels do not snug up, but it is possible to turn them all the way to the end of their travel, and this will give you the feeling that they are not able to turn any more. To allow full movement of the foot screws, position each of the foot screws halfway in its travel prior to attempting to level the instrument. There is often a mark used to indicate halfway.

Adjusting a Fish-Eye Bubble

Fish-eye bubbles are always used for getting the instrument roughly level. Adjusting a fish-eye bubble can be frustrating because it is possible to "chase" the bubble around and around the vial until the travel of the foot screws is exhausted. To prevent frustration, choose one foot screw and do not adjust it at all during the levelling process.

Refer to Figure 31. First look at the position of the bubble and adjust the foot screw to raise the corner of the instrument that seems to be opposite the bubble's position. Then, when the bubble is halfway across the circle, adjust the foot screw to raise the corner of the instrument that is now opposite the bubble's position. Lastly, adjust the two foot screws to position the bubble. Remember to only adjust two of the three foot screws.

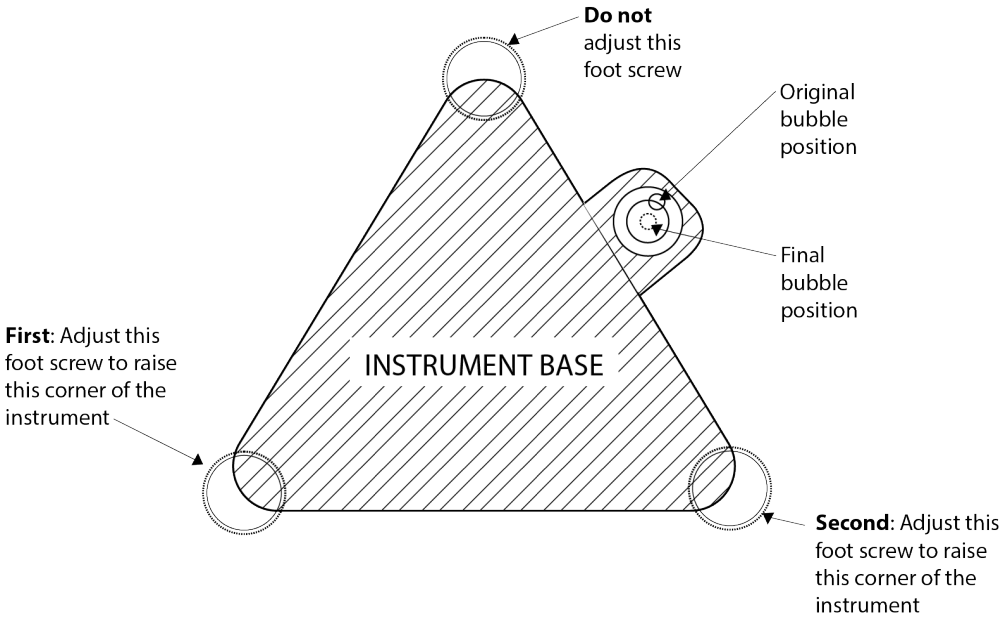


Figure 31 *Adjusting a three-pin instrument (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Adjusting a Tilting Level

Tilting levels use a fish-eye bubble with three-pin levelling to get the instrument head level. They also have a secondary eyepiece that, when viewed through, shows the end of a bubble that is split down the middle. When the instrument is sighted on the levelling rod, the operator looks into the split bubble viewfinder and fine-adjusts the bubble using the split-bubble adjustment screw (knob) so that the two ends line up (Figure 32). The telescope is now exactly level in that position, and this process must be repeated every time the telescope is moved to a new site.

Figure 32 *Split bubble*

Adjusting an Automatic Level

Once the fish-eye bubble in an automatic level is centred, it is rough-levelled, and there are no other adjustments to make. When you look through an automatic level, the light you see passes through a compensator (a prism that is suspended by a number of wires or nylon strands inside a cage). The suspended prism can compensate for the instrument being up to 12° out of level.

The prism completes the fine-tuning for level, and the instrument can be used immediately. If the instrument is lightly shaken before attaching it to the tripod, the prisms and wires will make a faint jangling sound. It is a good idea to check the fish eye from time to time to ensure that the level has not been knocked or bumped out of position, in which case it must be reset. If the automatic level sustains a sharp impact, it may cause the wires or strands to break and the instrument must then be repaired.

Set-up and Operation of Electronic Laser Levels

Select the location for the instrument so that the largest possible area can be covered.

The location should be on solid ground or floor, and out of the way of traffic. Then follow these steps:

1. Set up the tripod and attach the instrument. Level the instrument with the levelling screws until the bubble is in the centre circle.
2. Connect the power supply to the instrument, and turn the power switch on.
3. Using a level rod, establish the height of the instrument from the benchmark.
4. Calculate the vertical distance between the instrument and the elevation point you wish to find.
5. Attach the sensor or detector to the level rod at this mark.
6. If the elevation to be measured is higher than the instrument, hold the rod upside down. If it is lower than the instrument, hold the rod upright.
7. Raise or lower the level rod until the sensor indicates the correct level. Mark the end of the level rod at each location where elevations are required.
8. An alternative method is to mark the location of the beam directly on the wall, concrete form or column. Then measure up or down the required amount to establish the correct elevations.

Typical Levelling errors

There are many errors that can be made while using an optical level. The following is a list of things that can go wrong, resulting in incorrect measurements:

1. Instrument is out of level. The instrument must be level each time a sighting is taken to avoid incorrect rod readings. There are three reasons the instrument could be out of level:
    a. The instrument was not level to begin with.
    b. The instrument was accidentally moved between sightings.
    c. The instrument was set up on an unstable surface, such as soft ground, frozen ground or a wooden floor, and some settlement or movement occurred.
2. The rod is incorrectly read. Whenever you take a sighting, say the reading aloud, and then repeat the reading.

There is no special way to avoid this sort of error, but taking the reading twice will help.

3. The figures on the rod cannot be seen clearly. This can occur if the instrument is set up too far away from the rod. The instrument should be set up about halfway between a benchmark and the location where the reading is to be taken. Equal length backsights and foresights will cancel errors caused by the crosshairs not being in perfect adjustment.
4. The instrument is improperly focussed. Make sure the crosshairs are in sharp focus, and the telescope is properly focussed on the rod. Each person's eyes focus slightly differently, and these adjustments should be made each time you take an instrument out to use it.
5. The instrument was levelled using the stadia lines. There are also two other marks on the vertical crosshair called stadia lines. These are used for distance measurement and are not used in levelling. Be careful not to line your eye up with either of these when taking a reading.
6. The rod is not held plumb. If the rod is not plumb, the result will be a reading that is a higher number on the rod than the correct reading. The way to avoid this is to give the rod person a signal to slowly pivot the rod forward and backward over the centre point while holding it plumb to the vertical crosshair, and then record the lowest reading.
7. The rod person holds the rod at the wrong location or chooses a spot that is not stable. Good communication with the rod person is the best way to avoid this type of error.

Testing the Accuracy of an Optical Level

You should always test optical levelling equipment for accuracy before measuring or setting elevations. Even with all of the levelling devices adjusted correctly, the instrument may still not be able to accurately transfer elevations. The cause of error at this point is the accuracy of the crosshair position. The "reticle" that holds the crosshairs can be adjusted up or down and left or right to correctly position the crosshairs in the image.

When you are using the instrument for the first time, its accuracy is not known to you. If the instrument has been bumped or jarred, its accuracy is in question.

Figure 33 below shows two telescopes set exactly level. The upper telescope has the crosshairs set correctly. The lower telescope has the crosshairs set too high.

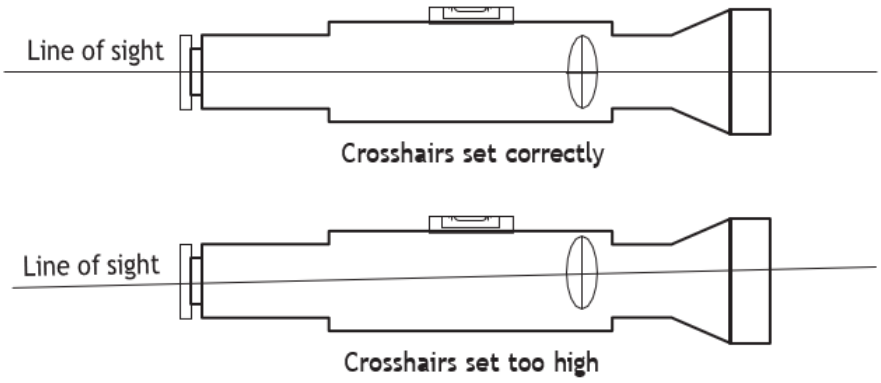


Figure 33 *Correct and incorrect setting of crosshairs (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The only way to check the position of the crosshairs at the job site is to do a peg test on the instrument.

1. Select a location that is reasonably flat alongside a building, or between two buildings, two columns or even two telephone poles. The required distance between locations to use in the test is about 30 m. Figure 34 shows the instrument set-up for checking the level's accuracy.

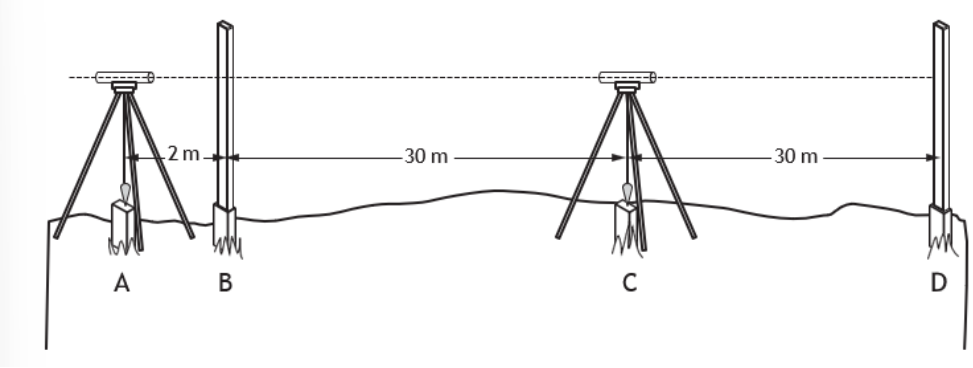


Figure 34 *Checking the accuracy of a level with a peg-test (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

2. Set up at location A and level the instrument.
3. Have the rod person precisely mark a piece of masking tape stuck to object B (the side of a building or column, etc.) exactly at the line of sight. You will guide this by sighting through the telescope and indicating that the rod person raise or lower the pencil, held horizontally, until it is accurately aligned.
4. Have the rod person now move to object D and mark the masking tape located at this point in the same manner as at B.
5. Move the instrument to location C and set up as you did before.
6. Have the rod person accurately mark the new lines of sight on the masking tape at objects B and D.
7. Measure the distance between the marks made on B and D. If they are the same, the instrument is working accurately. If they are not the same, the operation should be repeated. Human nature dictates that errors or inaccuracies are firstly blamed on tools or instruments, so a second check on the readings will eliminate or confirm that as a possibility. If on the second attempt the two differences are not the same, subtract one from the other and divide by 2 to find the error over 30 metres (as the second reading was taken over 60 metres).

Obtaining perfect results is not always practical; a maximum error of 6 mm or $\frac{1}{4}$„ over 30 metres is usually considered to be acceptable on the peg test.

If the inaccuracy is consistent, the instrument can be checked and sent for repair or to be recalibrated. Adjustment of the crosshairs is done by turning the crosshair adjustment screws. These screws are normally located under a cover just behind the eyepiece. Consult the owner's manual before trying to adjust the crosshairs or send the instrument to a survey equipment repair shop for adjustment.

Care and Handling of Levelling Equipment

Survey instruments are constructed to give many years of service in adverse weather conditions, but they can be damaged if they are not handled with proper care. Following these rules will ensure that no damage will occur to your instruments:

- During transportation always store the instrument properly in its case. If there is any chance that it will be subjected to jarring, give it further protection by enclosing it in a Styrofoam container.
- When first selecting an instrument, open the lid and carefully look to see how it is secured in its container. You must return it to its container in the same way each time you use it. When it is not in use, you must always return the instrument to its container for storage.
- When protective lens caps are not in use, leave them in the instrument container. Do the same with the thread protector ring and the cap for the tripod, if the tripod has these.
- Before the instrument is mounted on the tripod, make sure that the tripod is firmly set up and all leg adjusting screws and tripod head screws are properly snugged up.
- The mounting head or top plate should be as level to the horizon as you can get it by adjusting the legs.
- If the legs must be positioned on smooth concrete or any other surface where the points of the tripod legs are not able to dig in, use rubber tips or suction cups, or place the tripod in a triangular frame to prevent slipping (Figure 35).

Figure 35 *Triangular frames for the tripod* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

- While transporting the instrument from the case to the tripod, always grasp the instrument by its base, where it should be held to avoid any damage to any of its parts.
- Thread the instrument onto the tripod securely, but do not over tighten. This avoids stripping the threads or putting undue stress on any part of the instrument. This is no time to become distracted. If the instrument is not properly fastened to the tripod and, as a result, falls to the ground and is damaged, time is lost until it is repaired. A loss in both time and money can be avoided if care is taken each time the instrument is set up.
- Never force the instrument while turning it horizontally or while making any adjustments. Forcing it could result in damage. All adjustable features of any level are designed to be just snugged up but never over tightened or forced.
- When the lenses become dusty or dirty, try to wash with water. When doing this, never rub the lens with anything, as this will probably scratch the lens. The best way to clean lenses is to let them dry completely, then use a camel's hair brush in a circular motion starting at the centre of the lens and working outward. Remember to use the brush

lightly and blow out any particles of dirt as you proceed.

- Levels are built to be used in rain and snow but should not be left out needlessly. When you are finished, bring them inside and lightly dry them off (damp dry them), except for the lenses, which should always be left to dry on their own. Secure them in their container but leave it open so that the machine will completely dry. If you close the container the moisture will remain inside to corrode both the instrument and the case (if it is made of metal). Adding a package of desicant such as silicon will help control any small bits of moisture within the case.
- Avoid sudden extreme changes in temperature. If the instrument is kept in storage at room temperature, then taken directly outside into cold or damp conditions, there is a good chance the inner lenses will become fogged. Nothing can be done with it until the temperatures inside and outside the instrument equalize and the moisture trapped within naturally disperses. This can result in loss of time. To avoid this happening, many contractors keep their instruments in locked storage in the same conditions as those in which they will be used or, if properly protected, in their locked vehicle.
- Extreme heat can expand the air bubble in the level vials, making them very difficult to level. To avoid this, put up an umbrella or some sort of sunshade over the instrument.
- Avoid using the instrument where there is a lot of vibration from soil compactors, piledrivers, etc. This could put the level out of alignment, thus requiring repairs.
- The way in which an instrument is carried when mounted on its tripod is important (Figure 36). Leave the horizontal clamp loose so that the instrument can swing if it should accidentally hit anything. In wide open spaces, always pack it with the tripod legs in front and over one shoulder. This will help to avoid hitting the instrument, and if you should happen to trip, the tripod should contact the ground before the instrument does.
- If the route you must take is full of obstacles, especially doorways, either pack the tripod- mounted instrument in front of you so you can see what it might come into contact with, or dismantle it and put it in its container.

Figure 36 *How to carry a mounted instrument (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

- Never jar the instrument by banging it down when you are about to set it up, or at any other time. At all times, handle the tool as if it were a crate of eggs.
- Never leave the instrument unattended. There are many ways an unattended instrument can be damaged on a busy construction site. Some contractors paint the legs of the tripod in bright colours and attach streamers of

bright surveyor's tape as a precaution against accidents. Also, the instruments could be stolen if left unattended in an occupied area such as a busy downtown street.
- Check all connections for the various parts of the tripod. Looseness at any of the several connecting points could make it unstable and result in incorrect readings. The wood screw connections of wooden tripods that are subjected to wetting and drying tend to loosen.

Use Levelling Equipment to Establish Elevations

Reading the Levelling Rod

In the metric examples in Figure 37, the triangular black "comma" denotes the metres and decimeters area of the rod seen through the telescope. Reading #1 should be interpreted as 1.330 m; #2's reading is 0.850 m; #3 is 2.917 m.; reading #4 is 1.185 m. Rod reading #5 should be close to 2.147 m; #6 is 1.625 m; #7 is 1.540 m and #8 is 1.695 m. With a little practice, you should be able to read a metric rod to the nearest 0.001 m.

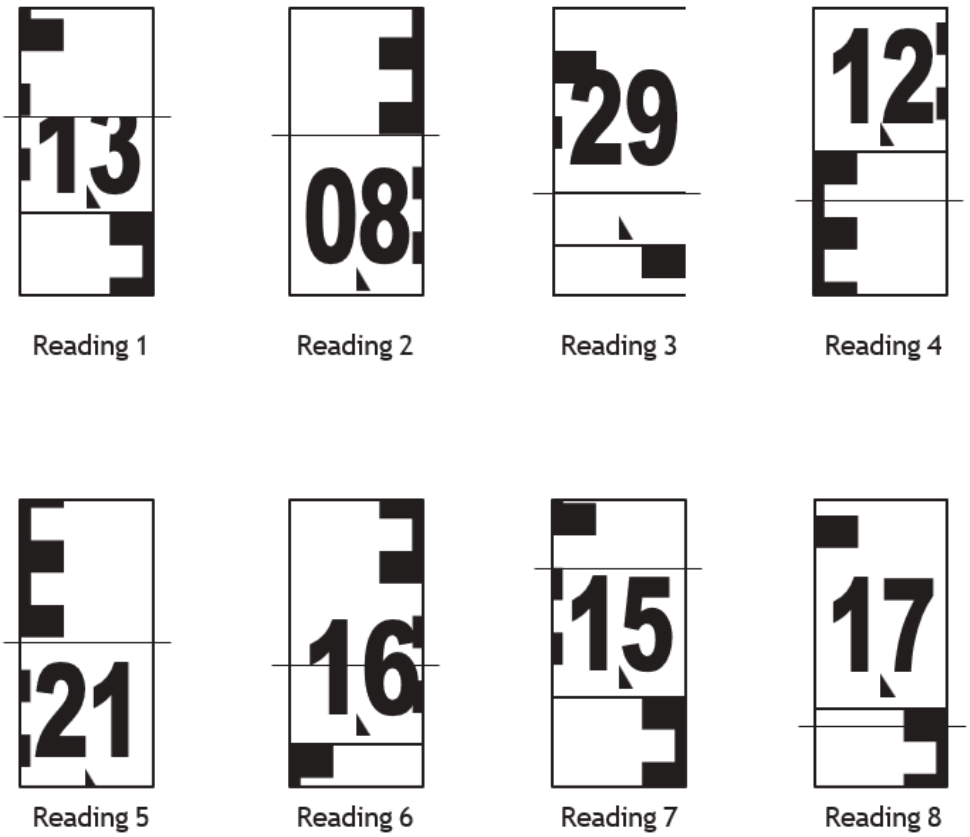


Figure 37 *Readings on a metric rod* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

When reading a rod in imperial measure, first determine whether the rod is in feet and inches or feet and decimals of feet. As mentioned previously, look for the presence or absence of the 11-inch mark.

Figure 38 shows examples of rod readings. The rod is calibrated in feet and hundredths of feet. The footage markings are usually visible in one or two locations between the large numbers representing feet, as shown by the "7" in the lower part of the image.

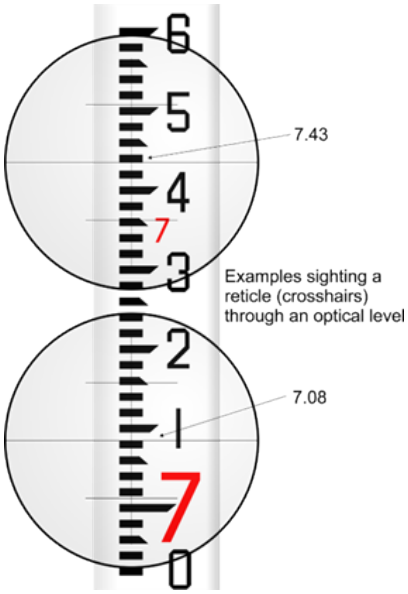


Figure 38 *Examples of engineer's rod readings (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The smaller numbers in black along the right side of the rod indicate decimals of feet, and line up with the pointed end of the black graduations. Each point on this scale represents 0.05′, so there are five graduations between points. This is different from the scales that are in feet and inches. On those scales, the pointed graduations occur every $\frac{1}{2}$″ , so there are only four graduations between points. On the imperial rods, you should be able to read to the nearest 0.005′ or $\frac{1}{16}$″ .

Recording the Readings

The measuring and setting of elevations at a construction site must be done accurately and to the exact specifications shown on the construction drawings. Maintaining a record of how the elevations were set and who set them is also of prime importance. Using a surveyor's field book to record all instances where elevations were measured or set allows a permanent record of the results to be kept.

The surveyor's field book is a small, hard-covered book measuring 4 inches by 7 inches. There are many types of field books; the standard field book used for levelling has six columns on each facing page. Some field books have level notes on the left and a grid or graph paper on the right. The grid paper is used to make plan views of horizontal layouts.

Each page in the levelling field book is divided into six columns and 32 rows. The lines on the pages are printed with waterproof ink. When recording instrument readings into the field book, use a pencil, not a pen. The ink from a pen may not be waterproof.

Readings should never be erased once they have been recorded. After a second look, if a reading needs to be changed, cross out the initial reading and put the new reading above it. Leaving the initial reading in the book shows that there was some concern with that reading.

The headings across the top of the pages should always be set up in the same way. Table 1 shows the standard layout of headings.

Table 1: ***Standard Layout of Headings in a Surveyor's Field Book***

STA	BS	HI	IFS	FS	ELEV

Glossary of Levelling Terms

As with any aspect of construction, there are terms, definitions and abbreviations that need to be understood. You should be familiar with the following terms:

Benchmark (BM)

The ***benchmark*** is listed first in this glossary because it is the starting point for all levelling. Before any elevation can be measured or set, a benchmark must be found to refer the elevations to. This should be a relatively permanent point of known elevation. It can be any object not likely to move, such as a lamp standard, rim of a manhole or catch basin or a fire hydrant. It is usually noted on the site plan in a set of working drawings. Nothing that is easily moved or shifted should be considered for a benchmark, as it must be used for the duration of the levelling exercise. Residential benchmarks are assigned arbitrary values such as 100.000 m. All parts of the structure are either above this mark and have a higher value, or below this mark and have a lower value.

If benchmarks are given a value relative to mean sea level on the Earth's surface, they are referred to as ***datum points***. The reason this is the more common way of giving benchmark values is that most structures must tie into existing utilities such as sewer and storm drains, the locations of which are always described with elevations relative to mean sea level. If you have this type of benchmark, it should be very apparent because the altitude of the locality where the structure is to be erected will be known.

Great care must be taken to protect benchmarks from premature demolition or any damage that would spoil their accuracy. Field book records should precisely identify benchmarks so that they can be found again if required when renovations or additions to the structure are made in future.

Backsight (BS)

The first reading of any survey job will be a ***backsight*** onto a fixed point of reference, usually a benchmark. The backsight column is just to the right of the (station) "STA" column in the field book. Backsight ("BS") readings are taken from a levelling rod held plumb on the benchmark or turning point. It is necessary to know the height of the instrument relative to a known elevation, so that work done can be related to that elevation. Therefore, it is a backsight reading that will establish the height of the instrument ("HI").

Datum

A ***datum*** is a clearly defined survey reference marker, from which ground and building levels are measured. This level is referenced to the distance above ***zero datum***, being mean sea level (the average between high and low tide).

Elevations (ELEV)

Elevations are the values assigned to points where elevations have been established relative to the benchmark. These readings are recorded in the "ELEV" column located at the extreme right of the field book.

Foresight (FS)

Foresight readings are taken on points of unknown elevation and are used to determine the elevation of a turning point or the elevation of the final point in a survey. They are essentially the same as intermediate foresights but are listed under their own column so that the math can be more easily checked for errors. FS readings are recorded in the fifth column from the left in the field book.

When determining the unknown elevation, the level rod would be held in a plumb position and the reading from it would be either added to or subtracted from the HI value to obtain the elevation of the turning point relative to the BM.

Height of Instrument (HI)

The ***height of instrument*** is the exact elevation of the line of sight of the instrument in relation to the benchmark (BM) or turning point (TP). It is not possible to find the elevation of any point until the height of the instrument is first established, so that is the first step in any levelling exercise. The "HI" column in the field book is the third from the left.

If the line of sight of the instrument is above the BM, then the level rod reading is added to the value assigned to the BM, thus establishing the HI.

If the line of sight of the instrument is below the benchmark, then the level rod reading is subtracted from the BM value to get the HI elevation.

Intermediate Sight (IS) or Intermediate Foresight (IFS)

Intermediate sights are readings taken on all other points of unknown elevation before the last location, which is the foresight or turning point. There is really no practical difference between the foresight and the intermediate sight, except where it is recorded in the field book and how it is used.

Station (STA)

The ***station*** is the spot where the rod is being held while a reading is being taken. The station is not where the instrument is set up. In the field book, the station column is the first one on the left side, and it is where sightings (or *shots*) are identified and their locations recorded. When setting up an instrument, the name of the benchmark used is recorded in this column, as are the names given to points where elevations are established or where unknown elevations are to be calculated.

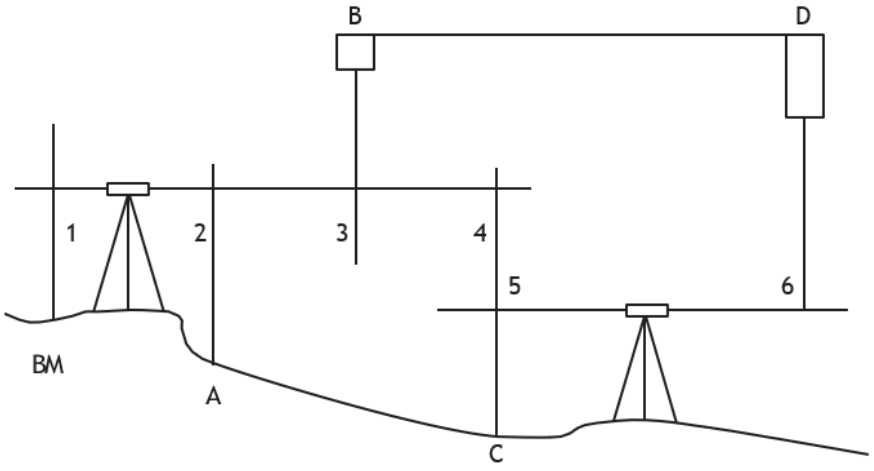
Turning Point (TP)

A ***turning point*** **(TP)** is set when moving the instrument to a new location. It can be either the last station elevation used or one that can be seen from the new instrument location. The point chosen for the TP must have a prominent point for the levelling rod to rest upon. Once the TP is established, the survey rod is held on it, a foresight reading is taken, and the elevation of the TP is calculated.

The instrument is then moved to the new location and levelled, and a backsight reading is taken on the TP. The levelling rod must be held in exactly the same point on a TP for both the foresight and backsight readings to ensure that the transfer of elevation is accurate. The backsight reading is added to the elevation of the TP to obtain the new elevation of the line of sight.

Example:

Using 100.000 m for the benchmark (BM), a backsight was taken on the BM to determine the height of instrument (HI).



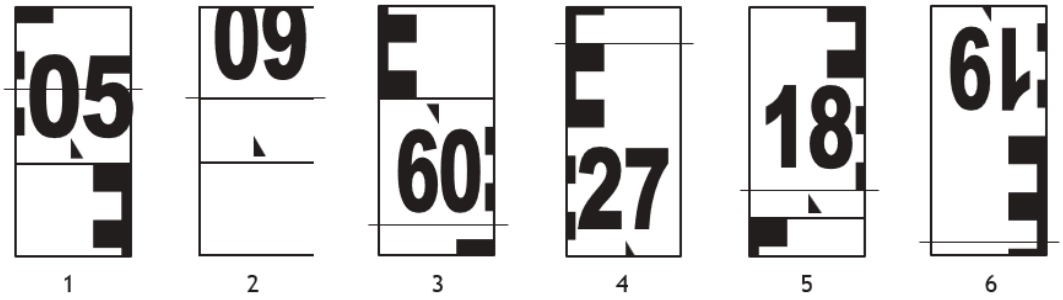


Figure 39 *Locations of level instrument, benchmark and stations and rod readings (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Table 2: *Values Entered in Field Book*

STA	BS	HI	IFS	FS	ELEV
BM	0.527	100.527			100.000 m
A		100.527	0.923		99.604
B		100.527	<0.945>		101.472
C		100.527		2.780	97.747
C	1.810	99.557			97.747
D		99.557		<1.988>	101.545

This height of instrument was used for the next three sightings. As station A is lower than the HI, rod reading #2 is subtracted from the HI to get the elevation for A. As B is above the HI, rod reading #3 is added to the HI.

Station C is a turning point. Once its elevation is determined as 97.747, a backsight from the new location can be taken. By adding the backsight to 97.747, the new height of instrument is found. It is then used with rod reading #6 to find the elevation of station D.

To help protect against errors, inverted readings are enclosed in brackets. The degree of accuracy is also important. Entering 9.42 m instead 9.420 m may lead others to think that measurements where only taken to two decimal places. Showing “m” after the benchmark elevation indicates that measurements are in metres, not feet.

Checking the Math

Total the backsight readings and subtract from that the total of all the foresight readings (not any IS readings). The difference should be the same as the difference between the benchmark elevation and the elevation of the last sight taken. If they differ, the math is out and should be rechecked. If you “close the circuit” (finish back at the benchmark), the two totals should be the same.

Using Instrument Readings

Grading Drains

When grading sanitary and storm drains within a building, the structure itself is normally used as the benchmark or reference for measurements. Using a tape measure, you can measure from the underside of the flooring or joists to the centreline of the piping regardless of whether it is being suspended or installed underground. Grade can be set accurately as long as the flooring or joists are themselves set level, which is usually taken for granted as the norm. However, when piping is to be installed underground outdoors, the only way to do this accurately is by using an optical or laser level and datums. In some cases, such as installing piping from the building to the connection at the property line, you must run your piping at a grade that you must establish in order to meet with the connection at the property line, so there are no changes in elevation due to the use of fittings. In some cases, your piping must be covered and compacted as you install it, so your calculations must be very accurate.

The following examples show the calculations that would need to be performed when grading pipe using elevations that are given in feet and decimals or in metric.

Remember that the relationship between grade, length and total fall, as learned in Level 1 of pipe trades training, is constant and can be expressed three ways:

- Grade × length = total fall
- Total fall ÷ length = grade
- Total fall ÷ grade = length

A tool for remembering these relationships can be a learning triangle (Figure 40).

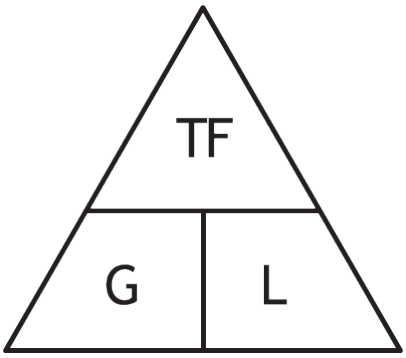


Figure 40 *Learning triangle for grade, length and total fall* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Note: Remember that when grade is in inches per foot, length must be in feet and total fall must be in inches.

Calculating Grade

Example 1: Calculate the grade in inches per foot on the drain in Figure 41.

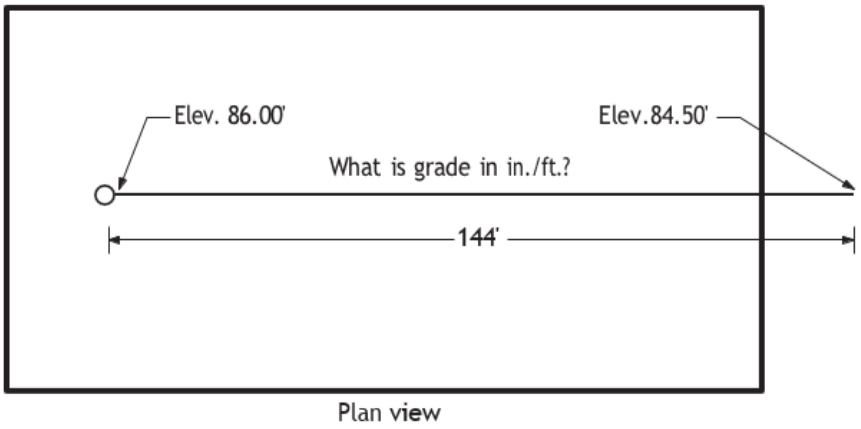


Figure 41 *Image for Example 1* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Formula: Grade = total fall ÷ length

Solution: Grade = (86.00′ − 84.50′) ÷ 144′

Grade = 1.5′ ÷ 144′
Grade = 18″ ÷ 144′
Grade = 0.125″/foot

Grade = $\frac{1}{8}$„ /foot

Calculating Length

Example 2: Calculate the length in feet of the drain shown in Figure 42.

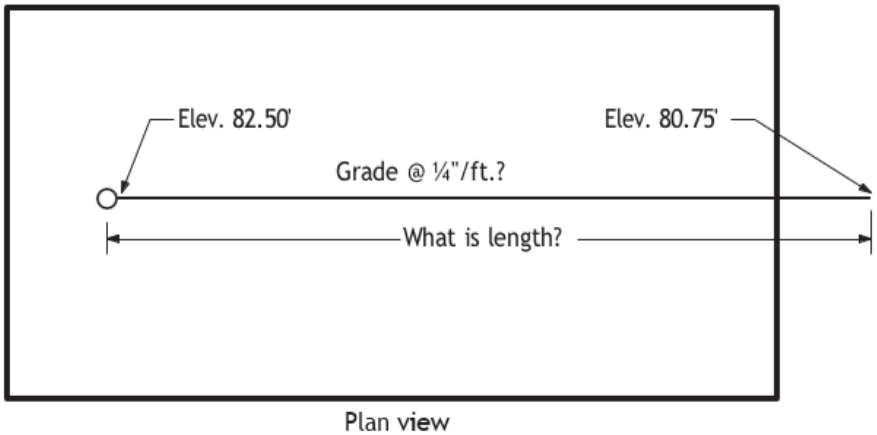


Figure 42 *Illustration for Example 2* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Formula: Length = Total fall ÷ grade

Solution: Length = (82.50′ − 80.75′) ÷ $\frac{1''}{4'}$

Length = 1.75′ ÷ $\frac{1''}{4'}$

Length = 21″ × $\frac{4'}{1''}$

Length = 84′

Note: In the above, express the TF as inches. Also, instead of dividing by a fraction, invert the fraction and use it as a multiplier. That way, the inches in the total fall and in the grade cancel each other out, leaving the only unit of measure in the answer as length in feet.

Calculating Total Fall

Example 3: Calculate the total fall on the drain in Figure 43.

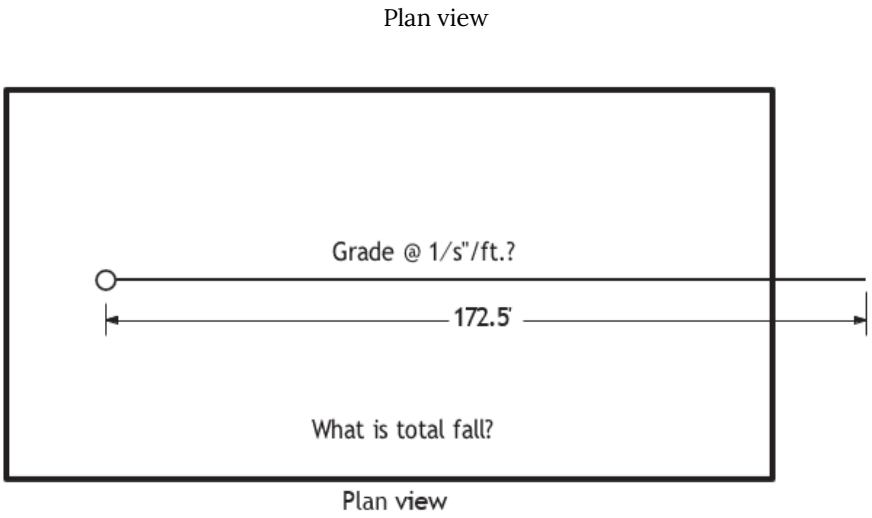


Figure 43 *Illustration for Example 3 (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Formula: Total fall = length × grade

Total fall = 172.5′ × $\frac{1''}{8'}$

Total fall = 21.562″

Total fall = 21 $\frac{9}{16}$″

Note: In the above, the feet unit of measurement in the length and in the grade will cancel each other out, leaving inches as the units in the answer.

Example 4: Calculate the elevations at points A and B in Figure 44.

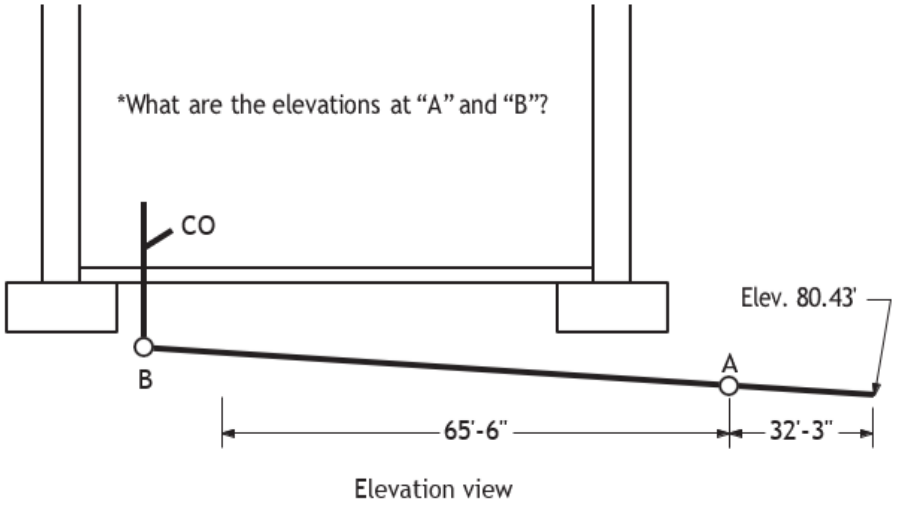


Figure 44 *Illustration for Example 4 (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Formula: Total fall = Length × grade

Solution for elevation at A:

Total fall = 32′-3″ × $\frac{1''}{4'}$

Total fall = 32.25′ × $\frac{1''}{4'}$

Total fall = 8.062″

Note: The foot units in the length and grade cancel out.

Total fall = 8.062 ÷ 12 = 0.67′
Therefore, elevation at A = 80.43′ + 0.67′ = 81.10′

Solution for elevation at B:

Total fall = (65′-6″ + 32′-3″) × $\frac{1''}{4'}$

Total fall = (65.5′ + 32.25′) × $\frac{1''}{4'}$

Total fall = 97.75′ × $\frac{1''}{4'}$

Total fall = 24.437″

Note: The foot units in the length and grade cancel out.

Total fall = 24.437″ ÷ 12 = 2.04′
Therefore, elevation at B = 80.43′ + 2.04′ = 82.47′

Example 5: Calculate the elevations at stacks A and B in Figure 45.

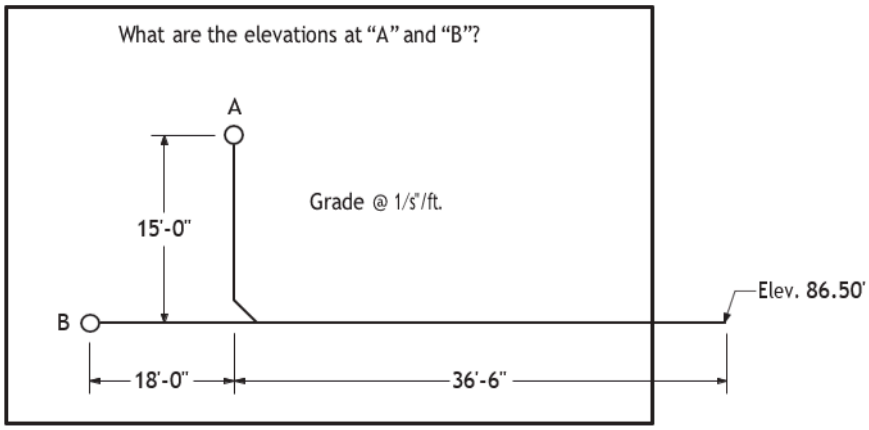


Figure 45 *Illustration for Example 5 (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Plan view

Formula: Total fall = length × grade Solution for elevation at A:

$$\text{Total fall} = (36'\text{-}6'' + 15'\text{-}0'') \times \frac{1''}{8'}$$

$$\text{Total fall} = (36.5' + 15.0') \times \frac{1''}{8'}$$

$$\text{Total fall} = 51.5' \times \frac{1''}{8'}$$

Total fall = 6.4375″

Note: The foot units in the length and grade cancel out.

Total fall = 6.4375 ÷ 12 = 0.54′
Therefore, elevation at A = 86.50′ + 0.54′ = 87.04′

Solution for elevation at B:

$$\text{Total fall} = (36'\text{-}6'' + 18'\text{-}0'') \times \frac{1''}{8'}$$

$$\text{Total fall} = (36.5' + 18.0') \times \frac{1''}{8'}$$

Total fall = 54.5′ × $\frac{1''}{8'}$

Total fall = 6.8125″

Note: The foot units in the length and grade cancel out.

Total fall = 6.8125 ÷ 12 = 0.57′
Therefore, elevation at B = 86.50′ + 0.57′ = 87.07′

Example 6: Calculate the elevation at stacks A and B in Figure 46.

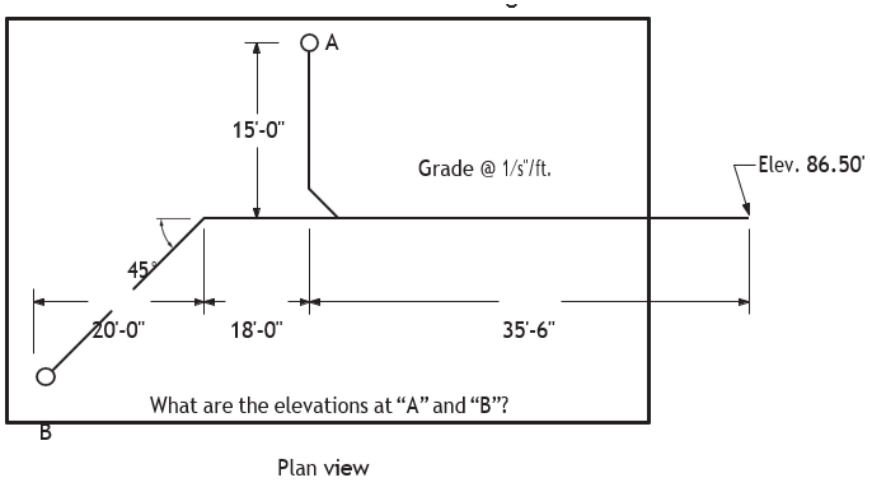


Figure 46 *Illustration for Example 6 (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Note: Because the drain from stack B has a 45˚ turn, it is necessary to use the offset formula for 45˚ to calculate the length of travel for the offset. The formula is:

Travel = offset × 1.414

Also note that the Y & $\frac{1}{8}$ bend on the drain from stack A does not add enough extra length above what a sanitary tee would (which is not allowed on a horizontal drain).

Formula: Total fall = length × grade S

solution for elevation at A.

Total fall = (35′-6″ + 15′-0″) × $\frac{1''}{8'}$

Total fall = (35.5′ + 15.0′) × $\frac{1''}{8'}$

Total fall = 50.5′ × $\frac{1''}{8'}$

Total fall = 6.3125″

Note: The foot units in the length and grade cancel out.

Total fall = 6.3125 ÷ 12 = 0.53′
Therefore, elevation at A = 86.50′ + 0.53′ = 87.03′

Solution for elevation at B: Total fall = (35′-6″ + 18′-0″ + travel) × $\frac{1''}{8'}$

Total fall = (35.5′ + 18.0′ + (20′ × 1.414)) × $\frac{1''}{8'}$

Total fall = (53.5′ + 28.28′) × $\frac{1''}{8'}$ Total fall = 81.78′ × $\frac{1''}{8'}$

Total fall = 10.22″

Note: The foot units in the length and grade cancel out.

Total fall = 10.22″ ÷ 12 = 0.85′
Therefore, elevation at B = 86.50′ + 0.85′ = 87.35′

Example 7: Calculate the following using Figure 47:

- Elevations of points A and B
- Depth of the drain at point B below the given datum of 100.00′ expressed in feet and inches to the nearest $\frac{1}{16}$″

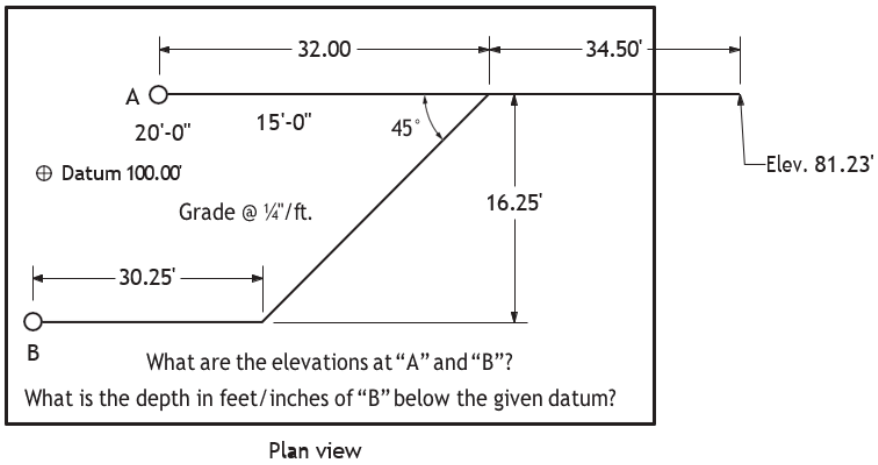


Figure 47 *Illustration for Example 7 (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Formula: Total fall = length × grade

Solution for elevation at A: Total fall = (34.5′ + 32.0′) × $\frac{1''}{4'}$

Total fall = 66.5′ × $\frac{1''}{4'}$

Total fall = 16.625″

Note: The foot units in the length and grade cancel out.

Total fall = 16.625 ÷ 12 =1.39′
Therefore, elevation at A = 81.23′ + 1.39′ = 82.62′

Solution for elevation at B: Total fall = (34.50′ + travel + 30.25′) × $\frac{1''}{4'}$

Total fall = (34.50′ + (16.25′ × 1.414) + 30.25′) × $\frac{1''}{4'}$

Total fall = (34.50′ + 22.98′ + 30.25′) × $\frac{1''}{4'}$

Total fall = 87.73′ × $\frac{1''}{4'}$

Total fall = 21.93″

Note: The foot units in the length and grade cancel out.

Total fall = 21.93″ ÷ 12 = 1.83′
Therefore, elevation at B = 81.23′ + 1.83′ = 83.06′

Solution for depth of pipe at B below given datum of 100.00′: 100.00′ – 83.06′ = 16.94′

0.94′ × 12 = 11.28″

0.28″ × 16 = $\frac{4.48}{16}$ = $\frac{4''}{16'}$ = $\frac{1}{4}$„

Therefore, the depth below B can be expressed as 16′-11 $\frac{1}{4}$„ .

Self-Test B-1.3: Use Levelling Equipment

Complete Self-Test 1.3 and check your answers.

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2734#h5p-22 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2734#h5p-22)

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Self-Test B-1.1: Describe Hand Tools Used in the Pipe Trades

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

1. The numbers 1218 printed on a hacksaw blade indicate:
    a. 18 in. long and 12 teeth per inch
    b. 8 in. long and 121 teeth per inch
    c. 12 in. long and 18 teeth per inch
    d. the date of manufacture—12th month 18th day
2. The teeth of a hacksaw blade always have a small amount of set to allow for:
    a. Ease of starting the cut
    b. Blade clearance through the cut
    c. Protection of the teeth
    d. Ejection of the waste
3. A wrench that has a box end at one end and an open end at the other is known as a(n):
    a. Double-duty wrench
    b. Double-ended wrench
    c. Open-box wrench
    d. Combination wrench
4. The size of an adjustable wrench is designated by its:
    a. Jaw length
    b. Jaw opening
    c. Total weight
    d. Overall length
5. All hand tools should be:
    a. Kept clean
    b. Varnished occasionally
    c. Greased regularly
    d. Soaked in solvent after each use
6. Interlocking slip-joint pliers are also known as:
    a. Vise-Grip pliers
    b. Water pump pliers
    c. Side grip pliers
    d. Oil pump pliers
7. The combination square contains a spirit level in its:
    a. Square head
    b. Bevel head
    c. Protractor head
    d. Fixed head
8. A centre punch has a tip that is ground to an included angle of:
    a. 30°
    b. 45°

c. 60°
d. 90°

9. Which dimension from Figure 1 correctly indicates thread pitch?

a. a
b. b
c. c
d. d

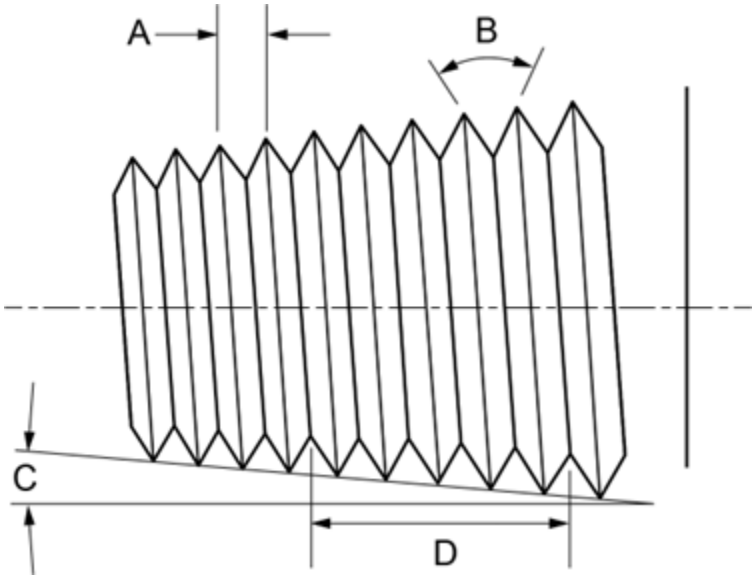


Figure 1 *Image for Question 9.*

10. A torpedo level is used in the piping trades.

a. True
b. False

11. Always file on the forward stroke and raise the file on the backstroke to prevent damage.

a. True
b. False

12. A smoother cut can be obtained from a file that is:

a. Single cut
b. Double cut
c. Round
d. Three square

13. Files that are clogged with waste material can be cleaned with:

a. File comb
b. Hardened steel pick
c. Soap and water
d. File card

14. Name the parts of the screwdriver shown in Figure 2.

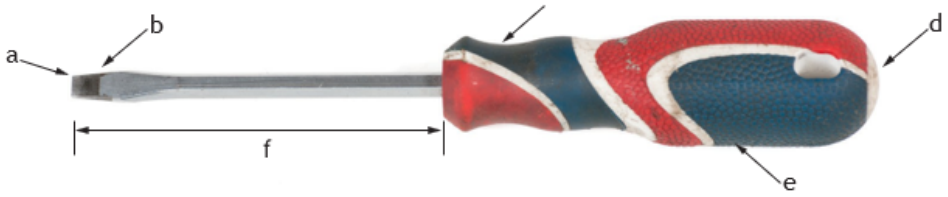


Figure 2 *Image for Question 14.*

a. a
b. b
c. c
d. d
e. e
f. f

15. C-clamps:

a. Exert only a limited amount of pressure
b. Do not require the use of protective padding
c. Are useful for small tight areas
d. Are also known as cabinet clamps

16. To protect your work piece when using a bench vise, you should:

a. Grip it as tightly as possible to prevent movement
b. Use soft vise jaw-caps
c. Grip it very lightly to prevent damage to the piece
d. Grip your work piece by the corners

17. The ball-peen hammer is used to round over bolt threads or rivets.

a. True
b. False

18. A bar that has a hook at one end and is about 750 mm long is called:

a. Wonder bar
b. Wrecking bar
c. Crowbar
d. Lining bar

19. A ball-peen hammer size is classified by the:

a. Length of the handle
b. Length of the head
c. Weight of the head
d. Weight of the entire hammer

20. A cracked hammer handle must be:

a. Replaced
b. Taped up to prevent slivers
c. Used for light hammering only
d. Soaked to close the crack

21. Identify the vises shown below:

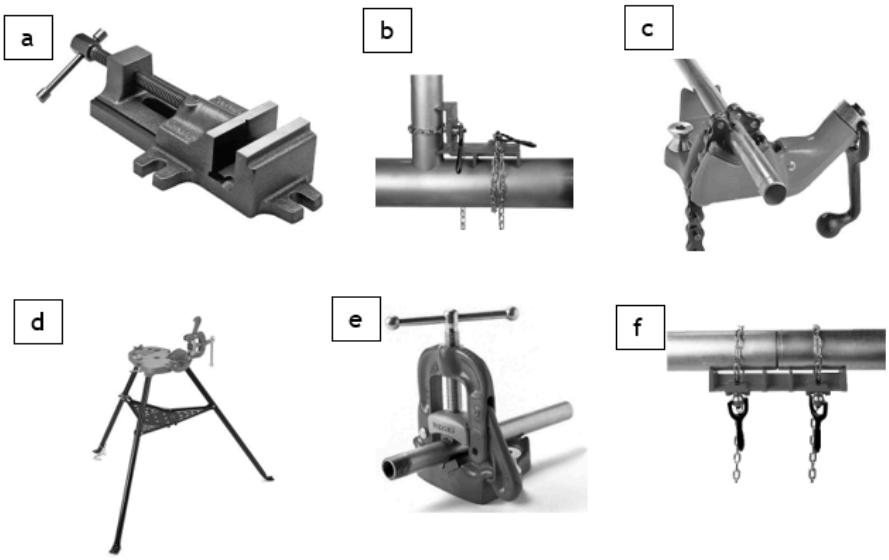


Figure 3 *Image for Question 21.*

a. _____

b. _____

c. _____

d. _____

e. _____

f. _____

22. What kind of vise comes with two pairs of legs and uses a connecting pipe?

_____

_____

23. Name the vise that holds and aligns pipe for tacking and is used on mains and risers.

_____

24. Name a principal advantage of the bench-mounted or portable chain vise.

_____

_____

_____

25. Identify the threaders shown below:

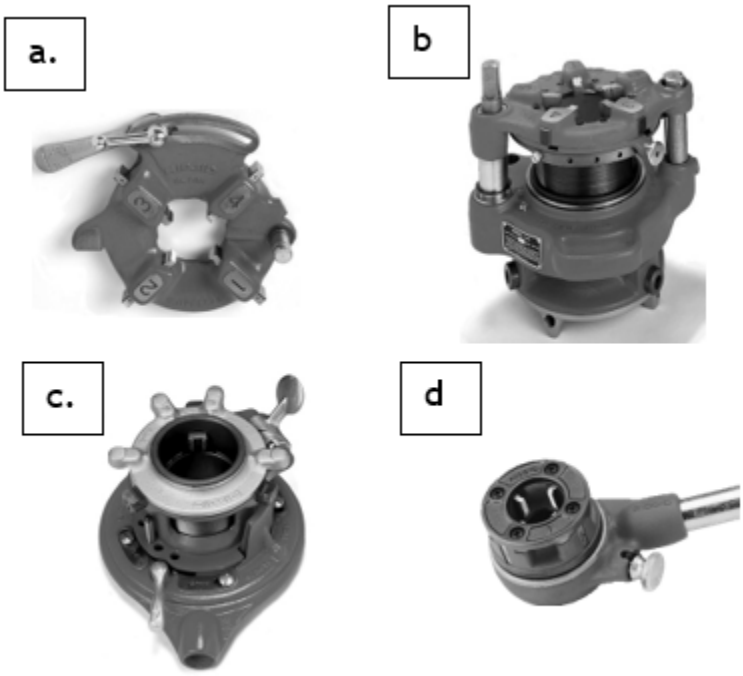


Figure 4 *Image for Question 25.*

a.

b.

c.

d.

26. Identify the cutters shown below

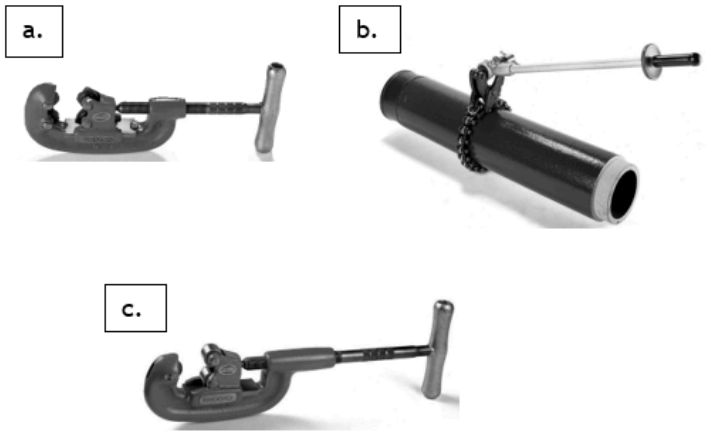


Figure 5 *Image for Question 26.*

a. _____

b. _____

c. _____

27. At what stage of a threading operation is reaming done?

_____

_____

_____

28. What type of reamer would be selected for use with a power vise or threading machine?

_____

29. Name the wrench that multiplies the turning force and is ideal for loosening seized joints.

_____

30. Name the standard wrench that has a jaw opening parallel to the handle and a narrow hook jaw head.

_____

31. Name the wrench especially designed for polished pipe.

_____

32. Describe two features of the basin wrench.

33. Name three uses for thread cutting oil.

34. What are multimeters used to test, in addition to amperage and voltage?
    a. Pressure
    b. Humidity
    c. Resistance
    d. Temperature
35. Analog meters are more popular than digital.
    a. True
    b. False
36. What is the name of the test used when testing a circuit for an open?
    a. Infinity test
    b. Overload test
    c. Continuity test
    d. This test cannot be done
37. Which of the following tools would use a series of prisms and magnifying lenses to accurately measure a liquid's concentration levels?
    a. Hydrometer
    b. Refractometer
    c. Spirit level
    d. Kaleidoscope
38. Which of the following tools is used to measure the relative densities of a liquid?
    a. Hydrometer
    b. Refractometer
    c. Spirit level
    d. Kaleidoscope

Answer Key: Self-Test B-1.1 is on the next page.

Answer Key: Self-Test B-1.1

1. c. 12 in. long and 18 teeth per inch
2. b. Blade clearance through the cut
3. d. Combination wrench
4. d. Overall length
5. a. Kept clean
6. b. Water pump pliers
7. a. Square head
8. d. 90°
9. a. A
10. a. True
11. a. True
12. a. Single cut
13. d. File card
14. a. tip b. blade c. ferrule
    d. head e. handle f. length of the blade
15. c. Are useful for small tight areas
16. b. Use soft vise jaw-caps
17. a. True
18. b. Wrecking bar
19. c. Weight of the head
20. a. Replaced
21. a. Machine vise
    b. Angle pipe welding vise
    c. Top screw bench chain vise
    d. Portable tri-stand yoke vise
    e. Bench yoke vise
    f. Straight pipe welding vise
22. Top screw stand chain vise
23. Straight pipe welding vise
24. Both vises distribute gripping pressure evenly around the pipe wall.
25. a. Quick-opening threader
    b. Jam-proof ratchet threader
    c. Ratchet drop head threader
    d. Geared pipe threader
26. a. Heavy-duty, four-wheel pipe cutter
    b. Soil pipe cutter
    c. Wide roll cutter
27. After cutting or drilling and before threading
28. Straight fluted ratchet reamer
29. Compound leverage wrench
30. Heavy-duty offset pipe wrench
31. Strap wrench
32. The basin wrench has:
    1. Spring-loaded jaws for one-hand ratcheting, and

2. A tension plug that holds the head of the tool at any angle up to 90°.

33. Thread cutting oil is used to:
    1. Lubricate the thread cutter during the threading operation
    2. Cool the tool and the work piece, and
    3. Flush away metal chips.
34. c. Resistance
35. b. False
36. c. Continuity test
37. b. Refractometer
38. a. Hydrometer

Self-Test B-1.2 Use Hand Tools

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

1. How many hacksaw teeth should be in contact with the material being cut?
    a. 1
    b. 2
    c. 3
    d. 4
2. Which is **not** one of the three designs of a file's cutting face?
    a. Single-cut
    b. Double-cut
    c. Broad tooth
    d. Curved tooth
3. What filing method is best used when attempting to finish a smooth surface by removing only small amounts of material at a time?
    a. Kick
    b. Draw
    c. Rasp
    d. Twist
4. What is the most important consideration in maintaining a cold chisel?
    a. Removing a mushroomed end
    b. Removing a mushroomed end
    c. Sharpening the cutting face
    d. Keeping the shaft painted
    e. Storing it in oil
5. When a true track is obtained, how much should the feed screw be tightened as the cutter is rotated around the pipe?
    a. One-sixteenth of a turn
    b. One-eighth of a turn
    c. One-quarter of a turn
    d. One-half of a turn
6. There are two types of wheels on the cutter arms of the internal glass cutter. One is called the cutter wheel, and the other is called_____ the wheel.
    a. Driver
    b. Draw
    c. Leader
    d. Follower
7. Many chalk lines are manufactured in a shape that allows them to be alternately used as a:
    a. Tape measure
    b. Tubing cutter
    c. Plumb bob
    d. Spirit level
8. What should initially be done to the surface of carbon steel pipe when preparing to mark a cut line while using a

wrap-around?

a. Apply oil to the vicinity
b. Paint the area with lacquer
c. Remove varnish with a wire brush
d. Grind of any certification markings

9. What filing method is best used when attempting to finish a smooth surface by removing only small amounts of material at a time?

a. True
b. False

10. What size pipe wrench is recommended when installing 32 mm and 38 mm (1¼ in. and 1½ in.) threaded pipe?

a. 61 cm (24 in.)
b. 46 cm (18 in.)
c. 36 cm (14 in.)
d. 30 cm (12 in.)

11. When bending tubing, the short-cutting of the corners gives "additional length" to the remaining section of straight tube. What is the length acquired commonly referred to as?

a. Loss
b. Gain
c. Cheat
d. Growth

12. How far should a crimp ring be installed from the end of the tubing?

a. 1 mm (1/32 in.)
b. 1.5 mm (1/16 in.)
c. 3 mm (1/8 in.)
d. 6 mm (¼ in.)

13. Cold weather PEX expansions should take place above what temperature?

a. 0°C
b. 4°C
c. –15°C
d. –40°C

14. Stop threading when the outer ends of the pipe dies are 2.5 cm (1 in.) past the end of the pipe.

a. True
b. False

15. The position of the _____ will determine the correct thread length when using the jam-proof ratchet threader.

a. Change plate
b. Work holder
c. Clamp screw
d. Gauge ring

16. When setting standard size thread using a geared threader, one of two reference lines may be used. One is the upper surface of the die head, and the other is called the _____ line.

a. Typical
b. Regular
c. Average
d. Standard

17. What should be done to carbon steel pipe before grooving the end wall?

a. File out any burrs.
b. Thread each end.
c. Install couplings.
d. Tighten feedscrew.

18. What is the name of the tool used to measure the diameter of a pipe groove (groove depth)?

a. Pipe tape
b. Roll tester
c. Diamometer
d. Groove gauge

19. To maintain a hand roll groover,

a. Clean the driveshaft knurls and lubricate grease fittings daily
b. Clean the driveshaft knurls and lubricate grease fittings monthly
c. Clean the driveshaft knurls monthly and lubricate grease fittings daily
d. Clean the driveshaft knurls daily and lubricate grease fittings monthly

Answer Key: Self-Test B-1.2 is on the next page.

Answer Key: Self-Test B-1.2

1. b. 2
2. c. Broad tooth
3. b. Draw
4. a. Removing a mushroomed end
5. c. One-quarter of a turn
6. d. Follower
7. c. Plumb bob
8. c. Remove varnish with a wire brush
9. a. True
10. b. 18 in.
11. b. Gain
12. c. 1/8 in.
13. c. –15°C
14. b. False
15. a. Change plate
16. d. Standard
17. a. File out any burrs
18. a. Pie tape
19. d. Clean the driveshaft knurls daily and lubricate grease fittings monthly.

Self-Test B-1.3 Use Levelling Equipment

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

1. What type of operations are laser and optical levels capable of performing?
    a. Vertical levelling only
    b. Horizontal levelling only
    c. Horizontal and vertical levelling
    d. Horizontal, vertical and angle levelling
2. Which instrument, when set to the fish-eye bubble, needs no further adjustment?
    a. Transit level
    b. “Dumpy” level
    c. Automatic level
    d. Engineer’s level
3. Which one of the following is the only level that is considered accurate throughout the full 360˚ circle without needing further adjustment?
    a. Transit level
    b. “Dumpy” level
    c. Engineer’s level
    d. Automatic level
4. What are the two categories of levels?
    a. Optical and laser
    b. Laser and electronic
    c. Fish-eye and bubble
    d. Bubble and streaming
5. What is the major advantage laser and electronic levels have over optical levels?
    a. Optical levels are easier to set up.
    b. Laser levels are less costly than optical levels.
    c. Optical levels can only use metric levelling rods.
    d. Laser levels need only one person to operate them.
6. Which one of the following has a prism or “compensator” in it?
    a. Tilting level
    b. “Dumpy” level
    c. Automatic level
    d. Engineer’s level
7. How many thumbscrews or “pins” do the least expensive levels typically contain?
    a. Two
    b. Three
    c. Four
    d. None
8. What does a tilting level have that the other optical levels do not?
    a. Second eyepiece
    b. Fourth thumbscrew
    c. Eyepiece focus knob

d. Extra fish-eye bubble

9. What type of beam does an electronic level use?
    a. Sonar beam
    b. Light beam
    c. Ultra-red beam
    d. Infrared laser beam
10. What following piece of equipment is shared by the optical instruments?
    a. Crosshairs and stadia lines
    b. Fish-eye bubble
    c. Rotating beam
    d. Sensor

11. Label the numbered parts in Figure 1.

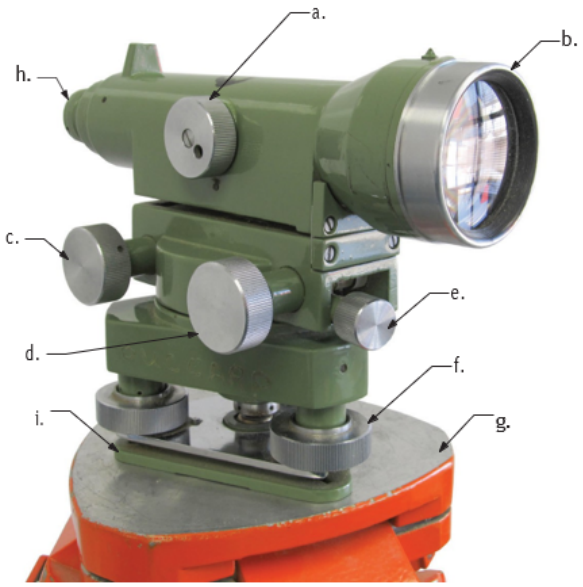


Figure 1 *Image for Question 11.*

a. _____

b. _____

c. _____

d. _____

e. _____

g. _____

h.

h.

i.

12. Where is the knurled knob found that is used to focus the crosshairs on all optical levels?
    a. At the eyepiece
    b. At the levelling head
    c. To the right of the telescope
    d. Just below the objective lens
13. How is focussing the telescope (field of view) accomplished on all optical levels?
    a. Tilting the barrel
    b. Realigning the levelling screws
    c. Turning the horizontal tangent screwturning the focus screw located on the barrel
14. Complete the following statement: "The slow motion screw will only operate when…"
    a. Horizontal clamp is tightened
    b. Horizontal clamp is loosened
    c. Tilt screw is tightened
    d. Tilt screw is loosened
15. How are most instruments secured to the tripod?
    a. Four bolts
    b. Adhesive tape
    c. Tongue-and-groove connection
    d. 5/8″ NC female thread connection
16. What piece of equipment would a tilting level have that is not found on a "dumpy" or an automatic level?
    a. Fish-eye bubble
    b. Split bubble
    c. Spirit vial
    d. Tripod
17. What is another term for the horizontal slow motion screw?
    a. Arbitrary screw
    b. Azimuth screw
    c. Cosine screw
    d. Philips screw
18. What is the purpose of the stadia lines?
    a. Measure mass
    b. Measure height
    c. Measure speed
    d. Measure distance
19. What is another term for a levelling rod?
    a. Tuscon rod
    b. Tallahassee rod

c. Philadelphia rod
d. Tuktoyaktuk rod

20. What are the two types of measuring scales used for levelling rods?

a. Feet and inches
b. Metric and imperial
c. Metres and millimetres
d. Architect's and engineer's

21. What scale would an imperial geodetic elevation be directly read in?

a. Metric
b. Engineer's
c. Architect's
d. Orthographic

22. What would be the distance between the instrument and rod if the upper stadia line reading is 4.357′ and the lower reading is 3.861′?

a. 49.60 inches
b. 4.96 feet
c. 49.60 feet
d. 496 feet

23. What is the smallest scale division on a metric rod?

a. 1 mm
b. 10 mm
c. 100 mm
d. 1000 mm

24. What is the smallest scale division on an architect's rod?

a. 1/8″
b. ¼”
c. 3/8″
d. ½”

25. What is the smallest scale division on an engineer's rod?

a. 1/8″
b. 0.001 ft
c. 0.01 ft
d. 0.1 ft

26. What distinguishing feature is present on the architect's and engineer's scales that helps to interpret rod readings?

a. Pointed graduations
b. Larger numbers
c. Yellow lines
d. Bold letters

27. What would this hand signal indicate?

Figure 2 *Image for Question 27.*

a. Come closer
b. Finished or OK
c. Rod, target or pencil up
d. Mark it there, readings complete

28. Moving the levelling rod forward and backward slowly through a small arc is done for what purpose?

a. Help the instrument person focus
b. Ensure the highest rod reading
c. Ensure that the rod is plumb
d. Keep rain off the rod scales

29. What special parts or device should be used when setting up on a floor with a smooth surface?

a. Triangle made of wood
b. Plumb bob
c. Tripod on rollers
d. Laser level

30. The direction of travel of the bubble will be the same as the movement of what?

a. Left finger
b. Right finger
c. Left thumb
d. Right thumb

31. When taking a sighting, which one of the following levels needs to be set only to the fish-eye bubble?

a. "Dumpy" level
b. Engineer's level
c. Automatic level
d. Builder's level

32. With the legs closed and extended, to what height should the tripod's top plate be adjusted before setting the tripod and mounting the instrument?

a. Top of your knees
b. Centre of your belly button
c. Bottom of your chin
d. Top of your head

33. When setting up a tripod on sloping ground, how should the legs be positioned?

a. One leg uphill
b. Two legs uphill
c. One leg fully extended

d. All legs fully extended

34. How should all the levelling screws be adjusted?

    a. As tight as possible
    b. As loose as possible
    c. Snugged up but not over tight
    d. Tightened snugly but with one screw backed off

35. Complete the following statement: “Once levelled with the fish-eye bubble, an engineer’s level…”

    a. Can be read as is
    b. Will not be very accurate
    c. Needs no further adjustment
    d. Must be fine adjusted to level

36. What does a four-pin instrument use for setting it up level and ready to use?

    a. Tubular level vial
    b. Fish-eye bubble
    c. Laser beam
    d. DC motors

37. When checking the accuracy of an instrument, how far apart should the two “checkpoints” or stakes be?

    a. 10 × 2 = 20 metres
    b. 15 × 2 = 30 metres
    c. 25 × 2 = 50 metres
    d. 30 × 2 = 60 metres

38. What should be the maximum error tolerance of the instrument over the distance in the preceding question?

    a. 3 mm or 1/8″
    b. 6 mm or ¼”
    c. 9 mm or 3/8″
    d. 12 mm or ½”

39. How should an instrument be transported from one job site to another?

    a. Properly stored in its case
    b. Moved with just its protective lens caps
    c. Left for the site superintendent to look after
    d. Left on the floor of a vehicle without its case

40. How should an instrument be placed into its case?

    a. In any way that it fits
    b. With or without its lens cap
    c. Any way, as long as the case is left open
    d. Must be placed back just as it came out

41. How should an optical level be picked up?

    a. Its base
    b. Its eyepiece
    c. Its telescope
    d. Its focus knob

42. How should the lens be cleaned if it has been splattered with mud?

    a. Should be wiped with a wet cloth immediately.
    b. Should be wiped with a dry cloth immediately.
    c. Cleaning should not be done until the lens is dry.

d. Wet it with water and dab the mud off with a camel hair brush.

43. What should be done after using an instrument in the rain?

    a. Put it back in its case as is.
    b. Wipe the whole instrument until it is completely dry.
    c. Damp-dry everything except the lenses and close it up in its case.
    d. Damp-dry everything except the lenses and leave it to dry in an open case.

44. Complete the following statement: "Sudden extreme changes in temperature…"

    a. Have no effect on optical levels
    b. Could cause the interior lens to fog up
    c. Could result in fogging up the horizontal swing mechanism
    d. Will only result in making the instrument too hot or cold to touch

45. How should the instrument/tripod be carried around a wide-open job site with no obstacles?

    a. In any manner that is convenient
    b. With the tripod and instrument held vertically
    c. Over your shoulder with the instrument pointing forward
    d. Over your shoulder with the tripod feet pointing forward

46. Which of the following is the best way to carry the instrument/tripod around a job site with obstacles such as doorways?

    a. In any manner that is convenient
    b. With the tripod and instrument held vertically
    c. Over your shoulder with the instrument pointing forward
    d. Over your shoulder with the tripod feet pointing forward

47. Vibration has a bad effect on optical levels.

    a. True
    b. False

48. Allowing the instrument to become hot could make it difficult to level.

    a. True
    b. False

49. What is a standard residential benchmark?

    a. 0.00′
    b. 50.00′
    c. 100.00′
    d. 1,000.00′

50. What does a backsight determine?

    a. Benchmark elevation
    b. Instrument height
    c. Foresight elevation
    d. Datum

51. Which of the following items should be used as a benchmark at a job site?

    a. Rim of a manhole
    b. Any part of a sidewalk
    c. Concrete block set in the ground
    d. Wooden peg at the corner of the property

52. What is the purpose of "Scotchlite" facing on a levelling rod?

    a. Cut down on glare

b. Make the rod waterproof
c. Bring the numbers into sharper focus
d. Increase visibility of the rod in poor light

53. What is the rod reading shown in Figure 3?

a. 0.272 m
b. 2.800 m
c. 2.892 m
d. 2.792 m

Figure 3
Image for question 53.

54. What is the rod reading shown in Figure 4?

a. 0.978 m
b. 0.988 m
c. 9.088 m
d. 9.078 m

Figure 4
Image for question 54.

55. What is the rod reading shown in Figure 5?

a. 0.241 m
b. 2.401 m
c. 2.410 m
d. 2.450 m

Figure 5
Image for question 55.

56. What is the height of instrument?

a. 99.203 m
b. 101.321 m
c. 102.118 m
d. 103.439 m

57. What is the elevation of station C?

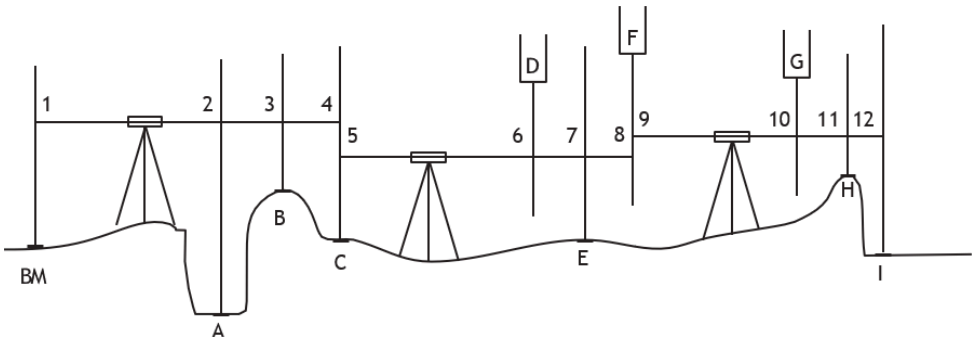
Table for question 57

STA	BS	HI	IFS	FS	ELEV
BM	1.321				100.000
A			2.417		98.904
B			1.998		99.323
C				2.118	

a. 99.203 m
b. 101.321 m
c. 102.118 m
d. 103.439 m

58. Figure 6 shows a schematic diagram and some sample rod readings. Use the information contained in them to fill in the field book page in the following table (include a math check). Note that the numbers on the schematic diagram represent corresponding numbered rod sections, and that BM elevation = 100.000 m.

    a. 99.203 m
    b. 101.321 m
    c. 102.118 m
    d. 103.439 m



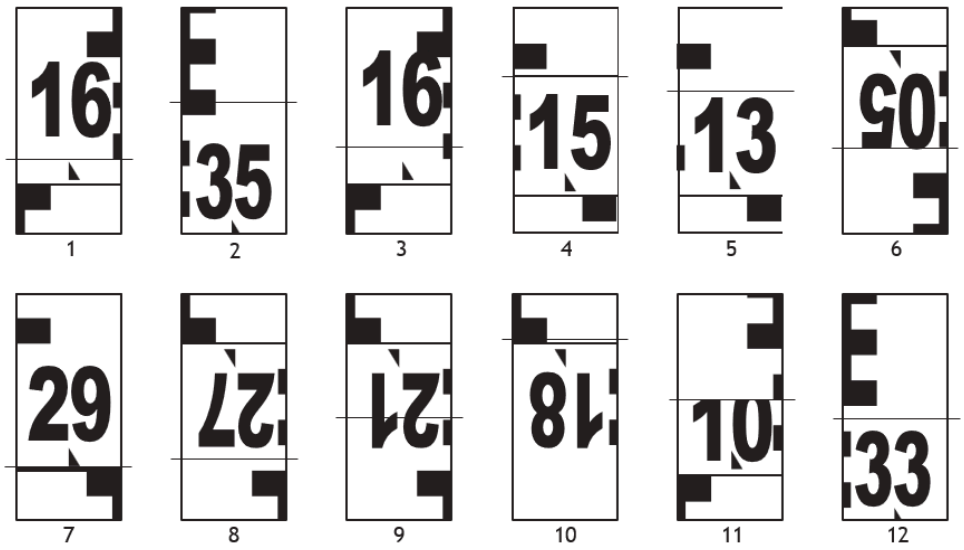


Figure 6 *Sample rod readings.*

Table for question 58

STA	BS	HI	IFS	FS	ELEV
BM					100.000 m

59. Calculate the elevations of A and B in Figure 7. Grade on drain = ¼”/ft.
    a. Elevation of A =
    b. Elevation of B =

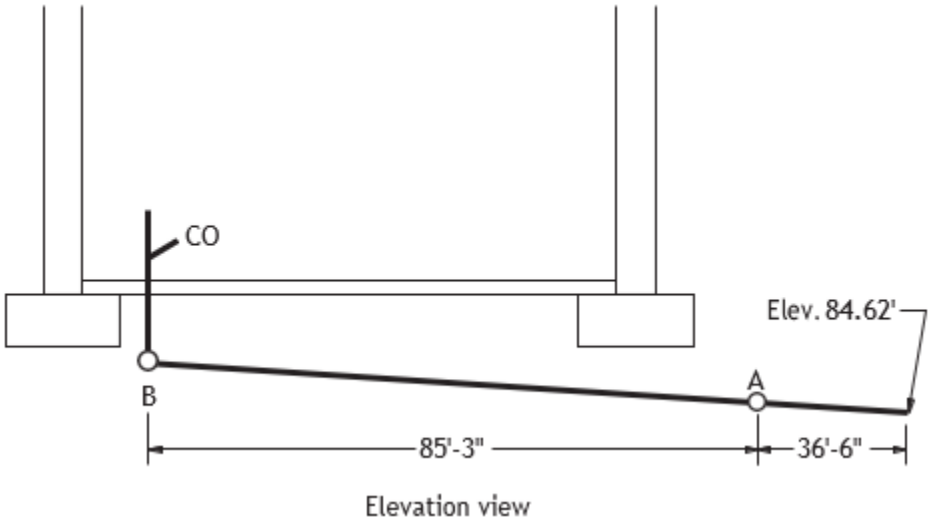


Figure 7 *Image for question 59.*

60. Calculate the elevations of A and B in Figure 8. Grade on drain = 1/8″/ft.
    a. Elevation of A =
    b. Elevation of B =

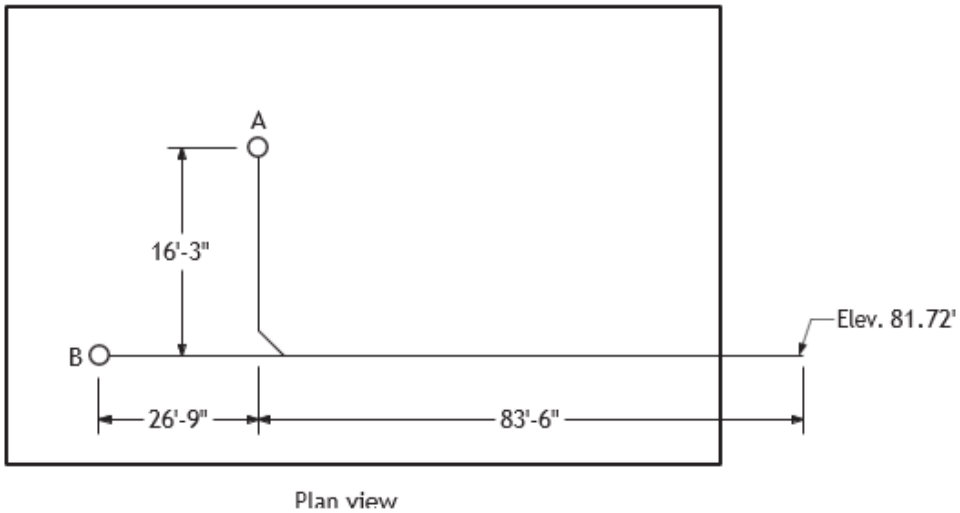


Figure 8 *Image for question 60.*

61. Calculate the elevations of A and B in Figure 9. Grade on drain = 1/8″/ft.

    a. Elevation of A =
    b. Elevation of B =

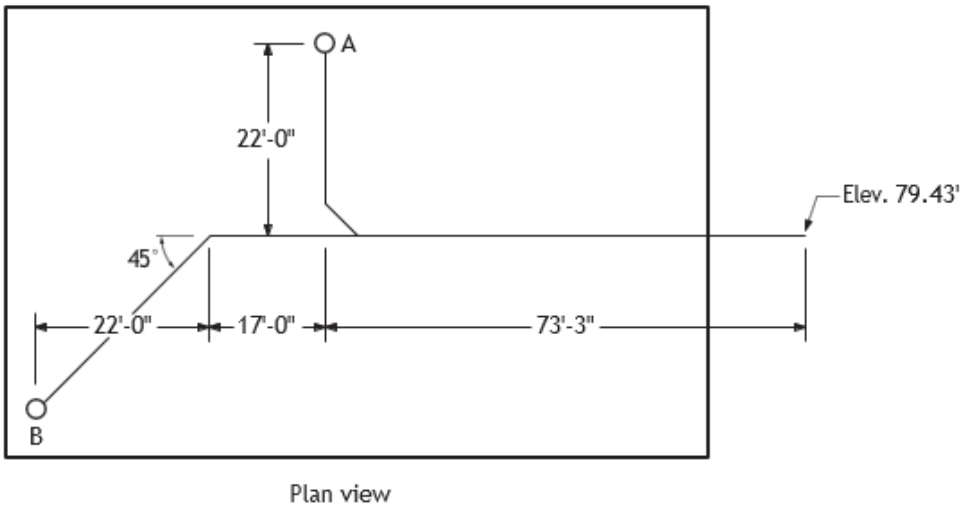


Figure 9 *Image for question 61*

62. Calculate the elevations at A and B in Figure 10. Grade on drain = ¼”/ft.

    a. Elevation of A =
    b. Elevation of B =

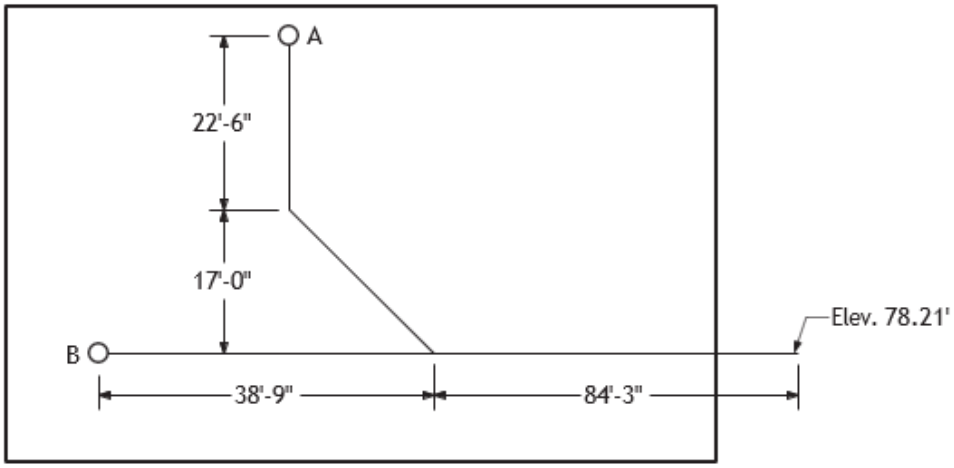


Figure 10 *Image for question 62.*

63. Calculate the following based on Figure 11. Grade on drain = ¼”/ft.
    a. Elevation of A =
    b. Elevation of B =
    c. Depth of drain at B below datum is _____ft _____in.

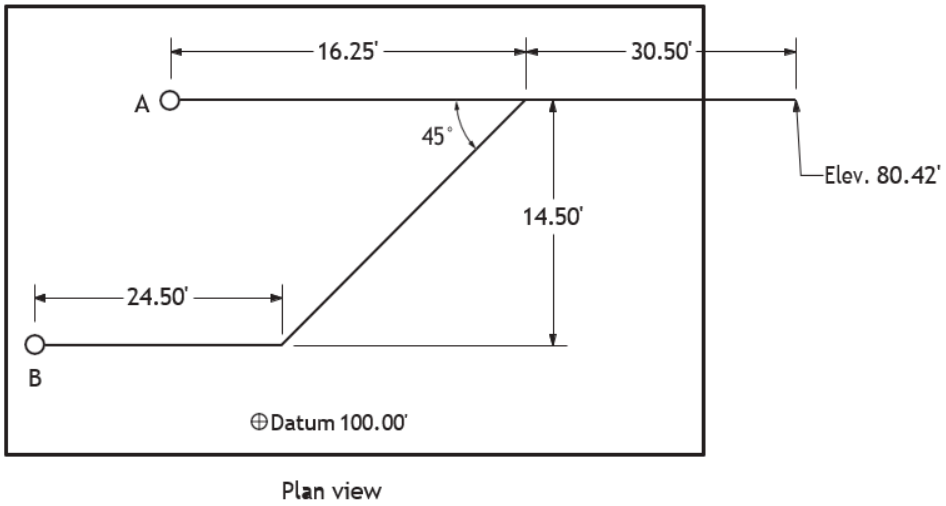


Figure 11 *Image for question 63.*

64. Convert the following readings to feet, inches, and sixteenths.
    a. 105.25′
    b. 116.62′
    c. 145.81′
    d. 174.39′
    e. 186.96′
65. Convert the following readings to feet and decimal feet, to the nearest 1/100.
    a. 8 1/8″
    b. 10 7/8″

c. 1′-3 ½”
d. 1′-7 ¼”
e. 1′-8 ¾”

66. Calculate the grade, expressed as a percentage, if the run of a sewer is 177 feet and the total fall is 3.54 feet.
67. Calculate the total fall, to the nearest 1/100 of a foot, if the run is 64 feet and the grade is 1.5%.
68. Calculate the length of a sewer if the grade is 1% and the total fall is 0.7 feet.
69. Calculate the grade, as a percentage to two decimal places, if the total fall is 18 inches and the run is 115 feet.
70. Change ¼ inch per foot to a percent grade to two decimal places.
71. What is the rod reading called that is taken on a point whose elevation is known?
72. What is the rod reading called that is taken on a point whose elevation is yet to be established?
73. Define the term geodetic datum.

Answer Key: Self-Test B-1.3 is on the next page.

Answer Key: Self-Test B-1.3

1. b. Horizontal levelling only
2. c. An automatic level
3. d. The automatic level
4. a. Optical and laser
5. d. Laser levels need only one person to operate them
6. c. An automatic level
7. c. Four
8. a. A second eyepiece
9. d. An infrared beam
10. a. Crosshairs and stadia lines
11. Focus knob (screw)
    a. Sunshade
    b. Tilting or split-bubble knob (screw)
    c. Horizontal (azimuth) slow motion knob (screw)
    d. Horizontal (azimuth) lock
    e. Levelling thumbscrew (pin)
    f. Tripod headplate
    g. Eyepiece
    h. Footplate
12. a. At the eyepiece
13. d. By turning the focus screw located on the barrel
14. a. The horizontal clamp is tightened
15. d. By a 5/8″ NC female thread connection
16. b. A split bubble
17. b. Azimuth screw
18. d. To measure distance
19. c. A Philadelphia rod
20. b. Metric and imperial
21. b. Engineer's scales are in feet and decimal feet, just like imperial elevations
22. c. 49.60 ft 4.357′ − 3.861′ = 0.496′; 0.496 × 100 = 49.60′
23. b. 10 mm or 1 cm
24. a. Each black mark is 1/8″ in width, as well as the white space between marks
25. c. 0.01 ft
26. a. Pointed graduations (marks)
27. c. Rod, target or pencil up
28. c. To ensure that the rod is plumb. The lowest reading is the one that is desired.
29. a. If soft rubber feet or suction cups aren't available, use a triangle fashioned out of 1×4's
30. c. The direction of the left thumb determines the direction that the bubble will move
31. c. The prism in the automatic level does the fine-tuning
32. c. If the unfolded tripod is set at chin level, the eyepiece will be at a comfortable height
33. a. With one leg uphill, the other two downhill for a more stable base
34. c. Snugged up but not over tightened
35. d. An engineer's (tilting, split bubble) level needs to be fine-levelled for each sight

36. a. A tubular level vial
37. 30 × 2 = 60 metres apart in total
38. b. 6 mm or ¼" over 30 metres or 100 feet
39. a. Taken off the tripod and stored in its case
40. d. Make sure it fits properly and doesn't jam parts when trying to close the lid of the case
41. a. By its base. This is the strongest part of the instrument
42. d. This is the best choice given. Never rub a lens with anything other than a camel hair brush
43. d. Once dry, use a camel hair brush on the dry lens in a circular motion
44. b. Could cause the interior lens to fog up
45. d. This way, if you trip and fall forward, only the tripod feet hit the ground
46. c. This way, the instrument is never out of sight and less likely to be damaged
47. a. True
48. a. True, the tubular level vial expands and the bubble is harder to centre
49. c. 100.00 feet is used, as residential plans are normally in imperial scale
50. b. Backsights determine the height of the instrument
51. a. The rim of a manhole is a stable and long-lasting item, suitable for use as a benchmark
52. d. Scotchlite or reflective facing is easier to see in low light conditions
53. d. 2.792 m
54. a. 0.978 m
55. c. 2.410 m
56. b. Benchmark of 100.000 m + BS reading of 1.321m = 101.321 m
57. a. HI 101.321 – FS reading of 2.118 m = 99.203
58.

Table 1 Solved table for Question 58

STA	BS	HI	IFS	FS	ELEV
BM	1.610	101.610			100.000 m
A		101.610	3.555		98.055
B		101.610	1.615		99.995
C		101.610		1.547	100.063
C	1.341	101.404			100.063
D		101.404	<0.540>		101.944
E		101.404	2.902		98.502
F		101.404			104.149
F	<2.129>	102.020		<2.745>	104.149
G		102.020	1.798>		103.818
H		102.020	1.030		100.990
I		102.020	3.345		98.675
J		102.020	<0.299>		102.319

59. Elevation at A = 85.38′
    Elevation at B = 87.16′
60. Elevation at A = 82.76′
    Elevation at B = 82.87′

61. Elevation at A = 80.42′
    Elevation at B = 80.69′
62. Elevation at A = 80.93′
    Elevation at B = 80.77′
63. Elevation at A = 81.39′
    Elevation at B = 81.99′
    Depth of drain at B below datum is 18′ – 0 1/8″
64.

    a. 105′ 3″
    b. 116′ 77/16″
    c. 145′ 9¾”
    d. 174′ 411/16″
    e. 186′ 11½”

65.
    a. 0.68′
    b. 0.92′
    c. 1.29′
    d. 1.60′
    e. 1.73′
66. 2%
67. 0.96′
68. 70 feet
69. 1.30%
70. 2.08%
71. A backsight
72. A foresight or intermediate sight
73. A geodetic datum is an elevation above mean average sea level.

PART II

B-2 USE PORTABLE POWER TOOLS

Plumber Apprenticeship Program – Level 1

A Person in Plaid Shirt Using a Power Tool (https://www.pexels.com/photo/a-person-in-plaid-shirt-using-a-power-tool-8961527/) (Mikael Blomkvist/Pexels) Pexels License (https://www.pexels.com/license/)

B-2 Use Portable Power Tools

Power tools are an important part of the pipe trade. They allow plumbers to cut, drill, thread, shape, and assemble materials safely and efficiently. However, improper use of power tools can lead to serious injuries and damage to equipment or materials. Safe work practices, proper tool selection, regular inspection, and the use of appropriate personal protective equipment (PPE) are essential. In this section, you will learn to describe portable and stationary power tools used in the pipe trade and demonstrate how to use them safely and correctly. Developing these skills will help you work confidently, efficiently, and responsibly on the job.

Learning Objectives

After completing this section, you should be able to:

- Describe portable power tools used in the pipe trades.
- Use portable power tools.
- Describe stationary power tools used in the pipe trades.
- Use stationary power tools

You will be required to reference publications and videos available online at WorkSafeBC. (https://www.worksafebc.com/en)

Supplementary Video Series: Trades Access Common Core — Tools and Equipment

To support your learning in this section, you may find the following video series helpful. These short instructional videos were developed by Camosun College and shared through BCcampus as part of the Trades Access Common Core learning resources. Playlist Details – Trades Access Common Core Line C: Tools and Equipment Videos – BCcampus (https://media.bccampus.ca/playlist/details/0_3g8xp22x/categoryId/175673)

Terminology

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

- **abrasive cut-off wheel:** A circular cutting wheel made of abrasive material that grinds through metal or other hard materials instead of cutting with teeth. It is commonly used on power saws or grinders to cut metal. (Section B-2.1)
- **angle drill:** A power drill designed with the chuck set at a right angle to the motor so holes can be drilled in tight or hard-to-reach spaces. (Section B-2.1)
- **angle grinders:** Portable power tools that use a rotating grinding wheel or disk to grind, cut, smooth, or polish metal and other materials. (Section B-2.1)
- **auger bit:** A drill bit with a spiral shape and a pointed tip used for drilling deep, clean holes in wood. (Section B-2.1)
- **carbide-tipped drill bits:** Drill bits with tips made of carbide, a very hard material that helps the bit stay sharp and drill through tough materials like masonry or hardened metal. (Section B-2.1)
- **countersink bit:** A drill bit used to widen the top of a hole so the head of a screw can sit flush with or below the surface of the material. (Section B-2.1)
- **snake (drain auger):** A flexible tool used to clear blockages in pipes and drains. It is pushed into the pipe and rotated to break up or pull out the material causing the clog. (Section B-2.1)
- **grinding wheel (or disk):** A round wheel made of abrasive material used to grind, shape, smooth, or sharpen metal and other materials. (Section B-2.1)
- **hammer drill (roto-hammer):** A power drill that combines rotating motion with a hammering action to drill into hard materials like concrete or masonry. (Section B-2.1)
- **hot tapping:** A method used to cut into a pipe while it is still in service and under pressure, allowing a new connection to be added without shutting off the flow inside the pipe. (Section B-2.1)
- **mechanical bending:** A process that uses a machine or tool to permanently bend pipe or tubing into a desired shape without cutting it. (Section B-2.3)
- **nipple:** A short piece of pipe, usually threaded on both ends, used to connect two fittings or sections of pipe. (Section B-2.4)
- **portable:** A tool or piece of equipment that is easy to carry and move from one place to another and may be cordless or use a rechargeable battery. (Section B-2.1)
- **portable band saw:** A handheld power saw that uses a continuous loop blade to cut metal, pipe, or other materials. (Section B-2.1)
- **power cut-off saw:** A power tool that uses a rotating abrasive wheel or blade to cut metal, pipe, or other materials. (Section B-2.1)
- **reaming:** The process of smoothing and slightly enlarging the inside of a hole or pipe to remove rough edges and improve fit. (Section B-2.4)
- **reciprocating saw:** A power saw with a blade that moves back and forth quickly to cut through wood, metal, plastic, or pipe. (Section B-2.1)
- **sabre saw (jigsaw):** A handheld power saw with a narrow blade that moves up and down to cut curves or shapes in wood, metal, or plastic. (Section B-2.1)
- **spade bit:** A flat drill bit with a pointed tip used to drill larger holes in wood. (Section B-2.1)
- **three-jawed chuck:** A clamping device on a drill that uses three jaws to hold a drill bit or other tool securely in place while it spins. The jaws tighten or loosen together to keep the bit centered. (Section B-2.1)
- **twist drills (drill bits):** Common drill bits with spiral grooves that remove material as the bit drills into

wood, metal, or plastic. (Section B-2.1)

- **wavy set:** A band-saw tooth pattern where small groups of teeth are bent slightly in alternating directions to make smooth cuts in thin materials. (Section B-2.1)

B-2.1 Describe Portable Power Tools Used in the Pipe Trades

Portable power tools play a major role in virtually every trade. In the piping trades, you will be expected to be familiar with a wide range of portable power tools. You must be able to identify these tools, explain their uses, and select portable power tools appropriate for various processes. This section will explore tools that are powered by sources such as electricity, compressed air, and explosive charges.

Electric Portable Power Tools

Electric tools have seen much advancement in recent years, especially in the progress of battery technology. Lighter and more powerful than ever, almost any corded tool that is manufactured today is available in a cordless battery-powered design. Truly ***portable***, cordless tools use a rechargeable battery cell that is composed of one of several different combinations of chemicals including nickel-cadmium, nickel-zinc, or lithium-ion.

Figure 1 *Cordless drill with rechargeable battery (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Corded, electrically grounded tools usually have a three-prong plug, with one prong serving as the ground pin. Double-insulated tools may have only two prongs.

Electric Saws

Portable electric saws are valued for the speed and efficiency with which they can do certain jobs. The circular saw, for example, is well suited for cutting cleanly into thick lumber and for trimming assembled work.

Portable Circular Saws

Portable circular saws can make straight cuts in a variety of materials and can also start cuts in the middle of a workpiece.

The size of the saw is identified by the diameter of the blade. As a rule, the larger the blade diameter, the more powerful the motor must be and the greater the depth of cut.

Figure 2 *Portable electric circular saw (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Portable circular saws can be used for both ripping and crosscutting. The depth of the cut is controlled by raising or lowering the base, and bevel cuts can be made by adjusting the tilt of the base.

The saw is usually guided freehand along a pencil or chalk line, so its accuracy depends on the operator's guiding skill.

Straight cuts can be made using the rip guide, a standard attachment on most circular saws. Even greater accuracy can be achieved by securing a straightedge to the work and guiding the base of the saw along it during the cut.

Circular saws can also start cuts in the middle of a workpiece. This makes them useful for cutting rectangular openings in materials such as plywood, a task that is difficult to do with a handsaw.

Saw Blades for Circular Saws

Circular saws use three types of blades:

- Crosscut
- Ripsaw
- Combination

Use crosscut blades for crosscutting (***perpendicular*** or against the grain) and ripsaw blades for ripping (***parallel*** or with the grain). Use a combination saw if the work requires you to constantly change from crosscutting to ripping.

Tooth Characteristics

This illustration shows two saw-blade teeth. The four characteristics that distinguish one type from another are ***pitch***, ***heel***, ***hook***, and ***gullet***.

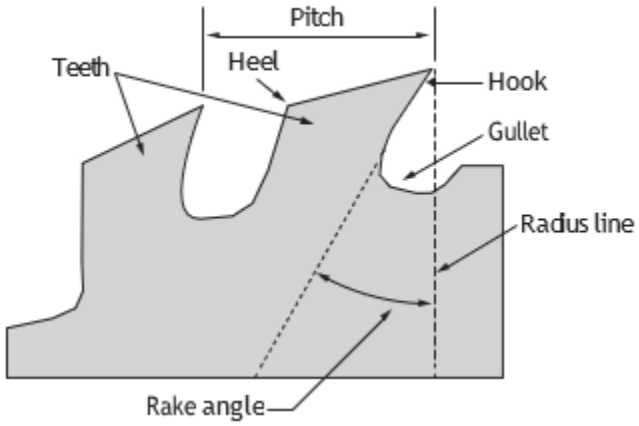


Figure 3 *Parts of a saw's teeth (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

There are several designs of blades. Each blade design is intended for a specific cutting task and will last longer and perform better if used only for the intended task.

Figure 4 *Rip blade (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Rip blades are designed to cut solid lumber along the length of the stock. The teeth are square across their cutting edge and will cause chipping if used for cross cutting.

Crosscut blades have teeth sharpened to a knife-like point. They will produce a smooth, chip-free cut across the grain of solid lumber and they are ideal for cutting plywood regardless of the direction of the cut.

A ***standard combination blade*** provides an adequate cut with or across the grain of solid wood, as well as on various plywood's and panel products. However, it does none of these cuts as well as blades specifically designed for each task.

The ***chisel combination blade*** is a popular blade for cutting solid lumber and plywood. The teeth are sharpened square across the front and on a bevel across the back, forming a slight point on the cutting edge. The blade is easily sharpened and, when sharp, cuts fast and produces edges smooth enough for most construction.

Non-ferrous metals can be cut with ***metal-cutting circular blades***. The blade resembles a fine-toothed crosscut blade, but the teeth are square across the cutting edge like those of the ripsaw. These blades usually require lubrication on their sides to prevent the waste material from binding to the blade. The most common type of lubricant is a wax-stick which is rubbed on the sides of the blade.

Ferrous metals (metals that contain iron and form sparks when cut or ground) can be cut with an ***abrasive disk blade***. This blade has no teeth and simply grinds a thin cut through the metal. The abrasive blade must be matched to the RPM of the saw and hardness of the steel being cut. Otherwise, the blade will either cut very slowly or wear out very quickly.

Masonry products are cut with an abrasive wheel similar to the type used for ferrous metals. Because ***masonry blades***

and ferrous cutting blades are similar in appearance, check to make sure you have the correct type of blade. Masonry blades will not cut metal, and metal cutting blades will not cut masonry.

Carbide-tipped blades remain sharp much longer than conventional steel blades. They can be used to cut wood, plastic and composition board as well as non-ferrous metals. The carbide tips, which are extremely hard and brittle, are brazed onto a standard-sized metal disk. The carbide tips are then ground to a shape suitable for the blade's intended use. The shape of the tooth illustrated in Figure 12 is known as triple chip and can be used for plastic laminates, hardboard, plywood, aluminum, brass and for crosscutting lumber.

Carbide is so hard and brittle that it can be chipped and dulled through contact with other hard materials. As a result, all carbide-tipped blades require careful handling. You must not let the carbide come in contact with any hard surface, such as the metal parts of a saw, other saw blades, or concrete and masonry.

Sabre Saw (Jigsaw)

Sabre saws are used to make curved or irregular cuts in wood, plastics or metal.

The blade action is a high-speed up-and-down motion, with the cutting taking place during the up stroke.

The sabre saw is designed mainly for light cutting, but is also capable of making cuts through materials 40 mm to 50 mm

(1 $\frac{1}{2}$ in. to 2 in.) thick. The blade length should be such that when the blade is at the top end of its stroke, the lower end

of the blade is below the bottom of the stock being cut.

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

Although the sabre saw is capable of starting a cut in the middle of a piece of wood; it is much easier and safer to drill a starter hole through the workpiece and use the hole as the start of the cut. The rapid up-and-down action of the blade may cause the workpiece to chatter, so the workpiece must be secured and the sabre saw held firmly against the work.

The most common types of sabre saw blades are shown in Figure 6. Note that there are two different end types, straight and hooked end. They cannot be interchanged.

The blades for plywood, particle board and plastics have fine teeth. The blade for cutting thicker plywood and lumber has coarse teeth.

The blade for cutting thin hardboard and plywood in a scroll pattern has fine teeth and is very narrow.

The blade used for cutting ferrous metals has very fine teeth set in a wavy pattern.

Figure 6 *Sabre saw blades* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Reciprocating Saw

The ***reciprocating saw*** makes cuts in any direction. It can do heavier work than the sabre saw. This type of saw can be used to cut metal, wood, fibreglass and virtually any other substance, using the correct blade.

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

A reciprocating saw is a type of saw in which the cutting action is achieved through a push-and- pull (hence reciprocating) motion of the blade.

This type of saw, also known simply as a *recip saw* or *Sawzall* (a trademark of the Milwaukee Electric Tool Company) has a large blade resembling that of a jigsaw and a handle oriented to allow the saw to be used comfortably on both vertical and horizontal surfaces. The typical style of this saw has a shoe or foot plate at the base of the blade, similar to a sabre saw. The user rests this foot against the surface being cut to counter the tendency of the blade to push away from or pull towards the cut as the blade travels through its cycle.

Indispensable in construction, demolition and service work, most of these tools have a quick- release blade function that allow speedy blade replacement without the use of additional tools.

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

Power Cut-off Saw (Chop Saw)

A ***power cut-off saw*** is used to cut sections of lightweight material to length. Power cut-off saws use a thin, abrasive, circular disk as a saw blade. The disk is made from mineral or synthetic grains that are fibre-reinforced and resin-bonded. This disk comes in thickness from 2 mm to 3 mm ($\frac{1}{16}$ in. to $\frac{1}{8}$ in.) and in diameters from 150 mm to 500 mm (6 in. to 20 in.).

The saw in Figure 9 is called a chop or cut-off saw. The chop saw has the mandrel and motor mounted on a pivoting frame. You operate it by grasping the handle fastened to the pivoting frame and lowering the rotating cut-off wheel into the workpiece. The workpiece is secured on the bed of the tool by built-in vise or clamp. Power cut-off saws are also manufactured with special features for a variety of applications.

Figure 9 *Cut-off (chop) saw.jpg* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

This saw cuts relatively quickly, but produces a considerable amount of heat at the site of the cut, which may damage the workpiece. It is used to cut steel that will not suffer too much from heat build-up.

Abrasive Cut-off Wheels

Abrasive cut-off wheels are designed for cutting masonry products or metal.

Metal-cutting wheels are available in two grades, fast-cut or long-life. Fast-cut wheels cut faster but wear out sooner than long-life wheels. Most metal-cutting abrasive wheels will cut steel, stainless steel, cast iron and aluminum.

Each abrasive cut-off wheel has a maximum speed listed in RPM (revolutions per minute). You must make sure that the rated speed of the cut-off wheel is greater than the speed of the motor, or the wheel will break apart and could possibly injure you or a workmate. Sparks and dust that are created can be a serious hazard to your eyes and lungs. Take extra precaution when operating this tool.

Portable Band Saw

Portable band saws are available in a variety of models and sizes.

Figure 10 *Portable band saw (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The size of the metal-cutting band saw is designated by the thickness of stock you are able to cut with it. Standard sizes are 115 mm, 180 mm and 255 mm (4 $\frac{1}{2}$ in., 7 in. and 10 in.). Some larger models are capable of cutting through a pipe that is 50 cm (20 in.) in diameter. The material being cut is typically held in a portable vise.

Metal Cutting Blades

Metal-cutting band saw blades are defined by their grades of steel, tooth formation, tooth set and blade width.

Grades of steel include:

- Carbon steel
- Semi-high-speed steel
- High-speed steel

Figure 11 *Band saw blades (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Carbon steel blades are used for general purpose cutting on a standard band saw. Blades made of carbon steel are the least expensive of the three types, but are less durable than the other grades.

Semi-high-speed steel blades cut 50% faster than carbon steel blades. They are harder than carbon steel, but are able to withstand mechanical shocks and vibrations that would break harder, more brittle blades.

High-speed steel blades cut better and last longer than other blades, but are more expensive and more delicate than the other two grades.

Tooth Formations

Tooth formations include:

- Regular
- Hook
- Skip

Band saw blades with ***regular teeth*** are used for straight and curved cuts in most ferrous and hard non-ferrous metals. Blades with regular teeth can be considered general-purpose blades.

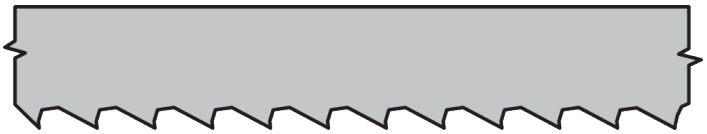


Figure 12 *Regular tooth (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The ***hook-tooth blade*** is best for fast cutting of non-ferrous metals. The large rounded gullets are capable of fast chip removal and the forward slope of the tooth requires less downward pressure to cut. Thin sections of metal should not be cut with this tooth style due to the wide spacing of the teeth.

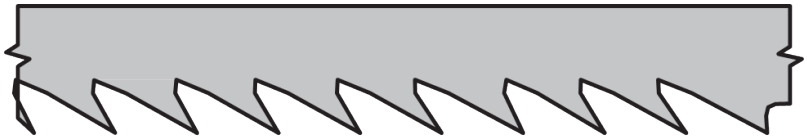


Figure 13 *Hook tooth (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The ***skip-tooth blade*** is very similar to the hook tooth. Unlike the hook tooth, which can only cut softer metals, the skip tooth is capable of cutting ferrous metals. The wide spacing of the skip tooth makes the blade suitable for fast cutting of large sections of steel.

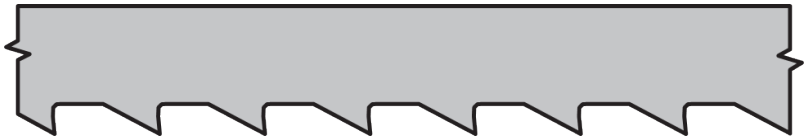


Figure 14 *Skip tooth (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hook and skip-tooth types are available in 3 to 6 teeth per inch. Regular-tooth styles range from 6 to 32 teeth per inch. The number of teeth per inch affects the cutting speed of a band saw, and the size of stock it is best suited to cut. Blades with large numbers of teeth per inch are able to cut small, thin pieces of metal but are slow for cutting large sections. Blades with few teeth per inch cut faster but are too coarse for cutting thin sections of metal. Too many teeth in the cut will result in destruction of the teeth.

Tooth Set

Set is defined as the left-and-right positioning of the teeth to provide a wider cut than the thickness of the blade (this creates the *kerf*). The wide cut provides clearance for the blade within the cut, preventing binding and overheating.

There are two types of tooth sets available on metal-cutting band saws, ***Raker*** and ***Wavy set***.

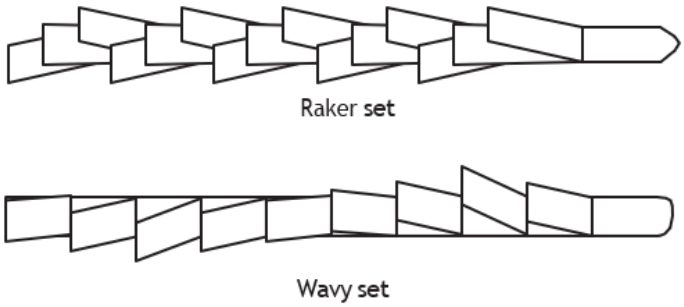


Figure 15 *Tooth set (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hook- and skip-tooth blades have raker set teeth. Regular-tooth blades with up to 24 teeth per inch come with either raker set or wavy set teeth. All regular-tooth blades with more than 24 teeth per inch have wavy set teeth.

Blade Width

Band saw blades are available in widths ranging from $\frac{1}{4}$ in. to 1 $\frac{1}{4}$ in. The narrower blades are able to cut curves of a smaller radius than are the wider blades. Wide blades used for straight cuts.

Portable Hand Drills

The portable electric hand drill can be used for a variety of tasks, including drilling holes, driving screws and mixing concrete. Cord-supplied drills may be double-insulated or of the three-prong type. Always make sure that you identify the type.

Most electric hand drills are manufactured with a pistol grip. A trigger switch is located on the pistol grip to allow for single-handed use during light-duty operations.

Heavy-duty portable hand drills incorporate removable side- and rear-mounted handles for extra control during two-handed operation.

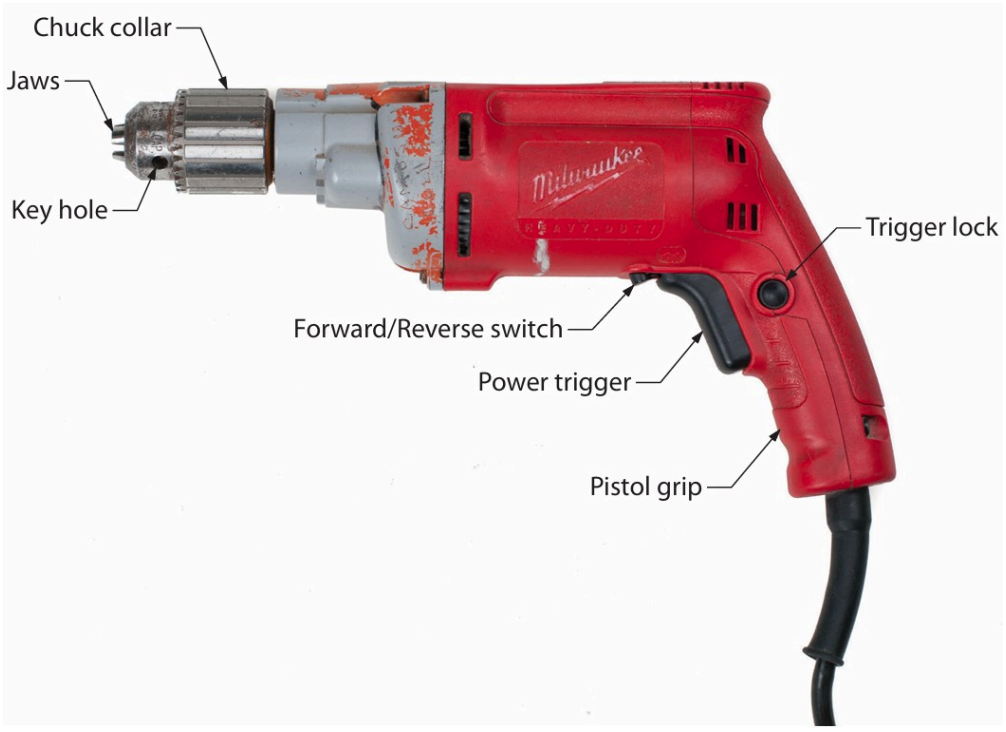


Figure 16 *Electric drill components (Camosun College/BCcampus) CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 17 *Cordless drill with rechargeable battery (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The drill bit is secured to the portable power drill by means of a chuck. The conventional style is a ***three-jawed chuck***. that can be opened and closed by rotating the knurled outer sleeve, but final tightening is done with a special wrench known as a "chuck key" (Figure 17). The chuck key is inserted into a hole on the chuck so that the teeth on the key engage matching teeth on the chuck sleeve. Final tightening with the chuck key should be performed at two points on the three-jawed chuck to ensure a tight contact.

Figure 18 *Chuck Key (Camosun College/BCcampus) CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 19 *Keyless chuck (Camosun College/BCcampus)* CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Another style of chuck is the quick-release hex chuck (Figure 19), originally designed to hold screwdriver bits but that also fits many drill bits that have hex shanks with a retaining channel.

Figure 20 *Hex shank screwdriver bit (Camosun College/BCcampus)* CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Control Switches

Some portable electric drills only have an on-off switch. This type of switch limits the use of the electric drill to those operations that require a clockwise rotation of the chuck at the fixed speed at which that particular drill turns.

Other drills are manufactured with a ***variable speed*** switch. These switches provide control over the chuck speed in relation to the travel of the control switch. This control allows the electric drill to be used for a variety of tasks.

Driving screws and drilling soft materials require a slow-turning drill, while other operations, such as drilling hard materials, require higher speeds.

An additional switch found on some drills allows the motor to turn counter-clockwise (“reverse”) as well as clockwise (“forward”). When both a variable speed switch and a reversible switch are present on an electric drill, the drill can be used to remove screws as well as to drive them.

$\frac{1}{4}$ Inch Drill Motors

Most $\frac{1}{4}$ in. drill motors are used for light-duty drilling operations. The $\frac{1}{4}$ in. means that the drill will accept a maximum $\frac{1}{4}$ in. shank size. The chuck on a $\frac{1}{4}$ in. drill motor turns about 1500 to 1800 RPM. Such high speeds are good for drilling small holes in soft metals but tend to burn drill bits if used for hard metals. The $\frac{1}{4}$ in. drill does not produce enough torque (turning power) at low speeds for driving screws.

$\frac{3}{8}$ Inch Drills

These drills can turn at a much slower speed than a $\frac{1}{4}$ in. drill. Average chuck speed is 750 to 900 RPM for $\frac{3}{8}$ in. drills. Considerably more torque is generated, making the $\frac{3}{8}$ in. drill more suitable for drilling larger holes in metal. A $\frac{3}{8}$ in. drill is often equipped with a forward-reverse switch and a variable speed switch.

$\frac{1}{2}$ Inch Drills

These drills generate substantial torque and are usually equipped with an additional handle to provide the operator with added leverage. Heavy-duty models have a pistol grip on one side, a removable T-handle opposite the pistol grip, and a D-handle at the back (Figure 20).

Figure 21 *Drive drill – ½ in. (Camosun College/BCcampus)* CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

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

Drill Bits (Twist Drills)

Twist drills are also commonly called *drill bits*. Twist drills may be made from carbon steel or high- speed steel. High-speed steel drills are harder and can drill harder metals. High-speed steel remains sharp longer than carbon steel and is able to withstand higher temperatures.

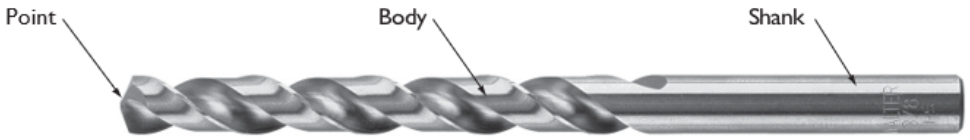


Figure 23 *Twist drill (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Drill Sizes

Twist drills are available in sizes designated by one of four different systems:

- Metric
- Number
- Letter
- Fractional

Metric

Twist drills in metric sizes are usually supplied in 0.5 mm increments. However, they can be purchased in increments of 0.1 mm. Metric twist drills are commonly available in sizes from 0.5 mm to 15.5 mm in diameter.

Number

Twist drills in the number system range from 0.0135 in. to 0.228 in. in diameter. Size #80 is the smallest (just under $\frac{1}{64}$ in. in diameter) and size #1 the biggest (just less than $\frac{1}{4}$ in. in diameter). These sizes are commonly used in the gas fitter trade and are referred to as *orifice drills*.

Letter

Letter sizes range from A to Z, and are a continuation of sizes larger than number size #1. Size A is equal to 0.2344 in. in diameter and size Z is equal to 0.413 in. in diameter.

Fractional

Fractional bit sizing is very common in the construction and service trades. Fractional sizes start at $\frac{1}{64}$ in. in diameter and increase in size by 64ths up to 1 in. Larger bits are available in fractional sizes at varying increments of $\frac{1}{32}$ in., $\frac{1}{16}$ in. and $\frac{1}{8}$ in.

By intermixing fractional, number and letter sizes you can get up to 138 different sizes less than $\frac{1}{2}$ in. in diameter. Larger drills (over $\frac{1}{2}$ in.) are available with reduced shank sizes so that they can be used in standard chucks.

Spade Bits

The spade bit shown below is designed to drill into wood products only. Spade bit sizes range from 9 mm ($\frac{3}{8}$ in.) to 38 mm ($1\frac{1}{2}$ in.) diameter.

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

The quality of the cut produced by the spade bit is not as good as most other bits. Therefore, its use is limited to rough work.

Self-Feeding Multi-Spur Bits

This ***self-feeding multi-spur bit*** uses the screw point to pull the bit through the wood while the sides of the bit guide it. Having a very short centre point, the multi-spur bit drills virtually flat-bottomed holes.

Figure 25 *Multi-spur bit (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Multi-spur bits are available in sizes from 25 mm (1 in.) to 75 mm (3 in.). Their cutting action cuts clean, but shallow holes. Many have replaceable screw points.

Self-Feeding Auger Bits

Auger bits drill clean, accurate, straight and deep holes through wood. The bit is guided by both the screw point of the bit and the sides of the hole. Waste from the hole is carried to the surface by the spiral flutes.

Figure 26 *Self-feeding auger bit (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Countersink Bits

When flathead screws are to be installed flush or below the surface of a wood workpiece, the ***countersink bit*** will drill a broad shallow hole to receive the head of the screw.

Figure 27 *Countersink bit (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Countersink bits may be used before or after the pilot hole for the screw shank and threaded portion has been drilled.

Carbide-Tipped Bits

Carbide-tipped drill bits are used to drill holes in hard, abrasive materials such as concrete, stone, masonry, brick and ceramic tile.

Figure 28 *Carbide-tipped bits (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Drilling into these materials requires a slow-turning drill (350–500 RPM) to prevent the bit from overheating. Special hammer/percussion drills can be used when multiple holes in masonry are to be formed.

Hole Saws

The ***hole saw*** is designed to cut large diameter holes in wood or sheet metal. The hole saw has an *arbour bit* (pilot bit) at its centre that enters the workpiece before the hole saw and serves to guide the hole saw as it enters the material.

Figure 29 *Hole Saws (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hole saws are available in sizes from 14 mm ($\frac{9}{16}$ in.) to 111 mm (4 $\frac{3}{8}$ in.) in diameter. The depth of the hole drilled is restricted by the length of the hole saw. Standard lengths are 12 mm ($\frac{1}{2}$ in.) or 28 mm (1 $\frac{1}{8}$ in.).

Hammer Drill (Roto-Hammer)

A ***hammer drill***, with heavy duty versions known as a *rotary hammer* or *roto-hammer*, is a rotary drill with a hammering action. The hammering action provides a short, rapid force to pulverize brittle material and provide quicker drilling with less effort. Many types allow the hammer and rotation functions to be used separately or in combination (hammer mode, drill mode, or both). When used in the hammer mode, the tool provides a function similar to a jackhammer for light chipping work.

Hammer drills are well suited for drilling holes in masonry or stone. They are also used to drill holes in concrete footings or slabs for supporting and installing piping. The hammering action helps to break up the masonry so that it can be removed by the drill bit's flutes.

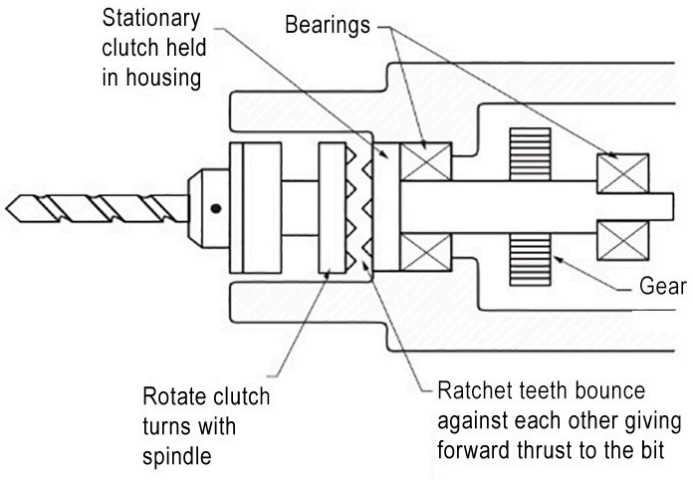


Figure 30 *Hammer drill ratchet teeth provide the percussion action* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Figure 31 *Hammer drill (roto-hammer) and masonry bits* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Demolition Hammer (Chipping Gun)

Demolition Hammers are larger and more powerful than roto-hammers and operate in hammer mode only, often

earning them the name as a "chipping gun or jack hammer." It is used for removing or demolishing concrete and masonry work.

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

Angle Drill Motor

Drilling straight holes in tight spaces requires the use of a specialized type of drill motor. ***Angle drills*** have their chuck mounted at right angles to the drive motor, allowing for the motor to remain horizontal when drilling vertical holes (and vice-versa). Multi-positional handle attachments help maintain control in close quarters.

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

Some manufacturers produce high-torque, high-powered angle drills that are specifically designed for cutting holes in wooden studs and joists for running pipe work. Known by names like *Hole-Hawg*, they offer impressive force that can handle self-feeding bits in excess of $4\ \frac{1}{2}$ in. in diameter.

Figure 34 *Milwaukee electric tool company's Hole-Hawg (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Always ensure that concealed objects such as nails and wiring have been located prior to drilling and maintain good balance during operation at all times.

Safety is paramount when using this tool because it generates substantial torque.

Pipe Saddle Drill

This specialized tool provides a slip-resistant platform to be used when drilling a pipe ***saddle*** (mechanical type of branch outlet). It allows for the drill motor to be centred on the convex pipe surface with adjustable straps and tensioning ratchets. Some varieties of pipe saddle drills allow for "***hot tapping***" into a live pipe so that the piping system need not be shut down and drained.

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

Extracted-Tee Drill

Tees can be extracted in the walls of some types of copper tube using a tool specially designed for this purpose. The drill's head does the unique job of both drilling and forming the branch outlet. The extracted outlet must be brazed because it is very shallow compared to a standard branch tee fitting, but the resulting formation is quite strong.

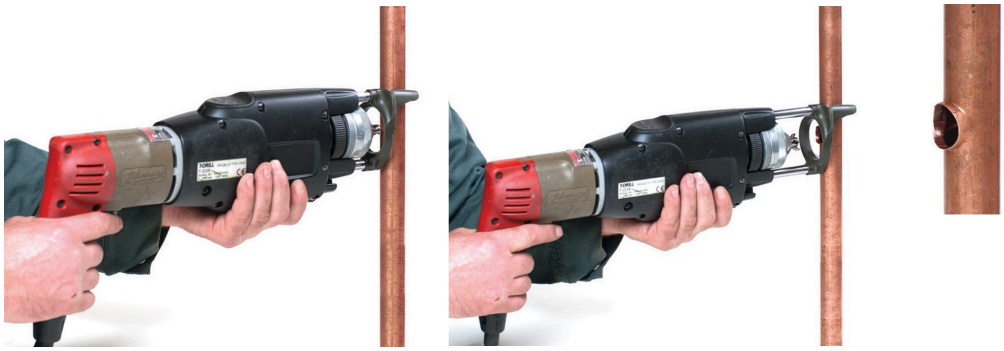


Figure 36 *Extracted-tee drill motor and branch outlets (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Coring Machine

Coring machines *(also called core drills)* are designed for producing horizontal or vertical round holes in masonry. Designed much like a drill press for concrete and brick, they have hollow steel cylindrical bits that create a long *core* (tubular sample) of the material. Commonly, the resulting penetration is used for the installation of pipe work in new construction, renovation or piping relocation work.

The bits used for coring machines are essentially diamond-tipped hole saws, minus the presence of an arbour bit. Water is fed to the bit through a direct hose connection, or by means of a portable tank to aid in the cooling of the bit and to remove *slurry* (mixture of concrete and water) from the kerf of the cut.

Coring machines must be securely fastened to the work surface by means of concrete anchors or the use of a brace to tension the stand of the machine firmly. Suction-type bases have been developed for quicker mounting without damage to the wall or floor finish.

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

Angle Grinders

Angle grinders may be used for removing excess material or for cutting material. There are many different kinds of disks that are used for various materials and tasks, such as cut-off disks, abrasive grinding disks, *honing* (abrasive) stones, sanding disks, wire brush wheels and polishing pads.

The angle grinder has large bearings to counter side forces generated during cutting. It is sometimes referred to as a ***side grinder***).

The motor drives a geared head at a right angle on which is mounted an abrasive disk that can be replaced when worn. Angle grinders typically have an adjustable guard and a side-mounted handle for two-handed operation. Light and powerful, they are essential for pipe fabrication work.

Figure 38 *Electric angle grinders with grinding disks (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Grinding Wheels and Disks

A ***grinding wheel*** *or disk* is a shaping or cutting tool made from natural or artificial abrasive particles. The wheels are made in numerous shapes and sizes. A small amount of stock is removed by each abrasive particle as it passes over the work. Grinding wheels are used for rough grinding, smooth finishing, and cutting or removing metal or other materials.

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

The most widely used abrasives in grinding wheel and disk construction are silicon carbide and aluminum oxide. Wheels containing particles of diamonds, either artificial or natural, are also made for limited special purpose application. The wheels and disks you encounter will usually be made of aluminum oxide.

The abrasive grain size determines the coarseness or fineness of the grinding wheel. The grain size is determined by the smallest screen mesh through which they can pass. For example, if the smallest screen through which the grains pass has 100 openings per inch, the grain size is known as 100 grit, with each grain approximately $\frac{1}{100}$ in. Grinding wheel abrasive grits from 6 to 24 are considered coarse, grits from 30 to 60 are medium, grits between 70 and 100 are fine and those over 100 are known as extra-fine.

One function of any bonding material is to hold each abrasive particle intact as long as it is sharp. When the particles become dull, they dislodge and expose other particles with sharp edges.

The hardness (***grade***) of a grinding wheel or disk refers to the strength with which the bond holds the abrasive particles together in the wheel, not the hardness of the abrasive particles.

The structure of a grinding wheel indicates how far apart the grains are spaced (***grain density***). If the spacing of the grains is close, the structure is dense. If the spacing is relatively wide, the structure is open. Grinding wheel structures are rated by numbers.

An ***open-structure coarse-grain wheel*** (which provides better chip clearance) is used on soft materials. ***Dense-structure fine-grain wheels*** are used where a smooth surface finish is required. Do not use wheels with a dense structure if the work material tends to clog the grinding wheel face.

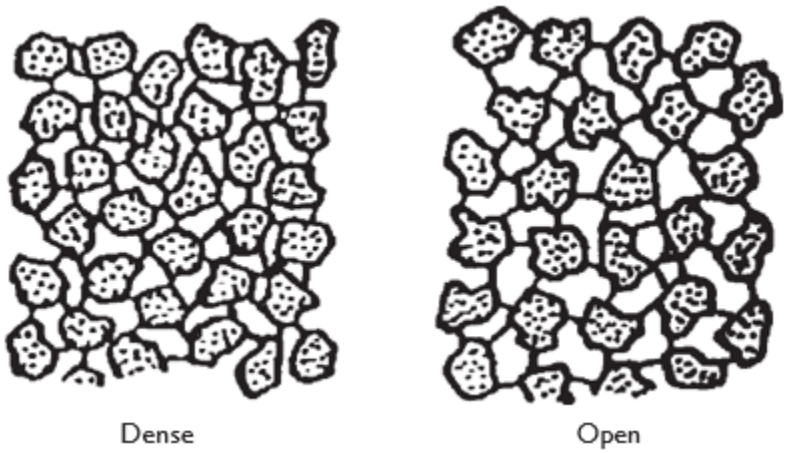


Figure 40 *Relative grain spacing (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Choose a wheel or disk structure by compromising between the desired finish and the material removal rate. Always select a grinding wheel with a rated RPM at least as high as the grinder spindle no-load speed.

Allowing the wheel to operate at or slightly below the maximum safe speed automatically determines the cutting speed preferred for that wheel when used against material for which it was designed.

Markings

The standard marking system for most grinding wheels indicates:

- The maximum permitted operating speed (in RPM or m/sec)
- The wheel diameter
- The wheel thickness
- The hole diameter
- The grit size

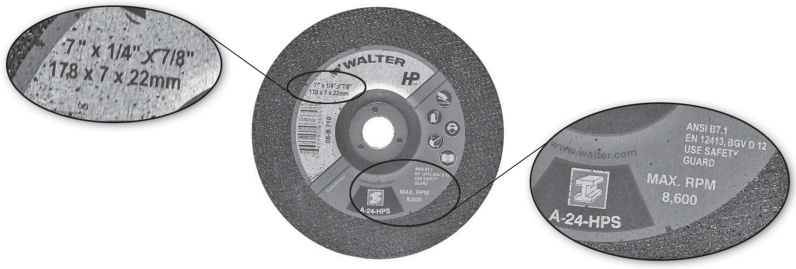


Figure 41 *Grinding disk with markings (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Portable Electric Pipe Fabrication Tools

There are many portable electric tools designed for on-site pipe fabrication.

Portable Power Drives

The ***portable power drive*** is usually used with a tri-stand vise for pipe support. Weighing as much as 25 lbs., it is a powerful but compact drive for turning a drop head threader or a large-geared threader. When used with the geared threader, the drive is mounted on the threader by using an adapter.

Figure 42 *Portable power drive (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

When a ***drop head threader*** is used, a support arm must be locked on the pipe if the pipe size is 1 in. or larger. In conjunction with the support arm, this drive can be used to turn drop head die threaders, with or without the use of a tri-stand supporting vise.

The maximum pipe capacity for most power drives is 2 in. pipe with a drop head threader and 6 in. pipe when using the geared threader.

Figure 43 *Threading with a portable power drive using a support arm (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

In addition to threading uses, some portable power drives will also power hoists and winches and other accessories and operate large valves. It is activated by a switch button on the handle.

Power Pipe Cutter

The portable power drive can be used to operate a heavy duty displacement cutter that can provide square cuts on pipe up to 12 in. NPS with wall thickness up to schedule 40. A hydraulic foot pedal provides the required force to feed the wheel through the pipe wall while the cut is achieved without dust or sparks.

Figure 44 *Power pipe cutter (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

A pipe roller is available for this tool that allows it to be used to rotate a pipe while a worker bevels one end for welding preparation.

Copper Cutting and Preparation Machine

The copper cutting and preparation tool is useful for cutting, reaming, de-burring and cleaning copper pipe and fittings up to 4 in. It is suitable when multiple cuts are to be made for numerous fit-ups.

Figure 45 *Copper cutting and preparation machine (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

Plastic Pipe and Tubing Power Cutter

These types of powered cutters are designed to make precise cuts in multiple types of plastic materials. They are battery powered and suitable for use on polyethylene (PE), polypropylene (PP), PEX, rubber hose, PVC and CPVC, with a capacity typically up to 2 in.

Figure 46 *Plastic pipe and tubing power cutter (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

Copper Tubing Power Cutter

This cordless tool can save time when making numerous cuts on copper tubing. Weighing typically less than 10 lbs., it can self-adjust for tubing sizes between $\frac{3}{8}$ in.–1 in. OD tube and has a compact head suitable when cutting in tight spaces.

Figure 47 *Copper tubing power cutter (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Power PEX Expansion Tools

Due to the memory capability of certain types of PEX, one method of joining the tubing is by expansion of the tube and a special PEX ring. Power tubing expanders are most commonly of the cordless electric type and have the added advantage of one-handed operation with heads that often have an auto-rotate feature.

Power Press Tool

A fast one-time connection for copper, stainless steel and even PEX tubing is the use of press-fitting technology. This is popular due to its speed of installation and the fact that no flame or heat is required for copper connections. The barrel on the head can often swivel to obtain multiple installation positions.

Figure 48 *Cordless pressing tool (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

Additionally, for tubing sizes over 2 in., press-rings are available that fit around larger fittings, typically up to 4 in. A special actuator-jaw attachment is used to press the ring while it remains around the fitting until the jointing process is complete. The jaws allow for a 180° swivel feature that permits the tool to connect to the ring at any angle relative to the tubing, allowing greater access in tight spaces. Note that the pressing action of the tool cannot be stopped once activated, so the operator must make sure that fingers are kept well away from pinch points.

Figure 49 *Press ring set for larger pipe diameters and press fittings (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

Electric Soldering Tools

Professional electric soldering tools (guns) are intended for rapid, flameless soldering of copper tubing up to approximately 3 in. in diameter. Specially designed for renovation and repair work, they often utilize long cables to aid in accessing the work.

Figure 50 *Electric soldering tool (RIDGID TOOLS/ Emerson Professional Tools) Used with permission.*

Fusion

Fusion is a heat process that is used to join two pieces of ***thermoplastic pipe*** (pipe that is capable of being re-melted and

re-molded). Pipe fusion involves using a tool that will melt two ends of the pipe to be welded and some method that will apply force to their surfaces until set. The two pieces then cool together and form a permanent bond. Generally, ***polyolefins*** (such as polypropylene and polyethylene plastic) are used for this application. (Polyolefins do not join by solvent cementing because they have excellent chemical resistance.)

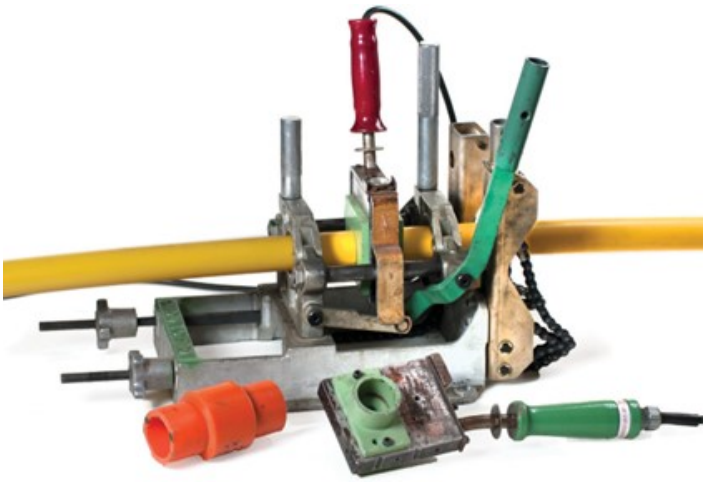


Figure 51 *Socket fusion tool set (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Portable Power Tubing Bender

Most of these powered benders have radius abilities of 180° and offer a selection of bending formers for different diameters of copper tubes, aluminum and soft steel tubing, and pneumatic and hydraulic tubing. Most come with features that allow for bench mounting of the bender for multiple bending at the job site. Maximum capacity for these models is usually $1\frac{1}{8}$ in. OD.

Figure 52 *Portable power tubing bender (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 53 *Portable power tubing bender in use (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Portable Piping Maintenance Tools

There are many portable electric tools designed for on-site piping maintenance.

Power Drain Cleaning Tools

Drain cleaning tools are used to unblock clogged or obstructed drainage and venting pipes. Most types use some form of rotating auger that moves down the pipe to break up or retrieve the obstruction, while other varieties of machines may use jetted water to blast through material.

A drain auger is also known as a ***snake*** and consists of a coiled metal wire often wrapped around a wire core. Augers work to clear drains in one of several ways:

- The end of the auger's wire digs itself into the obstruction much like a corkscrew, allowing retrieval of the object (hair, cloth, etc.).
- The end of the auger breaks up the object, allowing it to pass through the drain (tree roots, paper, etc.).
- The snake *scours* around the inside surface of the pipe, scraping off accumulated matter (ranging from mineral deposits to bacon fat) that was reducing the effective inside diameter of the drain.

Figure 54 *Handheld drain auger (https://commons.wikimedia.org/wiki/File:Handheld-Drain-Auger.png) (Pgdp123, Wikimedia) CC BY 3.0 (https://creativecommons.org/licenses/by/3.0/deed.en)*

Sink Machines

Typically using an auger that is approximately $\frac{5}{16}$ in. in diameter, ***sink machines*** are light-duty drain cleaners that are for drains sized 2 in. or less, such as kitchen sink, lavatory and shower drains. They are often powered by pistol-grip-style drill motors or small motors that are meant to be positioned on the counter top, or near the point of use.

Figure 55 *Sink machine drain cleaning tool with auto cable feed feature (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 56 *Sink machine cleaning a fixture drain (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Drum Machines

These larger capacity ***drum machines*** have the ability to vary the speed of the cable feed and rotation. Using $\frac{3}{8}$ in. or $\frac{1}{2}$ in. cables, they are capable of cleaning drain lines in excess of 4 in. Larger machines can be equipped with 100 ft cables of either $\frac{3}{4}$ in. or $\frac{5}{8}$ in. diameter that can clean drains as large as 10 in. In drum-style drain cleaning machines, a pneumatic foot switch is commonly incorporated as a safety feature. The switch uses air pressure—rather than electricity—to control the motor. This design eliminates the risk of electrical shock, especially in wet or damp environments where water contact is likely.

Figure 57 *Cable drum drain machine (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

Sectional Drain Cleaning Machines

Sectional drain cleaning machines allow the drain auger to be added in sections instead of being self-contained in a drum. Often, more than one size auger can be driven with the same motor. One characteristic of this style of drain machine is that it can offer the operator more control of the auger through the manipulation of the control handle.

Figure 58 *Sectional drain machine (RIDGID TOOLS/Emerson Professional Tools). Used with permission.*

Figure 59 *Sections of drain auger (snake) and common head attachments (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Water Jetters

Water jetters propel flexible lines through sludge, soap and grease blockages. As it is pulled back, it power-scrubs the line, flushing away debris. Most operate with over 2000 psi water pressure to provide the required cleaning power to do the job.

Figure 60 *Water jetter (RIDGID TOOLS/Emerson Professional Tools). Used with permission.*

Pipe Inspection Cameras and Locators

Pipe inspection cameras can visually show the nature or severity of obstructions or failures of piping systems. Especially valuable when inspecting underground services, pipe inspection cameras can record filmed data with the on-board hard drive, and some models make instant digital copies as well. LCD displays record the distance to the camera head to aid

in locating the problem, while some cameras can transmit a signal to be detected with pinpoint accuracy with the aid of a locator device.

Figure 61 *Pipe inspection camera system (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

Figure 62 *Digital pipe camera locator (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

Pipe Freeze Kits

Pipe freeze kits stop the flow of water while a system is inspected or repaired. Once the system maintenance is complete, the "***ice plugs***" are slowly melted and the system is put back in service.

There are electric versions of these systems (as shown), but many use bottles of refrigerant gases to perform the same task with a similar result.

Figure 63 *Electric pipe freeze kit and a frozen pipe (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

Pneumatic Portable Power Tools

Air tools are often used to do work in explosive or flammable atmospheres, such as in grain elevators or other places where sparking from inside an electric tool could cause a fire or explosion.

Safety with Air Tools

Using tools powered by high-pressure air can be very hazardous. In addition to the hazards of flying materials, there are many other dangers.

- Air tools are very noisy. Hearing damage can result unless proper ear protection is worn. This protection must be worn at all times, not only by the operator but by other persons nearby.
- Continuous vibration can cause damage to nerves. Use heavy gloves if you do a lot of impact work.
- Fittings often come loose from their retainers and can fly a considerable distance at high speed. When using air tools, be cautious of where you point the tool.
- High-pressure air is a severe hazard. Never expose yourself or your fellow workers to any direct blast of air as they can drive particles under your skin or inject air bubbles onto your bloodstream. Never use compressed air to clean your clothing because particles can be blown into your skin.
- Blowing air at your clothing could also react with some petroleum products and cause combustion.

Never use air tools in an area where the exhaust from the tool could stir up clouds of toxic chemicals or hazardous materials such as asbestos dust.

Air Supply for Air-Operated Tools

Air or pneumatic tools are operated by compressed air supplied by an air compressor. This compressor is pre-set to maintain a constant supply of compressed air at pressures ranging between 350 kPa (50 psi) and 1050 kPa (152 psi). A reservoir tank attached to the compressor retains a supply of compressed air to assure sufficient volume.

Figure 64 *Electric air compressor (Muhammad Abdullah, Freepik [AI generated]) Freepik Terms of Use (https://www.freepik.com/legal/terms-of-use)*

Compressed air may also be found piped to quick-connectors placed conveniently around the shop. High- pressure flexible rubber air hoses are used to connect the air-operated tool to the wall outlet. These hoses must be kept in good condition, and their end connections must be tight. A broken or severed hose can be uncontrollably whipped around by the escaping air pressure and can cause serious injury to anyone in its path.

Components of a Compressed Air Supply System

Compressed air for a power tool is supplied through a hose or pipe to the tool. The system has a drain-off valve for releasing moisture from the compressed air, a filter and pressure regulator, and sometimes a lubricator. A quick connector is used to attach the hose that feeds the air-powered tool.

Figure 65 *Typical compressed air system (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Filter and Regulator

A clean, dry air supply is of prime importance. Moisture in the air lines can damage tools or interfere with their performance. Water in the line tends to dilute and wash away the lubricant and can corrode internal parts. If water gets past the filter, it can enter the regulator mechanism and interfere with its operation. This can lead to erratic air pressure, which affects tool speed and may cause the ***speed governor*** (a built-in device that limits RPM) to malfunction. If the governor sticks or fails due to moisture or corrosion, the tool can over-speed, creating a dangerous condition for the operator.

Lubricator

In many tools, the compressed air must contain a lubricant to keep moving parts operating freely. A lubricator, attached between the regulator and the tool, supplies the lubricant in the form of a fine mist. The operator can control the amount of oil misted into the compressed air.

Quick Connectors

Connectors, which are also referred to as *quick couplers*, make it easier to connect and disconnect supply hoses and tools. The internal end of the connectors is designed to shut off the air flow when the external end is disconnected.

Air Hose

The air hose is made of rubber to make it flexible. The rubber is reinforced with braided thread or wire to make it strong, and coated inside to prevent air from leaking out past the layers. It is available in different lengths and diameters. Hoses can be joined together to reach longer distances. The most common lengths of single hose are 7.5 m and 15 m. The inside diameter must be no smaller than 8 mm. Hoses are available in a variety of pressure ratings and colours.

Air-Impact Wrenches

An ***air-impact wrench*** can be used to install or remove fasteners. In addition to rotary motion, there is a hammering effect much like the electric hammer drill to increase torque and make the tool more effective. There is a wide variety of sockets and attachments for this tool. Because impact wrenches are used for both assembly and disassembly, they are reversible.

Pneumatic impact wrenches are made in larger sizes than electrically-operated impact tools and are used more often in heavy-duty applications. Impact wrench sizes are designated by the size of the drive on the nose of the tool. The drive is usually square, with the most common sizes being $\frac{3}{8}$ in., $\frac{1}{2}$ in., $\frac{3}{4}$ in. and 1 in. It is used by inserting it into the drive end of a socket.

Although the sockets used with impact wrenches are similar to the ones that are used with hand tools, they are of a much stronger design in order to absorb the tremendous forces generated.

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

Do not substitute a conventional socket for an impact socket. Conventional sockets can fracture, fly apart, and cause injury.

Air-Operated Grinders

Portable grinders are valuable tools for sharpening other tools, removing burrs, bevelling corners and grinding welding beads. Accessories for brushing, buffing, filing and sanding can be attached to certain models, increasing their versatility.

The grinder spindle speed varies proportionally to grinder size and ranges from 4000 RPM on larger models to over 40 000 RPM on smaller ones. Each grinder has a throttle lever to regulate speed. Certain models have a throttle lever stop-screw that limits throttle depression and may be adjusted to maintain a desired maximum RPM.

Figure 67 *Typical heavy duty air-operated grinders (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

A heavy duty, air-operated grinder, which holds a depressed-centre (cup-shaped) grinder wheel may also be adapted for brushing or sanding. Two hand grips are featured for safe, controlled operation. One handle includes the air trigger or lever. This grinder is available with spindle speeds from 4500 to 7000 RPM.

Air-Operated Drills and Drivers

Pneumatic drills are operated by the force of air moving over the blades of a rotor. This turning force is transmitted to the chuck through a series of gears. The speed of the drill is controlled through its full RPM range by the amount the air-throttle lever or trigger is depressed. Many pneumatic drills are designed with mufflers to reduce the noise caused by the motor.

Chucks for pneumatic drills are made in different sizes corresponding to the drill capacity. Both keyless and key-type chucks are available. Both have three hardened steel jaws that are tightened and released by turning a threaded sleeve.

Figure 68 *Chucks and key (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

A keyless chuck has a knurled sleeve to permit hand tightening. The key-type chucks are adjusted by inserting a key into a hole on the chuck so that the teeth on the key engage matching teeth on the chuck sleeve.

The portable pneumatic drill is often preferred to an electric drill because it is light and has infinite speed control. In addition, it cannot overheat or be damaged by overloading. Another feature of the pneumatic drill is that it will stop quickly.

Air screwdrivers and nut drivers look very much like air drills. The main difference is in the chuck or bit holder. The tool bit is held in place by a ball-and-spring detent, which facilitates quick changes of bits.

To further enhance the versatility of power screwdrivers, a clutch device or a friction drive can be incorporated, which runs the screw or nut to the required depth or tension.

Air drills can also be operated safely in wet areas, a condition that would make the operation of an electric drill hazardous.

Air Hammers and Chisels

Air hammers are used for riveting, metal cutting and chiselling. They use a reciprocating piston that strikes a tool bit accessory that, in turn, strikes the workpiece.

Figure 69 *Air-operated hammer/chisel (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Air hammers and chisels can deliver between 1500 and 4000 blows per minute.

A typical tool bit (chisel) accessory is manufactured from high-quality alloy steel and heat-treated to withstand and deliver repeated blows from the striker piston. Many different bits are available to perform various tasks.

Powder-Actuated Tools

Powder-actuated tools are specially designed tools for driving fastening devices into steel or concrete. They are powered by an explosive powder charge similar to a rifle.

The explosive powder charge creates a rapid expansion of gas that either directly or indirectly, drives the fastener. The indirect system uses a captive piston whose velocity need not be nearly as great as that of a fastener alone to have enough energy to penetrate to the proper depth.

A number of manufacturers have designed different types and models of tools, each tool having specifically designed explosive charges and fasteners. These parts are not interchangeable.

Figure 70 *Powder actuated fastener tool (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

History

Developed in Europe in 1908, the first powder-actuated tool was a high-velocity device that made possible the underwater repair of ships. With welders working inside the ships, divers on the outside used the new tool to nail plates onto the hulls. A captive piston was incorporated into the design to reduce the velocity of the expelled pin.

The tool manufactured by *Hilti* appeared on the market in 1979. Nearly 10 years later, *Hilti* introduced an improved design for the captive piston. The result was a safer tool, with the fastening pin travelling at a still lower velocity.

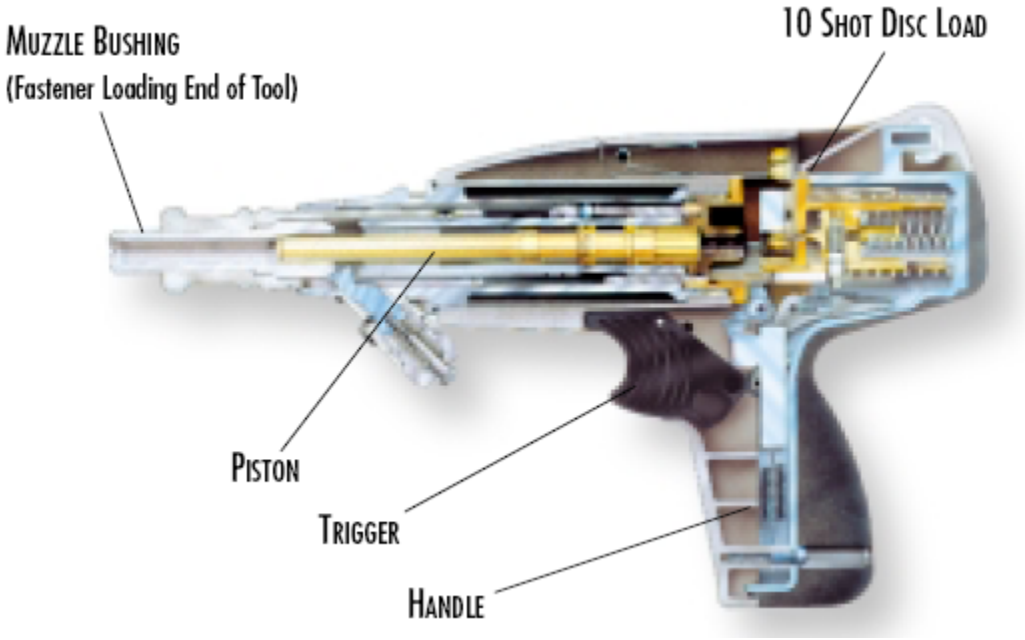


Figure 71 *Powder-Actuated tool diagram (Dustinmck/Wikimedia Commons) CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0)*

Because of its safety features and efficiency, the low-velocity, powder-actuated tool manufactured by *Hilti* is the most widely used in the piping industry. Even so, you should know that other tools are available, and that the speed with which they discharge fasteners varies. The speeds below are measured two metres in front of the tool.

To better understand how powder-actuated tools are used in practice, watch the following demonstration from the BCcampus Trades Access Common Core video series, developed by Camosun College: Hilti DX 450 Powder-Actuated Tool (BCcampus Line C Series) [7:09] (https://media.bccampus.ca/media/Hilti%2BDX%2B450/0_qkdz82jw?utm_source=chatgpt.com)

This video shows the operation, handling, and typical applications of a powder-actuated fastening tool in construction settings.

As you watch the video, consider:

- What safety precautions are demonstrated?
- What materials is the tool used on?
- Why is training required before using this tool?

Low Velocity

Type: *Hilti*

This tool operates on the captive piston principle.

Both the fastening pin and the driving piston move at a speed less than 100 m (330 ft) per second.

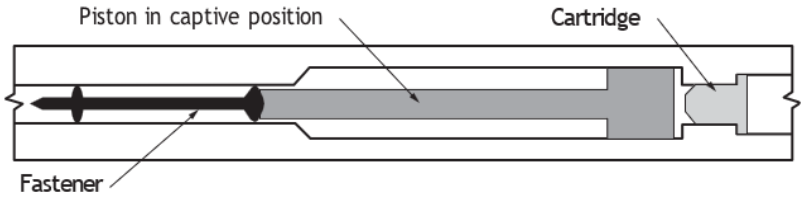


Figure 72 *Low-velocity, captive piston mechanism (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Medium Velocity

Type: Ramset

When fired, the fastening pin travels at about 100 to 150 m (330 to 500 ft) per second.

Figure 73 *Ramset gun (Bill Bradley [billbeee]/ Wikimedia Commons) CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/deed.en)*

High Velocity

Type: Omark Remington Phillips

These special tools have limited applications. They have no pistons, and the fastening pin is discharged at a velocity above 150 m (500 ft) per second. Speeds of 460 m/sec (1500 ft/sec) are not unusual.

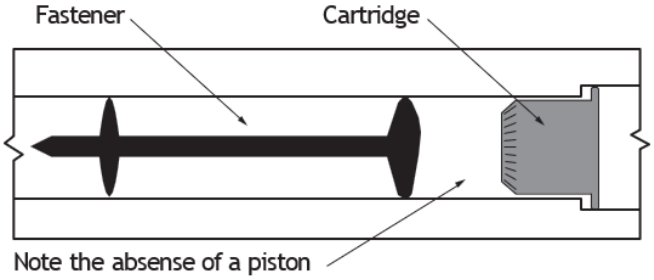


Figure 74 *High velocity tool mechanism (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Safety Features

The Hilti powder-actuated tool has a number of built-in safety features:

- A captive piston, already described.
- A built-in device that prevents the tool from firing if it is held at an angle of more than 7° off the work surface. To fire, the tool must be held flat against the work area, at a right angle to the work surface.
- A built-in stop ring or stopping mechanism. Designed to absorb impact, it is the first part of the tool to break down from the force of the impact. When the stop ring becomes deformed, it must be replaced or the tool will not function properly.

Powder Loads and Firing Methods

Low- and high-velocity cartridges are rated according to a colour code; beginning with the weakest rating (grey) through to the strongest rating (purple). Both low- and high-velocity types share the same colour code; the difference is that low-velocity cartridges have a brass case, while the higher- velocity types are encased in nickel.

Table 1: ***Cartridge Colour Code by Power Level (Low and High Velocity)***

Low Velocity (Brass Case)	High Velocity (Nickel Case)
Grey (Weakest)	Grey (Weakest)
Brown	Brown
Green	Green
Yellow	Yellow
Red	Red
Purple (Strongest)	Purple (Strongest)

Note: When selecting a cartridge, always start with the weakest load for that tool and increase the strength, one step at a time, until the proper fastening is obtained. Re-driving a fastener is not recommended, as it can damage the tool and weaken the grip of the fastener.

Cartridges

There are two designs used for cartridges: crimped and wadded. Both provide the same power. *Hilti* uses the crimped design and paints the cartridge tip to identify the strength of the powder load (grey to purple). The paint also acts as a waterproof barrier to keep the cartridge dry.

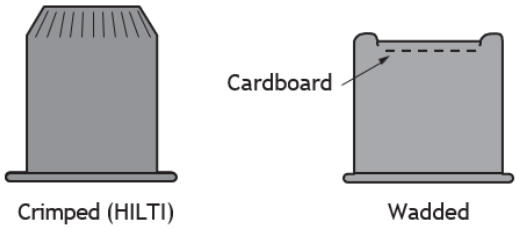


Figure 75 *Types of cartridges (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Wadded cartridges are not used by low-velocity or captive piston tools because the wads could plug the vent ports needed with the captive piston system.

Firing Methods

The cartridges for powder-actuated loads are either:

- Rim fired (the *Hilti* method) or
- Centre fired

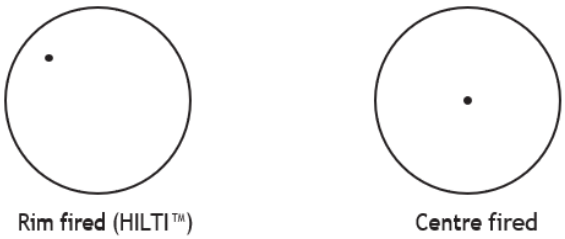


Figure 76 *Cartridge firing methods (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Types of Fasteners

Fastening pins are made of specially hardened steel. For fastening into concrete, the shank (the end of the fastener being driven into the concrete) is smooth. For fastening into steel, the shank is knurled, meaning that the tip has a series of small ridges to aid fastening.

Each tool model will accept only the type of fastener specially designed for it. Therefore, it is very important that the right fastener is selected for the tool.

In designing fasteners for its tool models, Hilti has incorporated a double guidance system.

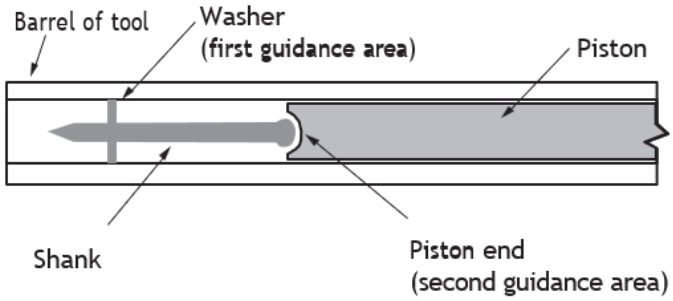
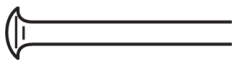
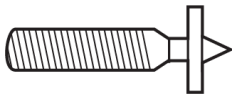
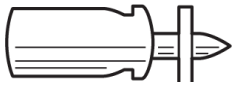


Figure 77 *Double Guidance System (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Interpretation of Fastener Codes

The follow table describes the fastener by its corresponding code.

Table 2: *Common Fastener Codes Used in Powder-Actuated Tools*

Code	Meaning	Illustration
DN	Dome head nail (small)	
W	Threaded	
NK	Round head nail	
DS	Dome head nail (large)	
TB	Eyelet fastener	
E	E in front of any code indicates that the fastener has a knurled shank and is used for steel only.	

Example 1:

Code **W6-20**

W – designates threaded

6 – designates a thread diameter of 6 mm ($\frac{1}{4}$ in.)

20 – designates a thread length of 20 mm

Note: The piston must be changed for each threaded fastener so that the bore in the piston matches the fasteners. Thus, codes W6-11, W6-20, and W6-30 call for pistons with different bores, because each threaded fastener has a different length.

Example 2:

Code **W6-20-22-S-12**

W – a threaded fastener

6 – thread diameter – 6 mm

20 – thread length – 20 mm

22 – shank length – 22 mm

S – steel washer

12 – washer diameter – 12 mm

Note: Three types of material are used for washers.

S – steel

P – plastic

D – dual (a combination of plastic and steel)

Self-Test B-2.1: Describe Portable Power Tools Used in the Pipe Trades

Complete Self-Test 2.1 and check your answers.

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2776#h5p-3 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2776#h5p-3)

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Camosun College. (2015). Trades Access Common Core Competency C-2: Describe Common Power Tools and Their Uses. Victoria, B.C.: Crown Publications. Download for free from the B.C. Open Textbook Collection (https://open.bccampus.ca/browse-ourcollection/find-open-textbooks/).

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Camosun College. (2022). *Hilti DX 450* [Video]. BCcampus. https://media.bccampus.ca/media/Hilti%20DX%20450/0_qkdz82jw

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- **Figure 66** Powder-Actuated tool diagram (https://commons.wikimedia.org/wiki/File:Powder_Actuated_Tool_Diagram.png) is by Dustinmck on Wikimedia Commons, and is used under a CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0) license.
- **Figure 68** Ramset gun (https://commons.wikimedia.org/wiki/File:Ramset-gun.jpg) by Bill Bradley [billbeee] on Wikimedia Commons is used under a CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/deed.en) license.

B-2.2 Use Portable Power Tools

Electric Portable Power Tools

Proper maintenance improves the service life and performance of the tool. Correct setup and operating procedures ensure good results and aid in the prevention of injury. If electrically powered tools are not handled cautiously and kept in good condition, they become dangerous sources of electric shock and serious wounds. Power tools may also be cordless. These tools are extremely versatile in that you do not need to have an electrical cord connecting the tool to the power source. These tools are safer than standard power tools in that the risk of electric shock is greatly reduced, and there is no cord that could contribute to a tripping or mobility hazard.

Using and Maintaining Electric Power Tools

The following are important considerations when using portable power tools:

- They should be stored in an appropriate storage area.
- They should be carefully inspected before being taken out of storage and used.
- They should be routinely cleaned and lubricated, if required.
- Cordless tools should have the batteries charged and ready for use.

The following are more specific rules for handling and maintaining electric power tools:

- To prevent damage to the tool, be sure that the voltage of the power source matches the requirements of the tool.
- Be sure that the batteries are the correct type for the tool and that they are properly charged.
- Keep a spare charged battery on hand.
- Be sure that the equipment is properly connected to the power supply and that the circuit is grounded or the tool double-insulated.
- Keep the plug and cord in good condition: there must be no loose prongs on the plug and the cord must not show any signs of deterioration.
- Be sure that the switches on the tool work properly.
- Make sure that the switch is in the off position before you connect a power tool to a power supply.
- Before you switch on equipment, check to see if all the guards are in place and in good working order.
- Never carry a power tool by the cord or yank the cord to disconnect it from the receptacle.
- Keep the cord away from heat, oil, and sharp cutting surfaces.
- Never operate a power tool near explosive or flammable liquids or materials.
- If you plan to cut into a wall, floor or ceiling, make sure that there is no live wiring behind it.
- If an extension cord must be used, make sure that it is approved for heavy-duty work.
- Keep the air cooling passages in the tool clean and free of obstructions.
- Compressed air may be used to clean the tool's air cooling passages, but the pressure must be limited to 69 kPa (10 psi) or less and eye protection must be worn, as dictated by workplace regulations.
- Make sure that the cutting edge of a tool is kept sharp and that the bit or blade is securely fastened in the tool.
- Stay focused on your work.

- Never operate power equipment until you are sure you know how to use it.
- Make sure that the work is secure and will not slip under the force of the tool.
- Make all required adjustments before you start up the tool.
- Know how you intend to use the tool before you activate it.
- Wear eye protection when you use power saws and other power equipment that kicks up dust and particles.
- Feed the work to the machine or the machine to the work carefully and at a pace suitable for both the machine and the operation.
- Turn off the power when you finish the work, then wait until moving parts come to a stop before you leave the machine.
- Never use a power tool with a deformed or cracked housing, or with a broken handle or part. Damaged or inoperative tools should be reported to a supervisor.
- Before storing a power tool, wipe dust, dirt and chips off it with a cloth.
- Clean plastic parts with a soft cloth lightly dampened with soapy water. Never clean them with solvents such as gasoline, thinner, benzene, carbon tetrachloride or alcohol as these substances damage and crack plastic.
- Never allow the motor portion to become wet with water or oil.
- Store tools properly. For example, drills, screw guns and routers should have the bits removed, a circular saw must have the guard in place, sabre and reciprocating saws must have the blades removed, or the blades must be adequately protected.

Grounding Tools and Equipment

All tools and equipment that are operated by electricity must be grounded or of the double-insulated type. Workplace regulations require that when used outdoors or in a damp location, portable electrical equipment, including temporary lighting, be protected by an approved *ground fault circuit interrupter* (GFI).

On tools that are not double-insulated, you must use a three-wire cord and the proper U-ground prong on the cord. By properly grounding the equipment, the operator should not receive an electrical shock if the tool or equipment develops a short circuit.

Portable Electric Circular Saws

When using portable saws:

- Make sure that there is enough *set* in the teeth to produce proper clearance for the blade
- Make sure that the work is well supported, as this will keep the ***kerf*** (the slot cut by the saw) open and prevent the saw blade from binding during the cut
- Support thin pieces near the cut and clamp small pieces to the workbench or sawhorse
- Never use a blade that is dull, has missing teeth, or requires setting

Figure 1 *Electric portable circular saw (BC Industry Training Authority, 2019).*
CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

- Adjust the depth of the cut to the thickness of the stock plus $\frac{1}{8}$ in. to $\frac{1}{4}$ in. (3 mm to 6 mm) more
- Check to make sure that the base of the saw, the guide and all other adjustments are tight
- Place the base of the saw on the stock, making sure that the blade is clear before you turn the saw on
- While making the cut, stand to one side of the cutting line
- Never reach under the material while it is being cut
- If the saw stalls during a cut, release the trigger, back out the saw until it is free of the material, then resume the cut
- If the saw continues to stall, unplug it and look at the condition of the blade and the set of the teeth
- When you come to the end of a cut, release the trigger and allow the blade to come to a standstill—lift the saw away from the stock but do not twist the saw as you lift, otherwise you may score the work
- Always make sure that all guards are in place and functioning properly before using the saw

Powered Cut-Off (Chop) Saws

You need to be especially safety-conscious while operating this tool. Consider the following before using a powered cut-off saw:

- Make sure the blade guard is in place before operating the machine
- Secure the workpiece in the vise or clamp. Never hold the piece with your hands
- If you are cutting long pieces, have the end supported or held by an assistant, as the piece could kick back and break the cut-off blade
- Use a face shield, not just eye protection
- Use leather gloves to handle the cut pieces as they will be hot and likely will have sharp edges
- Do not use excessive force when cutting, and be careful not to bump the blade onto the work, as this could break the blade
- During the cutting operation, do not stand in line with the cut-off blade. Stand off to one side so that if the blade breaks, you will not be in line with flying pieces
- Avoid the temptation to use the side of the abrasive cutting blade for grinding purposes as it will weaken the blade

Reciprocating Saws

Plunge-Cutting Wood with a Reciprocating Saw

To save time on the job site, a plunge cut can be made in plywood without having to pre-drill a starter hole.

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

1. To make plunge cuts into wood or similar material, start by holding saw parallel to material, resting saw guide firmly against material but without having blade touch material.

Figure 3 *Hold saw parallel to material (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

2. While holding saw firmly against material, press the OFF/LO/HI switch and pivot handle end of saw, slowly bringing blade in contact with material.

Figure 4 *Pivot Handle Up* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

3. Raise saw slowly to upright position, keeping saw guide pressed firmly against material, and guide saw in this position along line of cut.

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

Portable Electric Drills

During heavier drilling operations, use both hands: one to apply force to the back end of the drill, and the other to hold the handle to counteract the ***torque*** generated by the drill. Always allow the motor on a reversible drill to come to a complete stop before switching the motor direction. Failure to do so will damage the motor.

Safety

If the bit jams, the forces used to turn the drill bit will be suddenly transferred to turning the electric drill. This sudden spinning of the tool in your hands can bruise, sprain muscles, or even break bones depending on the speed and torque of the tool. The risk of jamming increases with the diameter of the drill bit.

The more powerful the motor of the drill, the more force you will need to stop the drill from rotating. The faster the rotation of the drill bit, the more violent the reaction to jamming. If a risk of jamming exists, you should never lock the switch in the ON position. Keep your body clear of any path within the rotation of the drill. Be extremely cautious when drilling from elevated platforms or ladders.

Sharpening a Twist Drill

A correctly sharpened twist drill will cut mild steel with ease. Metal shavings should be produced equally by the two cutting lips of the drill. These shavings should eject from the hole in the shape of spiral coils. When the drill bit becomes dull, it must be sharpened.

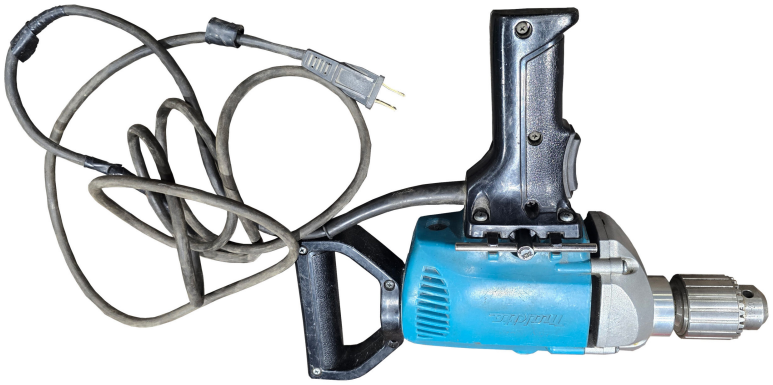
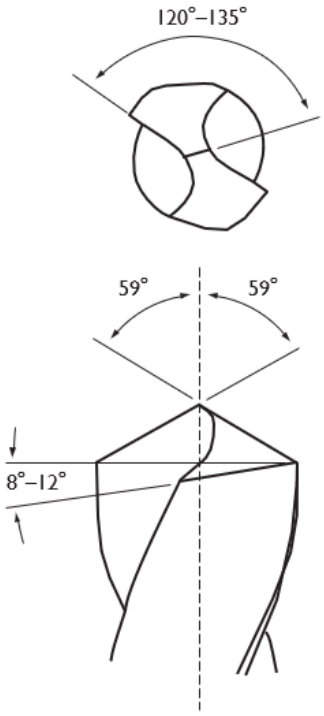


Figure 6 *Electric hand drill (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

There are jigs made to hold twist drills at the proper angle to the grindstone for sharpening. These jigs are not always available, so it is valuable to learn how to sharpen a twist drill by the free-hand method.

Correct Drill Bit Angles

For normal use, a twist drill will have the cutting lips at 59° to the axis of the drill. Check the angle of the cutting lip with a drill grinding gauge. Both lips should be at the correct angle and equal in length.



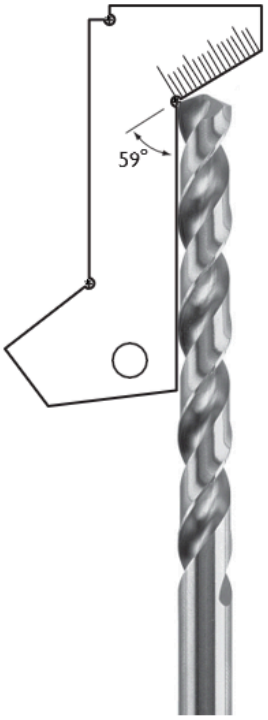


Figure 7 *Cutting angle*
(BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Figure 8 *Checking the angle*

Lip clearance on a drill bit can be compared to the heel clearance of a wood chisel. Not enough lip clearance will result in the cutting edge being held away from the workpiece surface. This chisel in the center image will cut when moved in the direction of the arrow because the heel clearance allows the cutting edge to make contact with the surface of the wood. Too much lip clearance, as shown at right, leads to rapid dulling of the cutting edge.

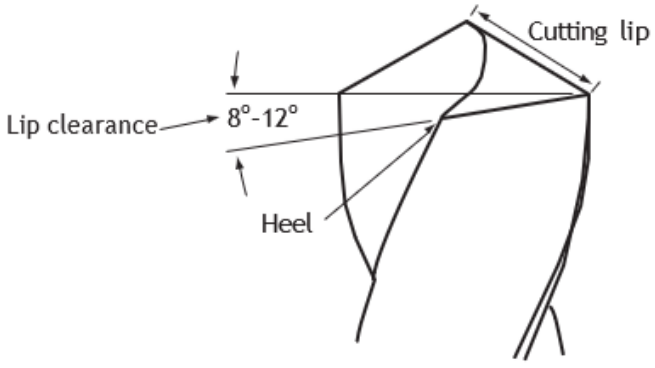


Figure 9 *Chisel heel clearance (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Lip clearance on a twist drill is the angular difference between the heel and an imaginary horizontal line perpendicular to the lip. On a twist drill, a lip clearance of 12° is usually considered adequate. The heel of each cutting face rises 12° from the left end to the right end.

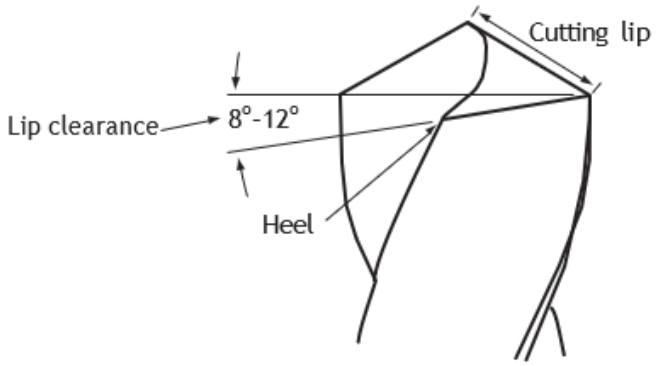


Figure 10 *Lip clearance (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Another method of measuring the lip clearance angle is to use the 12° end cut on the drill grinding gauge. To use this gauge accurately, place it on its edge on a flat surface. Lay the twist drill behind the gauge with the point of the drill toward the 12° end of the gauge. The slope of the heel should be parallel to the 12° end of the gauge.

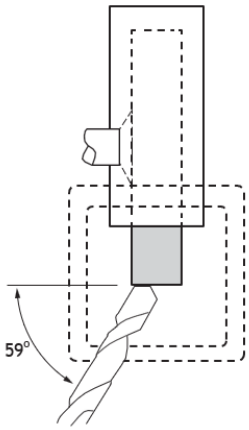


Figure 11 *Placement of the twist drill (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The drill should be lying with its cutting lips parallel to the flat surface and should be sighted, as illustrated.

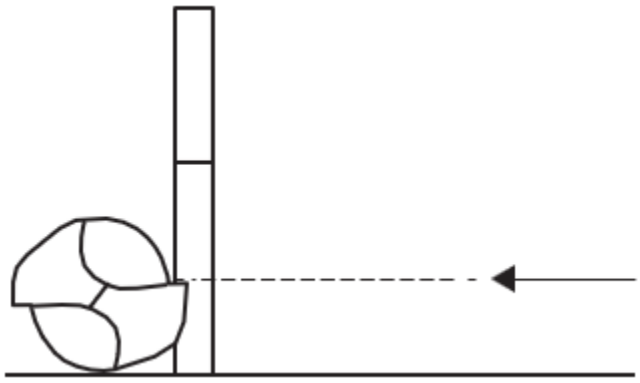


Figure 12 *Checking the twist drill* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Hammer Drills

Drilling and setting concrete anchors is commonly done with a hammer drill or roto-hammer.

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

There are many types of concrete anchors, but all serve the same purpose. They provide a secure mount for a bolt or a stud so that attachments can be made to a wall or foundation.

Consider the following points when setting anchors.

1. The strength of the concrete determines the holding power of the anchor. Drill only anchors into cured concrete and do not attempt to fasten to ***spalled*** (fractured) or cracked surfaces.
2. Follow the manufacturer's instructions for installing the anchor.
3. Most concrete anchors use a wedging action to hold the anchor in place. The wedging action will work only if the diameter of the hole is the correct size for the anchor being used. Refer to the anchor manufacturer's specifications for the appropriate diameter of hole.
4. The depth of the hole is also critical. Use the depth gauge to ensure the depth is exactly as specified by the manufacturer.

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

Always use steel bits with carbide tips when drilling into concrete with a hammer drill or a rotary hammer. Carbide-tipped bits are extremely hard and are designed to stand up to concrete. Helix-shaped bits are designed specifically for concrete. The helix shape removes the maximum amount of debris and helps to prevent the drill from binding in the hole.

Carbide tips are extremely hard, but also very brittle.

Never try to straighten a bent bit in a hole or to use the drill like a lever because the tip of the bit will chip and may break off.

Handle carbide-tipped bits with care. Do not allow them to drop onto hard surfaces. Store them in separate spaces to keep the tips from hitting together.

Carbide-tipped bits are usually very expensive to replace.

Demolition Hammers

Demolition hammers are used to chip or break up concrete foundations, walls or blocks.

- Use the shortest bit that is practical for the job. Long bits tend to bend and absorb some of the blow's energy.
- Make sure that the bit is sharp before you start work (careful to not remove the bit's *temper*).

- When you work with a demolition hammer, start the bit into the edge of the block or slab and turn it toward the edge. Take small "bites."
- Always allow the weight of the hammer to assist in the breaking action. Use its weight to your advantage but always maintain your balance.

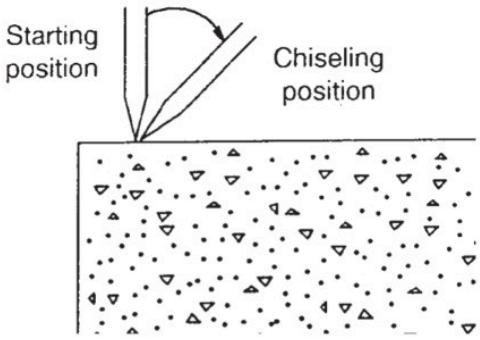


Figure 15—Working toward the edge when chipping concrete

Figure 15 *Working toward the edge when chipping concrete* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

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

Portable Grinders

Wheel (Disk) Selection

Selection of the correct grinding wheel or disk not only depends on the abrasive type, grain size, bonding material, grade, structure, size and shape, but also on the grinding machine, the material to be ground, and the nature of the operation. Medium-grain wheels (30 to 60 grit) are often chosen when only one metal-removing or sharpening operation is desired and the resulting surface finish is acceptable. Wheels having coarse grains (below 30 grit) work best with softer materials where material can be removed rapidly. Many bench grinders, for example, will have one wheel with a 30 grit and the other with a 60 grit.

When using ***zip disks (cut-off disks)***, ensure that your entire face and body are out of the disk's path and that you wear a face shield and safety glasses. Cases have been well documented where cutting disks have shattered in operation and severely injured or even killed workers.

Never use a cutting disk or blade for grinding purposes. They are designed to cut on their edge only.

There are some rules that must be observed when using portable grinders:

- A*lways* wear a face shield
- Use a portable shield to prevent sparks from hitting other workers
- Wear leather gloves and protective clothing
- Always use hearing protection
- Use both hands to control the grinder unless the grinder is so small that full control can be achieved with one hand
- Ensure that the RPM rating of the disk or wheel will not be exceeded by the RPM of the tool
- Secure the workpiece to prevent any movement during the grinding operation
- Ensure that the wheel or disk is suitable for the type of material on which you are working
- Ensure that the disk or wheel has not been damaged
- Remove flammable materials before grinding
- Never grind near disassembled components that could be contaminated or damaged by grit and sparks
- Keep sparks away from glass or finished surfaces
- Never remove the guard from a grinder and never use a grinder without a guard

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

Portable Electric Pipe Fabrication Tools

Geared Threader with a Portable Power Drive

1. Insert the pipe in the threader and centre the end of the pipe in the throat of the dies.
2. Turn the work holder with a socket wrench to centre the pipe and hold it in position.
3. Tighten the clamp screw, securely locking the pipe in the work holder.
4. Place the oiler directly under the threader.

Notes:

- Long pieces of pipe must be supported by a pipe support, with the pipe free to rotate as it is threaded.
- If the pipe is installed in a tri-stand vise, the die head must be free to rotate. Both the tri- stand vise and the power vise, however, must be bolted to the floor.

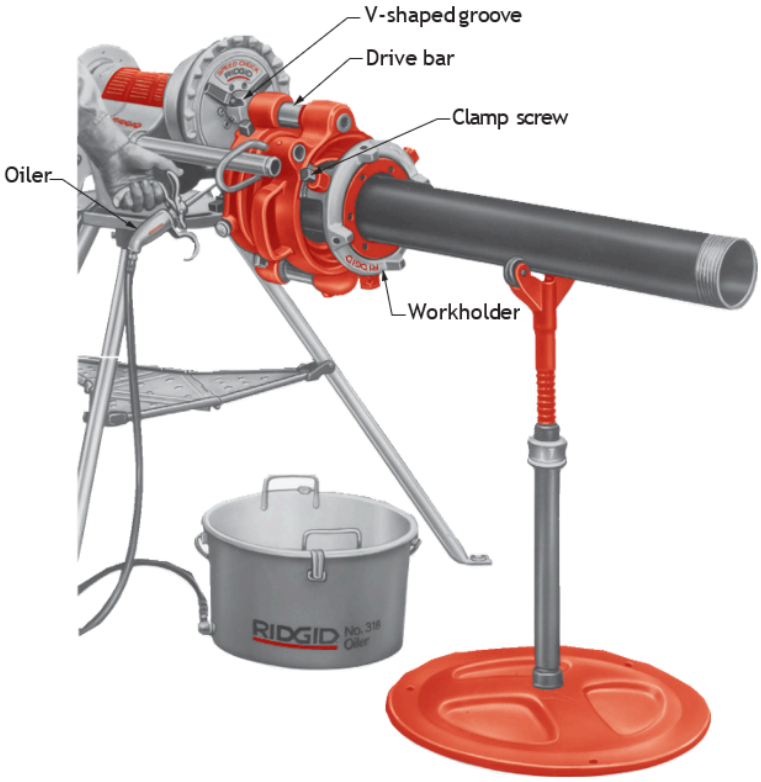


Figure 18 Oiler and geared threader (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Figure 19 *Using the portable power drive with the geared threader* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Pneumatic Portable Power Tools

All air tools require a large volume or flow of compressed air at a specified dynamic air pressure in order to operate efficiently. Dynamic air pressure is described as the pressure that is maintained while the air tool is in use. Static air pressure is the air pressure in the line when the air tool is not in use. The static pressure is always higher than the dynamic pressure. An air line and hose of the correct size are prime factors in maintaining adequate dynamic air pressure.

Filters and Regulators

When air is excessively wet, water shoots out of the exhaust port, which is unpleasant for the operator and can damage the work. In cold weather, moisture in the tool's air passages may freeze, rendering the tool inoperable.

Most of the moisture is removed at the compressor before it can enter the system. To remove any moisture still remaining, a filter and moisture separator is located at the beginning of the air-line hose. The trap on the water separator should be drained on a daily basis when the system is in regular use.

The regulator regulates the air pressure. A gauge at the front of the regulator shows the pressure reading. Air tools are rated for capacity and performance at an operating air pressure according to manufacturer's specifications. The pressure regulator should be preset to maintain this level of pressure at the tool.

Lubricator

The manufacturer's instructions for each type of tool should be followed, since lubrication requirements of air tools are different. Air tools require specially formulated air tool oil. Other oils, unless specifically recommended, should not be used because they can cause sticking and sluggish performance. In addition, some lubricants may contain toxic additives, which become a serious respiratory hazard when vapourized.

Some air tools have built-in oil reservoirs for continuous lubrication. The best way to ensure proper air tool lubrication is to connect air line lubricators at the end of each pipeline leading to an air tool hose. The air-line lubricator mixes a small amount of oil with the air, and all parts of the tool except those requiring a grease lubricant are then kept adequately lubricated. The lubricator reservoirs are usually made from clear plastic, allowing the oil level to be checked easily.

Air Hose

Air hoses must be protected from cuts and other damage and from oil or grease. Never drive over them or use them to pull attached air tools across the ground or floor.

Never leave air hoses lying on the floor where they can become damaged or weakened by being run over by vehicles or equipment. Store hoses so that the ends are connected.

Figure 20 *Store hose with ends connected (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Air-Impact Wrench

Be careful when using large impact wrenches, as the torque can twist the tool out of your hands.

The pneumatic impact wrench shown has a square drive. Torque is controlled by regulating the airflow to the motor of the wrench. Even though there is little torque reaction, air-impact wrenches can produce very high torque values and you need to exercise caution. In-line air pressure regulators are sometimes required to control torque.

Air-Operated Grinder

A portable pneumatic grinder is more convenient to use if a 1 m (3 ft.) foot whip (leader) hose is attached directly to the tool and the air-line coupling is away from the tool. Although larger hoses are preferred for many pneumatic grinders, all hoses must have inside diameters of at least $\frac{1}{4}$ in. Before using, adjust the throttle lever stop-screw. The grinder speed is regulated by the distance the throttle lever is pulled or turned.

Air Hammers and Chisels

An air hammer or chisel may incorporate the use of a tool ***retainer***. Its primary purpose is to keep the chisel or other attachment from flying off the end of the pneumatic hammer due to the intense vibration and ***percussive force*** generated during use. One type of tool retainer is the ***beehive spring***, which threads on the barrel. The ***quick-change spring*** (a slight design variation of the beehive spring) has a retaining hook that can be pushed sideways for fast and easy tool bit installation or removal. To provide a more secure hold, a U-shaped ***safety collar*** can be used with either spring. Another retainer that reduces the possibility of a tool bit becoming loose is the *safety sleeve*. The safety sleeve is not used in conjunction with a spring but simply threads on the barrel.

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

The following safety rules apply to air hammers and chisels:

- Always use hearing and eye protection
- Always point the tool away from yourself and anyone else
- Always disconnect the air hose when changing the tool end

General Safety Precautions for Pneumatic Tools

The following safety rules apply to all pneumatic tools:

- When you use or work around a pneumatic tool, wear hearing protection, safety glasses with side shields, and steel-toed safety boots.
- Always inspect the air hose for fraying, kinks, loose or clogged fittings and air leaks.
- Keep the stapler or nailer pointed in a safe direction. Never assume that the stapler or nailer is empty. The tool you think is empty may fire and seriously hurt you or a fellow worker.
- Disconnect the tool from the air supply when you load the tool or change the depth of drive adjustment.
- Always disconnect the tool from the air supply to clear a jam, to change tool bits, or when you have completed the task.
- Carry the tool by the handle only. Never carry it by the air hose and do not touch the trigger while you carry it.
- Never operate a pneumatic tool if it is not working properly.
- Always use the recommended air pressure and check the gauge twice a day. Never use bottled air or gases to power the tool as they could cause the tool to explode.
- Clean the tool at least daily and lubricate it as needed. Never operate a dirty tool.
- Do not weaken the tool housing by abusing the tool: do not throw the tool, strike the tool housing, or use the tool as a hammer.

Powder-Actuated Tools

Powder-actuated tools, like any power tool, can be extremely dangerous if handled improperly. For that reason,

they must be used in accordance with local Workplace Safety Regulations. Strict attention must also be paid to the manufacturer's instruction manual.

Figure 22 *Using a powder-actuated tool (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

To ensure proper operation of the double guidance system, these points should be considered:

- The washer must fit snugly into the chamber.
- The proper cartridge and fastener must be selected for the tool being used.
- The piston and the nail are each number coded. The numbers must match.

In selecting ***fasteners***, the operator of the powder-actuated tool must also consider:

- The type of material to be penetrated: concrete or steel?
- The amount of ***penetration*** required.
  ▸ For concrete, approximately 25 mm (1 in.) penetration is required. For steel, penetration should be a maximum of 12 mm ($\frac{1}{2}$ in.).

- The length of fastener required.
  ▸ Type of material plus amount of penetration will determine the length of the nail. For example, to fasten a 50 mm × 100 mm (2 in. × 4 in.) onto concrete, a 75 mm (2 $\frac{7}{8}$ in.) nail would be needed for 25 mm (1 in.) penetration into the

concrete.

Material Suitability for Powder–Actuated Fasteners

Fasteners can be set into two materials only: concrete and steel.

The holding ability of a ***powder-actuated fastener*** depends on the force of compression of the material into which the fastener is driven. On penetration, the fastener displaces and compresses the material. The material then tries to return to its original form and, in that effort, exerts a squeezing effect (Figure 24). This is called ***holding action***.

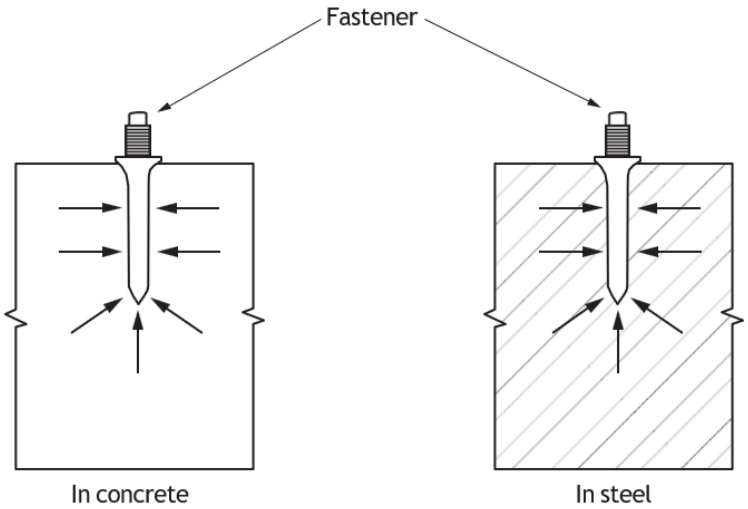


Figure 23 *Holding action on fasteners* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Concrete

Notes about driving fasteners into concrete:

1. The fastening pin must be set only into the solid part of the concrete block. Also, because only the horizontal joint is under pressure, never fire a fastener into the vertical mortar joint.
2. The minimum thickness of concrete into which a fastener can be set must be three times the penetration of the

fastener; but at no time may the concrete be less than 75 mm (3 in.) thick. When fastening into concrete block, be sure the web is at least 75 mm (3 in.) thick.
3. Fastenings must always be at least 75 mm (3 in.) away from a concrete edge.

A good way to determine if a concrete block has a rating adequate for a powder-actuated fastener is to test its strength by using a fastener as a centre punch.

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

Set the fastener against the concrete. Strike the fastener with a hammer and note the effect. If the concrete is not marked, it is too hard for fastening.

In addition to avoiding concrete that is too soft, too hard, or brittle, follow these additional "**do-not**" safety rules:

1. **Do not** set a fastener into an area where bits of concrete have exploded away as a result of an earlier attempt to insert a fastener. These chipped surfaces, known as spalled areas, are hazardous for powder-actuated fastenings.
2. **Do not** attempt a fastening into precast concrete beams containing pre-stressed cables. Pre-stressed cables struck by a fastener may cause the beam to weaken. In extreme cases, the beam could fail or the cable could rupture and cause injury.
3. **Do not** attempt to set powder-actuated fasteners close to the edge of a concrete block. The block will shatter.
4. **Do not** use a powder-actuated tool where atmospheric conditions are conducive to an explosion or fire. Flammable vapours can be ignited by the spark when the tool is fired.

Steel

Steel must be at least 5 mm ($\frac{3}{16}$ in.) thick for powder-actuated fastenings; but the operator should expect penetration of up to 12 mm ($\frac{1}{2}$ in.). (The tip will protrude through $\frac{3}{16}$ in. steel.)

The fastening pin must be a minimum of 50 mm (2 in.) away from any weld or torch cut and at least 12 mm ($\frac{1}{2}$ in.) away from the edge of the steel.

To determine whether or not it is safe to set a fastener into steel, use the fastener as a centre punch. If, when struck with a hammer, the fastener marks the steel, it will penetrate.

Materials that may be fastened onto concrete or steel are:

- Wood
- Plywood
- Sheet metal
- Plastic

Note: Threaded or eyelet fasteners are used for holding light materials or loads, such as suspended ceilings.

Materials that cannot be fastened onto concrete or steel are:

- Brick
- Ceramic tiles
- vitrified tiles
- Glass
- Asbestos

Powder-Actuated Tool Regulations

Most jurisdictions require that operators of powder-actuated tools be trained or certified before using the equipment to ensure safe operation and handling. Guidance on the safe use of powder-actuated tools is provided by organizations such as CCOHS: Powered Hand Tools – Powder-Actuated Tools (https://www.ccohs.ca/oshanswers/safety_haz/power_tools/powder.html) webpage, and workplace requirements are set out in provincial health and safety regulations, including Powder Actuated Tools 12.51 Standards (https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation/part-12-tools-machinery-and-equipment#SectionNumber:12.51) in the Occupational Health and Safety Regulation of British Columbia (WorkSafeBC) webpages. These sources outline requirements for operator training, safe handling, storage of power loads, and the proper use of fasteners and equipment.

The following *sample regulations* and safety practices illustrate common requirements for the safe use of powder-actuated tools and should be considered good practice. Always consult the applicable workplace health and safety regulations in your jurisdiction and follow the manufacturer's instructions for the specific tool being used.

- A low-velocity powder-actuated tool, with a fastener test speed rating of less than 100 m (330 ft.) per second, must be used unless no low-velocity tool is available on the market that is capable of doing the fastening task.
- When not in use, a powder-actuated tool must be unloaded and the tool and power loads must be securely stored and accessible only to qualified and authorized persons.
- Power loads of different power levels and types must be kept in different compartments or containers.
- Only a qualified person may handle or use a powder-actuated tool or power loads.
- The operator must have immediately available when using or servicing a powder-actuated tool:
  ▸ a copy of the manufacturer's operating instructions for the tool
  ▸ a copy of the power load and fastener charts for the tool, and
  ▸ any accessories or tools needed for use or field servicing of the tool, including personal protective equipment

- A powder-actuated tool must not be used in an explosive or flammable atmosphere.
- A powder-actuated tool may only be loaded when it is being prepared for immediate use, and must be unloaded at once if work is interrupted after loading.
- A powder-actuated tool must not be pointed at any person.

- If a powder-actuated tool misfires, the operator must hold the tool firmly against the work surface for at least 5 seconds. Then follow the manufacturer's instructions for such occurrences and, until the cartridge has been ejected, keep the tool pointed in a direction that will not cause injury to any person. Place the misfired cartridge into water to prevent accidental discharge.
- A powder-actuated tool fastener must not be driven into very hard or brittle materials, such as cast iron, glazed tile, hardened steel, glass block, natural rock, hollow tile, and most brick.
- A powder-actuated tool fastener may only be driven into easily penetrated or thin materials or materials of unknown resistance if the receiving material is backed by a material that will prevent the fastener from passing completely through.
- A powder-actuated tool fastener must not be driven into steel within 13 mm ($\frac{1}{2}$ in.) of an edge, or within 50 mm (2 in.) of a weld except for special applications permitted by the tool manufacturer.
- Except for special applications recommended by the manufacturer, a powder-actuated tool fastener may not be driven into masonry materials:
  - ▸ Within 75 mm (3 in.) of an unsupported edge with a low velocity tool, or
  - ▸ Within 150 mm (6 in.) of an unsupported edge with a medium or high velocity tool
  - ▸ A powder-actuated tool fastener must not be driven:
  - ▸ Into concrete unless material thickness is at least 3 times the fastener shank penetration
  - ▸ Into any spalled area, or
  - ▸ Through existing holes unless a specific guide means, as recommended and supplied by the tool manufacturer, is used to assure positive alignment.
- Clean powder-actuated tools daily or after every 100 fastenings.
- Only have authorized service shops repair defective tools.

Figure 25 *Medium powder-actuated fasteners (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Self-Test B-2.2: Use Portable Power Tools

Complete Self-Test 2.2 and check your answers.

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2786#h5p-4 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2786#h5p-4)

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B-2.3 Describe Stationary Power Tools Used in the Pipe Trades

Stationary power tools are used in the piping trades for fabrication and production of material used for installation, alteration and repair of systems. Commonly, many of these tools will be found on larger construction projects and in fabrication shops.

Metal Cutting Band Saw

Metal cutting band saws are available in a variety of models and sizes.

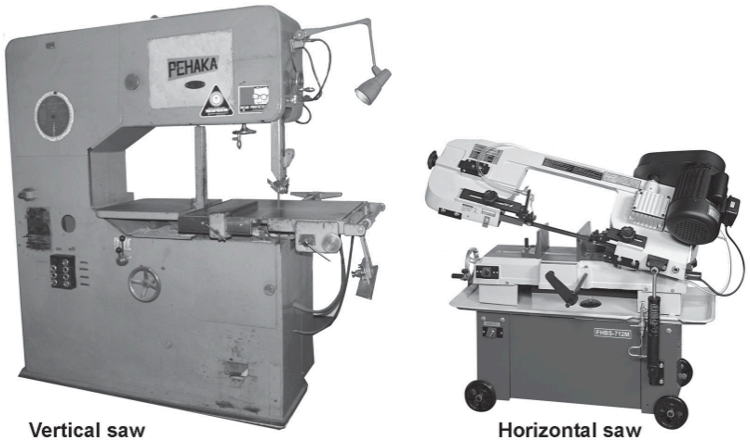

Figure 1 *Metal cutting band saw (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The size of the metal-cutting band saw is designated by the thickness of stock it can cut. Standard sizes are 115 mm, 180 mm, and 255 mm (4 $\frac{1}{2}$ in., 7 in. and 10 in.). Some larger models are capable of cutting through a pipe that is 50 cm (20 in.) in diameter. A built-in vise holds the material being cut. The vise can be rotated to allow a range of cutting angles.

These saws produce an accurate cut without an excessive buildup of heat. Some saws are equipped with a mist spray cooling system that cools and lubricates the saw blade.

The smaller models regulate the amount of cutting pressure by use of an adjustable counterweight. Larger models use a hydraulic system to regulate the feed pressure. All models are designed to shut off once the workpiece is cut. These features allow the saws to be left unattended during long cutting operations. If several smaller pieces need to be cut, they can be cut simultaneously, providing they can all be secured in the vise.

The speed of the saw blade can be reduced to prevent heat buildup during a heavy cut. Speeds may range between 21 m/min (65'/min) to 90 m/min (300'/min).

Wear the appropriate safety equipment with all cutting machines including safety glasses and a face shield, which will protect your eyes from small particles of metal that can be sent flying during the operation.

Metal-Cutting Blades

Metal-cutting band saw blades are defined by their grades of steel, tooth formation, tooth set and blade width. Grades of steel include;

- Carbon
- Semi-high speed
- High-speed steel

Tooth formations include:

- Regular
- Hook
- Skip

Carbon Steel

Carbon steel blades are used for general purpose cutting on a standard band saw. Blades made of carbon steel are less expensive to buy but are less durable than the other grades.

Semi-High-Speed Steel

Semi-high-speed steel blades cut 50% faster than carbon steel blades. They are harder than carbon steel but are able to withstand mechanical shocks and vibrations that would break harder, more brittle blades.

High-Speed Steel

High-speed steel blades cut better and last longer than other blades but are more expensive and more delicate than the other two grades.

Regular Tooth

Band saw blades with ***regular teeth*** are used for straight and curved cuts in most ferrous and hard non-ferrous metals. Blades with regular teeth can be considered general-purpose blades.

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

Hook Tooth

The ***hook-tooth blade*** is best for fast cutting of non-ferrous metals. The large rounded gullets are capable of fast chip removal and the forward slope of the tooth requires less downward pressure to cut. Thin sections of metal should not be cut with this tooth style due to the wide spacing of the teeth.

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

Skip Tooth

The ***skip tooth*** is very similar to the hook tooth blade, except for the fact that the skip tooth can cut ferrous metals, whereas the hook tooth can cut only softer metals. The wide spacing of the skip tooth makes the blade suitable for fast cutting of large sections of steel.

Figure 4 *Skip tooth (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hook- and skip-tooth types are available in pitches from 3 to 6 teeth per inch. Regular-tooth styles range from 6 to 32 teeth per inch. The number of teeth per inch affects the cutting speed of a band saw, and the size of stock it is best suited to cut. Blades with large numbers of teeth per inch are able to cut small, thin pieces of metal but are slow for cutting large sections. Blades with few teeth per inch cut faster but are too coarse for cutting thin sections of metal.

Tooth Set

Set is defined as the left-and-right positioning of the teeth to provide a wider cut than the thickness of the blade. The wide cut provides clearance for the blade within the cut, preventing binding and overheating.

There are two types of tooth sets available on metal-cutting band saws: the raker set and the wavy set.

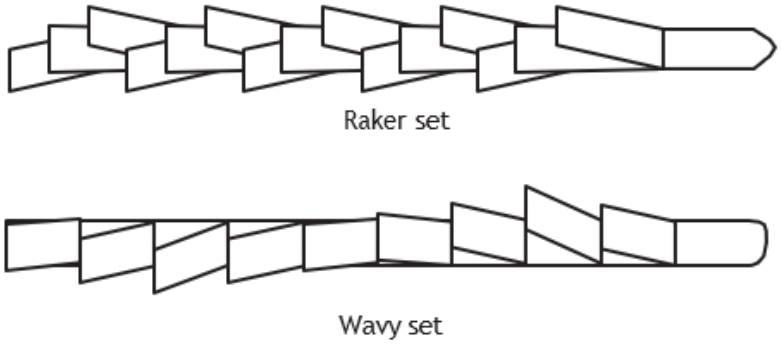

Figure 5 *Tooth Set (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Hook- and skip-tooth blades have raker set teeth. Regular-tooth blades with up to 24 teeth per inch come with either raker set or wavy set teeth. All regular-tooth blades with more than 24 teeth per inch have wavy set teeth.

Blade Width

Band saw blades are available in widths ranging from 6 mm to 32 mm ($\frac{1}{4}$ in. to 1 $\frac{1}{4}$ in.). The narrower blades are able to cut curves of a smaller radius than the wider blades. Wide blades are used for straight cuts.

Stationary Grinder

Stationary grinders may be mounted on a bench or a free-standing pedestal.

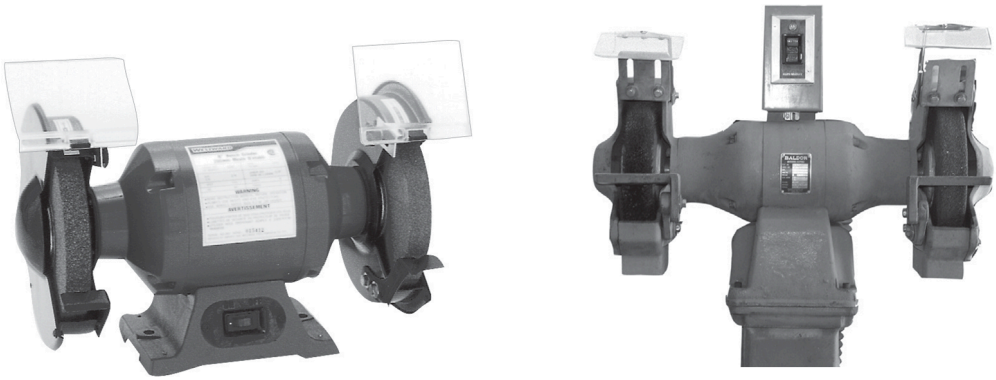

Figure 6 *Bench Grinder (left) and Pedestal Grinder (right) (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Stationary grinders consist of an electric motor with grinding or wire wheels attached to both ends of the motor shaft. The wheels are enclosed in guards that support a tool rest at the front and a spark shield. The wheels rotate so that they travel toward the operator from the top of the wheel.

Tool Rest

The ***tool rest*** is adjustable and must be positioned no lower than the centre of the wheel. The distance between the front edge of the wheel and the tool rest must not be more than 3 mm (1/8 in.).

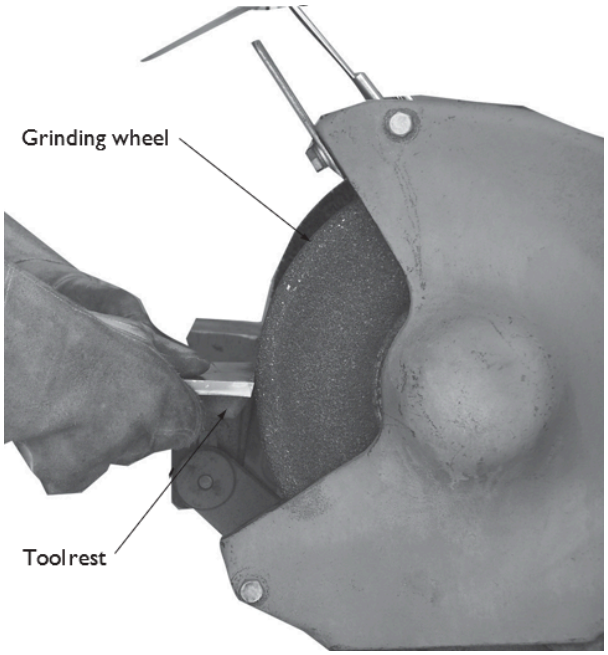

Figure 7 *Bench grinder using a tool rest (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Spark Guard

Sparks are created during the grinding of ferrous metals or when using the wire wheel. To reduce the number of sparks that hit the operator, a ***spark guard*** is mounted at the upper end of the exposed portion of the wheel. The spark guard should be mounted as close as possible to the surface of the wheel. During wire wheel brushing, grit, dust and wires may be thrown off. The spark guard reduces operator risk from flying debris. A spark guard is not a substitute for a face shield. A face shield must also be worn when sparks are expected.

Grinder Ratings

Stationary grinders have motors with different horsepower ratings. As the horsepower increases, the grinding wheels become wider and larger in diameter. Motor speeds are reduced as the diameter of the grinding wheel becomes larger.

The wheels on stationary grinders are secured between two large clamping washers or flanges held tight by a nut on the end of the spindles. The nut on the left (as seen from the front) has a left-hand thread. Removing this nut requires a clockwise rotation. The nut on the other end of the grinder has a standard right- hand thread.

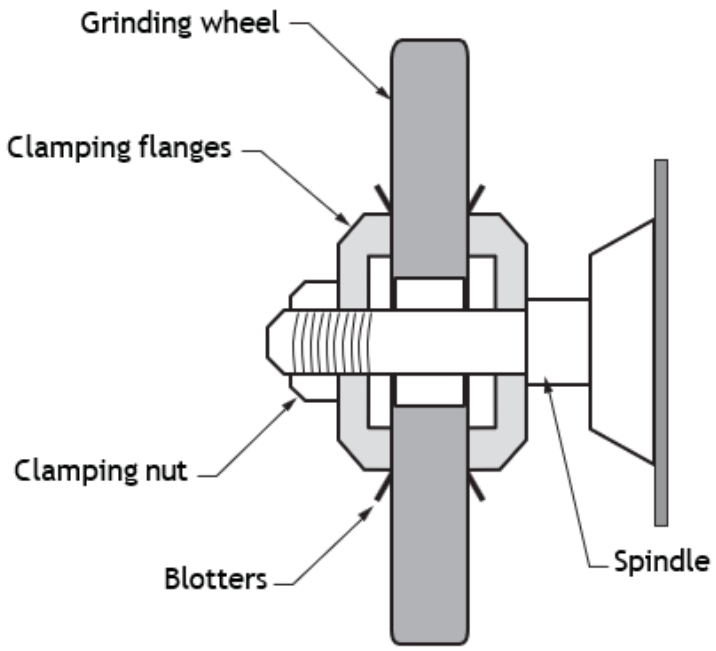

Figure 8 *Grinding Wheel* (*BC Industry Training Authority*, 2019). *CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

When replacing a wheel, make sure the new wheel has an RPM rating that either matches or exceeds the no-load speed of the motor.

Grinding wheels are supplied with a blotter-type paper disk on each side. The disks serve to cushion the strain caused by the flanges when the clamping nut is tightened.

Grinding wheels with hair-line cracks are unsafe and must be discarded. To test for cracks, simply stand the wheel on

edge and tap the sides with a hard object, such as a screwdriver handle. Cracked grinding wheels will give off a dull sound, while a good wheel will give off a ringing sound.

Power Drives and Accessories

Power drives (also called power vises) rotate pipe so that hand tools can be used for cutting, reaming and threading operations. They are also used to drive tools that groove or thread pipe. The drive centres, holds, and rotates the workpiece as the various operations are performed.

A Forward-Off-Reverse switch selects the desired direction of rotation. To change the rotation of a vise in operation, turn the switch to the off position and wait for the machine to stop completely before flipping the switch to the opposite position.

Power vises may be mounted on a bench or on a three- or four-legged stand, depending on the type of vise and the work conditions.

Power vises, like the Ridgid Model 300 power drive, are widely used in the piping industry. This machine is designed to accept a carriage of power-driven accessories, as well as for use with hand tools.

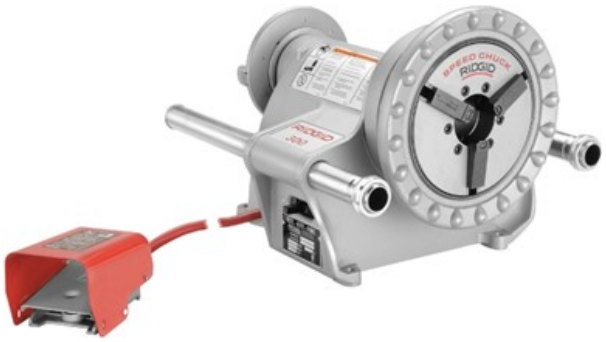

Figure 9 *Ridgid Model 300 Power Vise (RIDGID TOOLS/ Emerson Professional Tools) Used with permission.*

Accessories for the Model 300 Power Drive

With mounted accessories, the Model 300 power drive can serve as a threading machine. The die head, cutter, and reamer are positioned on a carriage, which slides onto support bars.

A. Die head and dies for threading
B. Pipe cutter with wide rollers for straight cuts at power-drive speed. Capacity: 3 mm to 50 mm (⅛ in. to 2 in.) pipe
C. Reamer. Capacity: 3 mm to 50 mm (⅛ in. to 2 in.) pipe
D. Carriage with lever
E. Three-legged stand to hold the vise and pipe at the proper working height. The stand folds up when not in use and is held together by a chain lock.
F. Foot switch and power cord which allows for remote operation.
G. Oiler
H. Oil reservoir

Figure 10 *Model 300 Ridgid (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

The ***oiler*** is used for applying thread-cutting oil to produce accurate, smooth threads and keep dies cooled and lubricated.

The oiler includes a hand-operated pump, a hose, and a reservoir containing a screen and chip pan. It is used only during the threading operation.

The clip-on tool tray is designed to hold hand tools while working with the power drive.

Figure 11 *Clip-On Tool Tray (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The ***nipple chuck*** (Figure 12) holds nipples or studs for threading when the vise jaws may damage the threads or when they are too short to be held in the vise. The chuck releases them easily when threading is complete.

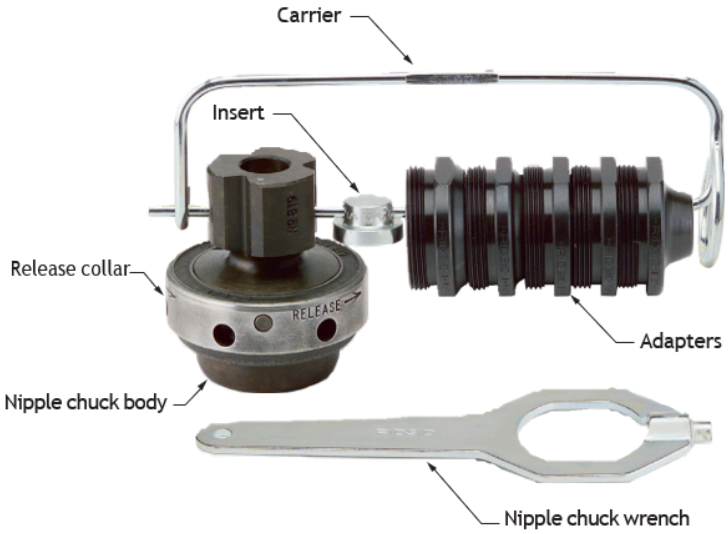

Figure 12 *Nipple Chuck (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The telescoping universal jointed drive shaft, when used with a power vise, can drive a geared threader. The pipe must be secured in a separate stationary vise. The drive shaft length can be extended from 104 cm (41 in.) to 127 cm (50 in.).

Figure 13 *Telescoping Universal Jointed Drive Shaft (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 14 shows two types of adjustable pipe supports. Right-angle rollers in one style let pipe turn freely. The capacity is 10 in. pipe. Pipe supports can also be made on-site from scrap pipe, threaded rod and channel iron.

Figure 14 *Adjustable Pipe Supports (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

Stationary Threading Machines

The threading machine differs from a portable power drive in that the cutter, the reamer, the carriage for the die head, and the pump to circulate thread cutting oil are built-in parts of the machine, not optional attachments. All machines are operated by a foot switch.

The threading machine is a portable machine that has the power and capacity to cut, ream, and thread large diameter pipe and conduit from 13 mm to 10 cm ($\frac{1}{2}$ in. to 4 in.). They can be bench mounted or fitted to a stand.

As an example, the Ridgid No. 535 pipe and bolt threading machine has a hand speed chuck or auto-chuck (to hold pipe without slipping), and the pipe can be inserted from the front or the back. Like other power threading machines, this model has tools that operate independently and swing up and out of the way when not in use. A variety of dies and die heads are available for the No. 535. A reversible pump re-circulates thread cutting oil making them a self-oiling threader. Some machines have die heads with oil passages built right into the head.

The machines can be bench mounted or fitted to an open leg or wheeled stand. Pipe capacity for the Model 535 is 13 mm to 50 mm ($\frac{1}{2}$ in. to 2 in.).

Figure 15 *Pipe and Bolt Threading Machine No. 535 (RIDGID TOOLS/ Emerson Professional Tools) Used with permission.*

The Ridgid Model 1224 threading machine threads 6 mm to 50 mm ($\frac{1}{4}$ in. to 2 in.) pipe at 36 RPM and 6 cm to 10 cm (2 $\frac{1}{2}$ in.to 4 in.) pipe at 12 RPM.

Due to their larger capacity, machines like these are ideal equipment for large construction sites and pipe fabrication shops.

Figure 16 *Ridgid Model 1224 Stationary Threading Machine (RIDGID TOOLS/ Emerson Professional Tools) Used with permission.*

Compact styles of threading machines have also been developed for the pipe trades industries that are well suited to light duty and service work, typically for pipe up to 25 mm (1 in.) in diameter. Most can be mounted on roll-away

folding stands or simply placed on a bench or tailgate for quick threading at the jobsite. Some threaders have even been developed to use an oil-free solvent to cool the dies when threading, providing for cleaner fabrication where required.

Figure 17 *Ridgid Model 1210 Oil-Free Compact Threading Machine (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

Stationary Grooving Equipment

Through the use of special equipment, piping can be smoothly and uniformly grooved for mechanical couplings and fittings. As with power threading operations, an adjustable pipe support will often be required when using grooving attachments.

The Ridgid Model 975 combo roll ***groover*** uses rollers to form grooves in standard and thin-wall pipe. It can be combined with a power drive for machine grooving jobs, but it is also designed to manually groove pipe in-place. The 975 also comes with a permanently fixed depth setting gauge for quick setup.

Figure 18 *Ridgid Model 975 Combo Groover (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

Designed for quick, multiple field work, groovers like the Ridgid Model 916 are designed to be driven only by some type of power drive. Groovers like these use a single-stroke feed mechanism that allows for quick operation and minimal effort. These units have capacities of 15 cm (6 in.) diameter for copper and light wall steel, and 8 cm (3 in.) for schedule 40 steel pipe.

Figure 19 *Ridgid Model 916 Stationary Power Driven Groover (RIDGID TOOLS/ Emerson Professional Tools) Used with permission.*

Also intended to be driven by a power vise, the Model 918 is an example of a heavy-duty hydraulic groover designed for light wall pipe up to 30 cm (12 in.) in diameter, and schedule 40 steel up to 20 cm (8 in.). The 15 tons of force exerted at the forming wheels allows for precision grooving.

Figure 20 *Ridgid Model 918 Stationary Power Driven Hydraulic Groover (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

It has an extra set of support legs for additional stability and a built-in pressure gauge for accurate control of hydraulic pressure while grooving. With one of the largest capacities available, it can handle light wall pipe up to 60 cm (24 in.) and Schedule 40 pipe as large as 30 cm (12 in.).

The Ridgid 920 roll groover is a larger version of the 918 hydraulic machines, but like other groovers discussed in this section it still requires the use of a power drive to provide the muscle.

Figure 21 *Ridgid Model 920 Large Capacity Stationary Power Driven Hydraulic Groover (RIDGID TOOLS/Emerson Professional Tools) Used with permission.*

External mounting and drive action can provide quick, accurate cutting and grooving of ductile iron pipe and heavy-walled carbon steel pipe. Cut grooving removes less material from the wall of a pipe than threading does, and allows for some pipe separation and deflection.

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

Drill Press

The ***drill press*** is one of the most practical power tools because of its versatility and ease of operation. A drill press can be floor or bench mounted.

Figure 23 *Drill press (Camosun College/BCcampus) CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Construction

The four basic parts of the drill press are the base, column, table and head. The head is the entire working mechanism attached to the upper end of the column. The table can be moved up and down on the column. On some models, the table can be swung to either side or tilted.

The chuck is moved downward by means of simple rack-and-pinion gearing worked by the feed lever. The feed lever is returned to its normal position by means of a coil spring. You can lock the feed and pre-set the depth to which it can travel.

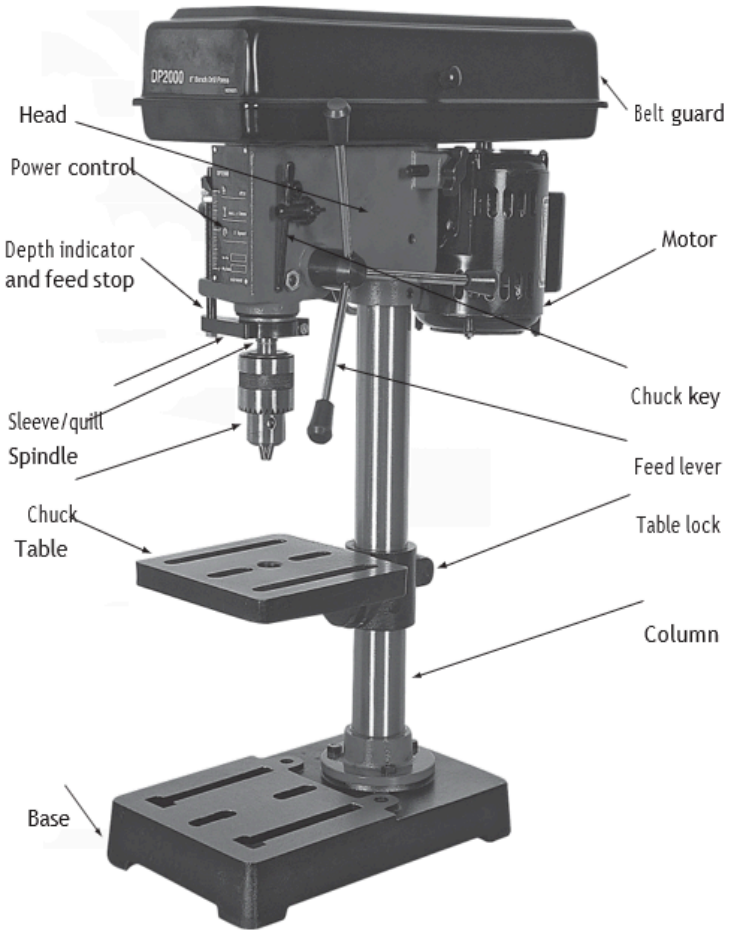

Figure 24 *Drill Press (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Power and Speed

The drill press is fitted with pulleys or gears so that different speeds can be obtained. The average drill press can obtain speeds of 680, 1250, 2400 and 4600 RPM. When the machine is used exclusively for metal work, a larger cone pulley is used on the spindle to give lower speeds of about 470, 780, 1300 and 1950 RPM.

Stationary Pipe Benders

Mechanical bending is a metal forming process used to permanently change the shape of pipe or tube.

Procedures like "***ram bending***" or "***rotary draw bending***" are used to form the workpiece into the shape of a die. Straight tube stock can be formed using a bending machine to create a variety of single or multiple bends and to shape the pipe or tube into the desired form.

One side effect of bending the workpiece is that the wall thickness changes; the wall along the inner radius of the tube becomes thicker, and the outer wall becomes thinner. To overcome this, the tube may be supported internally or

externally to preserve the cross section. Depending on the bend angle, wall thickness and bending process, the inside wall of the bend may crease.

Figure 26 *Portable Hydraulic Tube and Pipe Bender (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Self-Test B-2.3: Describe Stationary Power Tools Used in the Pipe Trades

Complete Self-Test 2.3 and check your answers.

If you are using a printed copy, please find Self-Test A-2.3 and Answer Key in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2788#h5p-5 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2788#h5p-5)

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Camosun College. (2015). Trades Access Common Core Competency C-2: Describe Common Power Tools and Their Uses. Victoria, B.C.: Crown Publications. Download for free from the B.C. Open Textbook Collection (https://open.bccampus.ca/browse-ourcollection/find-open-textbooks/).

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B-2.4 Use Stationary Power Tools

Stationary Grinding Tools

Before starting a grinder, check the condition of the grinding wheel. Place a fixed reference object on the tool rest so that it just touches the face of the wheel, then turn the wheel by hand. The wheel should just contact the object at all times as it makes a full turn. If not, the wheel is ***out-of-round***. Out-of-round wheels cause the workpiece to vibrate during grinding.

Check the condition of the face of the grinding wheel. If it shows excess signs of metal particles, it will need to be cleaned. Grinding wheels with a surface embedded with metal (Figure 1) tend to generate heat rather than to grind. The left image of Figure 1 shows dulled grains and particles of metal embedded in the wheel, while the right image shows a sharp cutting and unclogged grain surface.

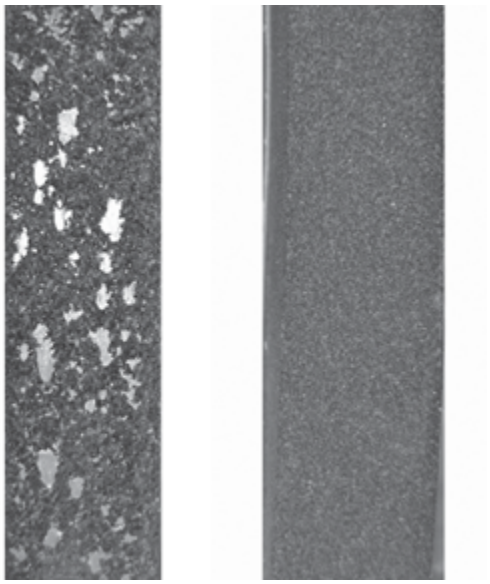

Figure 1 *Metal in a grinding wheel (left), clean grinding wheel (right) (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

To remedy out-of-round or dirty wheels, use a wheel dresser on the face of the stone. Where the grinder design permits, the tool rest must be backed away from the grinding wheel enough to allow the dresser to hook over the front edge of the tool rest. While the grinder is running, the handle of the dresser is raised until the sectional washers touch the wheel's face and the dresser is moved across the width of the grinding wheel. Turn off the grinder. When the grinding wheels have stopped turning, check the entire face for metal particles or out-of-round. Repeat dressing as necessary.

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

Remember to re-position the tool rest no further than 3 mm ($\frac{1}{8}$ in.) from the wheel after dressing.

When you are using a stationary grinder, you should rest the workpiece on the tool rest and apply enough pressure against the wheel so that grinding or brushing takes place. Avoid applying so much pressure that you cause a noticeable reduction in the motor's rotation speed.

Tools such as drill bits, screwdriver tips and cold chisels occasionally require grinding to improve their performance. You should grip such tools close to the area being ground so that you can feel any build-up of heat. If heated to the point of showing colour (yellow, purple or blue), the hardness of the tool will be affected. To prevent overheating, make sure the grinding wheel is clean, and dip the workpiece in water frequently to cool it.

The Right Wheel for the Job

Selection of the correct grinding wheel not only depends on the abrasive type, grain size, bonding material, grade, structure, size and shape but also on the grinding machine, the material to be ground and the nature of the operation. Medium-grain wheels (30 to 60 grit) are often chosen when only one metal-removing or sharpening operation is desired and the resulting surface finish is acceptable. Wheels having coarse grains (i.e. below 30 grit) work best with softer materials, where material can be removed rapidly. Many bench grinders will have one wheel with a 30 grit and another with a 60 grit.

Grinding Cold Chisels

The two areas on a cold chisel that may require grinding are the cutting edge and the end that is struck by the hammer.

Flat chisels should have a cutting edge ground to an included angle of approximately 60 and should have a slight curve to the width. The struck end should have all signs of mushrooming removed.

When using the grinding wheel, the chisel should be held at the desired angle and moved across the face of the wheel. Grind one side and then the other to form a sharp edge. The pressure applied to the chisel against the wheel should not be great enough to overheat the chisel end and draw (remove) the temper. If the temperature of the chisel end rises to a point where the metal turns blue, the temper has been lost and the end softened so that it will no longer stand up to normal use. Frequently dip the chisel end in water when grinding to keep the metal cool and to prevent overheating.

Sharpening a Twist Drill

Before you sharpen a twist drill, check the dull bit with your grinding gauge to ensure that the cutting lips are at 59° and that it has a 12° lip clearance. If it has the proper angles, these can act as a guide when you sharpen the drill tip. If the angles are not correct, you will know which areas require more grinding.

Place the twist drill so that the cutting lip to be ground is facing up and its cutting edge is level. Move the shank to your left until the axis of the drill is at 59° to the surface of the grindstone.

If the drill has a correct lip angle, the cutting edge will be exactly parallel to the surface of the stone.

Rotate the shank of the drill while sharpening so that the axis of the drill forms an angle of 12° to the horizontal.

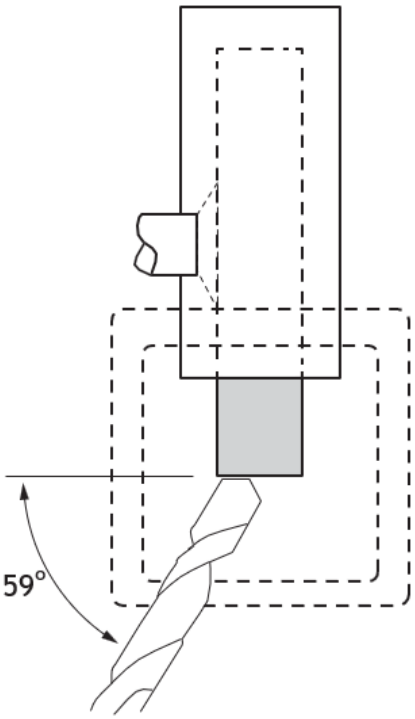

Figure 3 *Placement of the twist drill (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

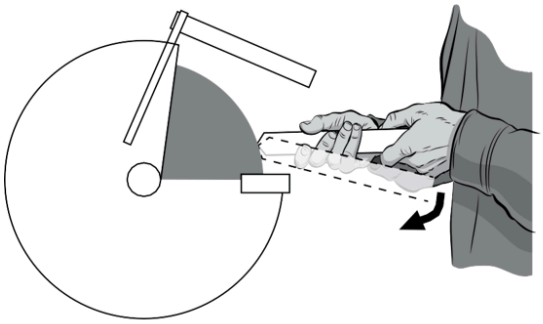

Figure 4 *Axis at 12° (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Begin sharpening the cutting lip of the drill, continuing to lower the shank end of the drill bit as the grinding proceeds. You may wish to practise this motion several times with the grinder turned off. When this "dry run" (practice motion, with the grinder off) feels right to you, rotate the drill one half turn and see if you can repeat the required angle and motions.

When doing the actual sharpening, always start the grinding at the cutting edge, and tilt the bit so that you finish at the heel. Try not to remove any more metal than is required to achieve a sharp cutting lip. Check the length of each cutting lip often to maintain equal lengths.

If both cutting lips are at the same angle (59°) and the same length, the point of the bit will be centered. If the point is not centred properly, it is because one or both of these conditions has not been met.

You must be careful not to overheat the drill bit during the grinding operation. Dip the end of the twist drill in cold water frequently to prevent excessive heat buildup. Never allow the surface of the drill to get so hot that it turns blue from the heat—the temper (hardness) of the metal will be destroyed, and the drill will no longer remain sharp during use.

Safety with Stationary Grinders

There are some rules that must be observed when using stationary grinders:

- Always wear a face shield
- Wear leather gloves and protective clothing
- Always use hearing protection
- Use both hands to control the work
- Ensure that the RPM rating of the wheel will not be exceeded
- Ensure that the wheel is suitable for the type of material
- Never reverse a wire wheel, as the wires in the wheel will have taken a "set"
- When cleaning small parts, hold them with pliers, never with your hands
- Ensure that the wheel has not been damaged
- Ensure that all guards are in place
- Ensure that the tool rest is properly adjusted
- Always stand to one side when starting the grinder
- Remove flammable materials from the work area

- Have people not involved in the grinding operation leave the area
- Never grind on the side of a grinding wheel, as this can weaken the wheel and cause it to break apart.

Be sure all grinding wheel safety devices such as wheel guards, spark deflectors, eye shields and tool rests are installed and properly adjusted before operating a grinder.

Stationary Threading and Grooving Tools

In this section you will learn safe procedures for cutting, reaming, threading and grooving using various styles of power vises and cutting machines.

Safety Precautions for Operating a Power Vise

1. Know the machine. From the information in this guide and the operator's manual, find out what the vise will do and how to operate it to accomplish that work. Know, as well, the limitations of the machine.
2. Avoid accidental starting. Make sure that the machine's Reverse/Off/ Forward switch is in the Off position and that the foot switch will operate freely. These checks must be made before the machine is connected to a power source.
3. Ground the machine. The machine should be grounded while in use to protect the operator from electric shock. The machine is equipped with an approved three-conductor cord and three-prong grounding type plug to fit the proper grounding type receptacle. The green (or green and yellow) conductor in the cord is the grounding wire. Never connect this wire to a live terminal. If the unit is for use on less than 150 volts, it has a 115 V plug. If it is for use on 150 to 250 volts, it has a 230 V plug.

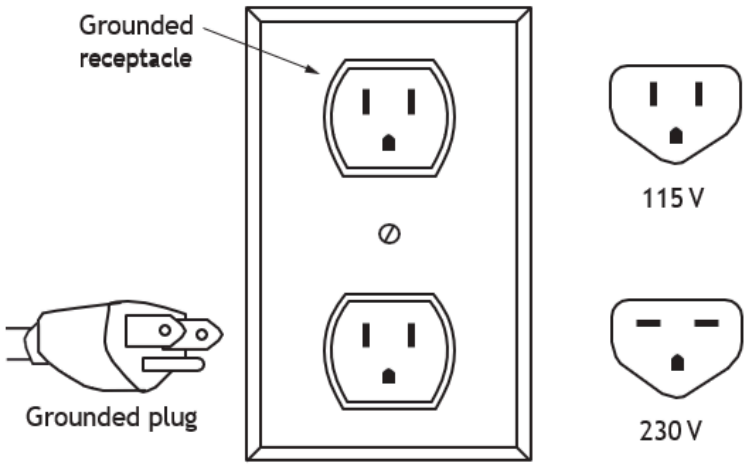

Figure 5 *Equipment grounding (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

4. Use only three-wire extension cords that have three-prong, grounding-type plugs and three-hole receptacles that accept the machine's plug. Replace or repair damaged or worn cords immediately. When the machine is used

outdoors, use only those extension cords that are suitable for use outdoors and are so marked.
5. Remove tools from the machine. Form the habit of checking to see that the machine is clear of adjusting wrenches and other tools before starting.
6. Support the work. Support long, heavy work with a floor pipe support.
7. Secure the machine. Make sure that the machine is stable. A power drive must be bolted to the floor when used with a universal drive shaft.
8. Do not reach across the machine. Operate the machine from the switch side only. Keep proper footing and balance. Be sure your foot can be removed safely from the foot switch at all times. Do not reach across the machine, and keep clothing, hands and tools away from moving parts.
9. Maintain the machine in top condition. Use sharp cutting tools and keep the machine clean for best and safest performance. Follow lubricating instructions.
10. Work in a safe environment. Do not use the machine in damp or wet locations. Do not expose the machine to rain. Keep work area well illuminated. Allow sufficient space to operate machine and accessories properly and for others to pass safely. Keep the power cord away from heat, oil and sharp edges. Make sure that hand tools that are not being used are not, in any way, obstructing machine operation.
11. Disconnect the power cord. When adjusting, servicing or changing accessories, disconnect the power cord. The cord should be in top condition, and examined at regular intervals.

Safety Precautions for Operating a Model 700 Portable Power Drive

Follow the safety procedures for operating power vises modifications:

1. Check the off switch. Before plugging in the power cord, push down on the switch button a couple of times to make sure that the switch button spring returns the switch to the Off position. A safety feature of this machine is that the power drive automatically stops when the operator lets go of the switch button on the handle of the machine.
2. Use the proper accessories. The support arm assures safe operation when using this machine with drop head threaders in any position. The Model 700 power drive may also be used with a geared pipe threader. In that case, the power drive is not used with the support arm.

Cutting Pipe Using Power Tools

In this section, you will learn safe procedures for cutting pipe using different stationary power tools.

Inserting Pipe in a Power Vise or Threader

The following general procedure describes inserting pipe into power vises or threading machines:

1. Measure and mark the length of pipe being worked.
2. If pipe is long enough to be retained by the centring device, insert the pipe through the front or rear of the machine. If the pipe is short, insert it into the front of the machine.
3. Make certain that the pipe is centred in the centring device, if used, and tighten the device.

4. Tighten the chuck jaws with a repetitive counter-clockwise ***snap-spin*** of the hand wheel.

This hammering action tightens the jaws on the pipe. A clockwise rotation snap-spin releases the jaws.

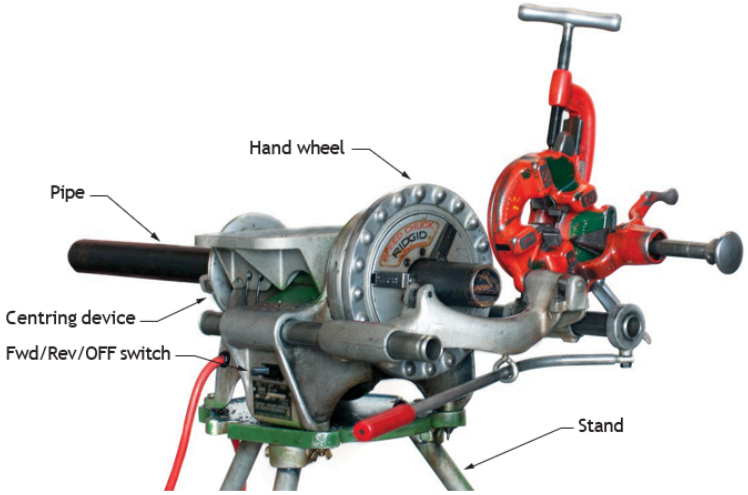

Figure 6 *Power drive on stand with pipe installed (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Cutting Pipe with a Hand Cutter Using a Power Vise

The following general procedure describes cutting pipe using a hand cutter and power vise:

1. Measure, mark, and secure the pipe in the power drive.
2. Engage the pipe with the pipe cutter and align the cutter wheel with the mark on the pipe.
3. Rest the pipe cutter frame on the support bar, which is located on the switch side of the machine. Tighten the feed screw (sometimes called a feedscrew) handle.
4. With the power cord plugged in, turn the main switch to the forward position.
5. Place foot on the foot switch to operate the machine.
6. Continuously tighten the feed screw handle until the pipe cut is completed (Figure 7).

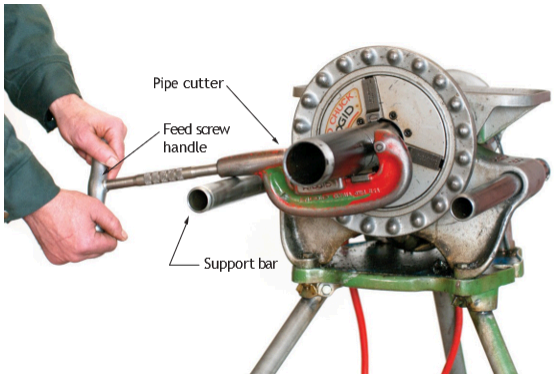

Figure 7 *Cutting pipe with hand cutter (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

7. Release the foot switch.

Figure 8 shows hand cutters that can be used with power drives. The heavy-duty wide roll pipe cutter is especially suited for power drive use as the wide-rolls keep the cutter from wobbling.

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

Accessories for cutting, reaming, threading and oiling can be mounted on the power vise to con- vert it into a power threader. Below is a standard power vise with cutting, reaming and threading attachments installed. On this unit, oiling must be done manually.

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

Cutting Pipe with a Power Vise Cutter

Assume the correct operating position for cutting, threading, and reaming. Stand on the switch side of the power vise, straddling the nearest tripod leg. The left foot operates the foot switch.

Figure 10 *Operating a foot switch (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

1. Measure the pipe and mark the place where the cut is to be made.
2. Swing the reamer and threader out of the way.
3. Move the pipe cutter down onto the pipe.
4. Use the carriage lever to move the carriage to the point where the cutter wheel lines up with the mark you have made on the pipe.
5. Tighten the cutter feed screw handle until the cutter wheels are snug against the pipe.

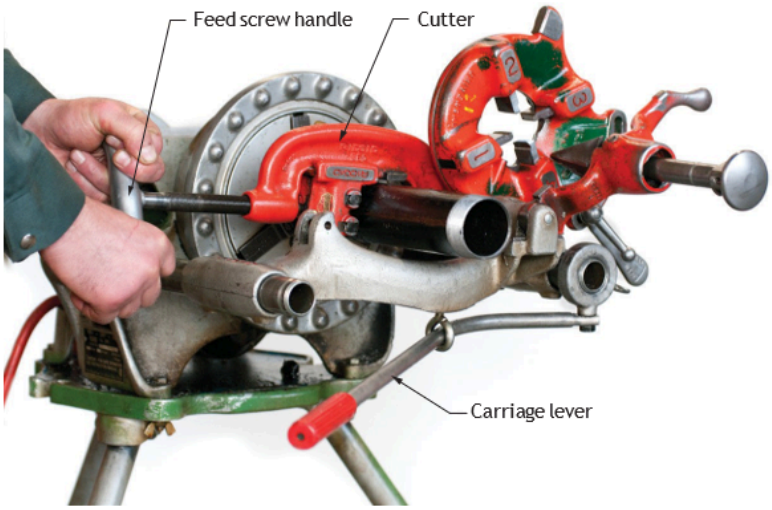

Figure 11 *Tightening cutter screw wheel (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

6. With the main switch still in the forward position, step on the foot switch.
7. Using both hands, continuously turn the cutter feed screw handle until the pipe is cut off.
8. Release the foot switch.
9. Return the pipe cutter to its out-of-the-way position.

Cutting Procedure Using a Power Threader

1. Measure the pipe and mark the cut-off point.
2. Insert the pipe into the chuck.
3. With the reamer and the die head in an out-of-the-way position, bring the cutter down over the pipe, and position it on the mark you have made.
4. Turn the cutter handle to cut.

To use length gauge on machine carriage, place cutter wheel against end of stock and set pointer to "0", raise to clear stock, and turn carriage hand wheel until pointer is at length desired.

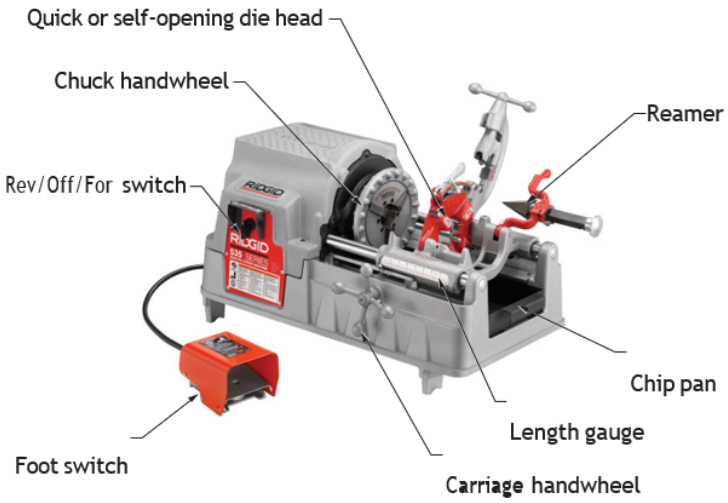

Figure 12 *Power threader (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Reaming Pipe Using Power Vises or Threading Machines

In this section, you will learn safe procedures for ***reaming*** using various styles of power vises and reaming tools.

Reaming Pipe Using a Power Vise and Hand Threader

Follow the safety precautions for power vises, outlined in Safety Precautions for Operating a Power Vise.

1. Check to see that the main switch is in the forward position.
2. Insert the reamer into the end of the pipe and hold firmly onto handle and handgrip (Figure 13).

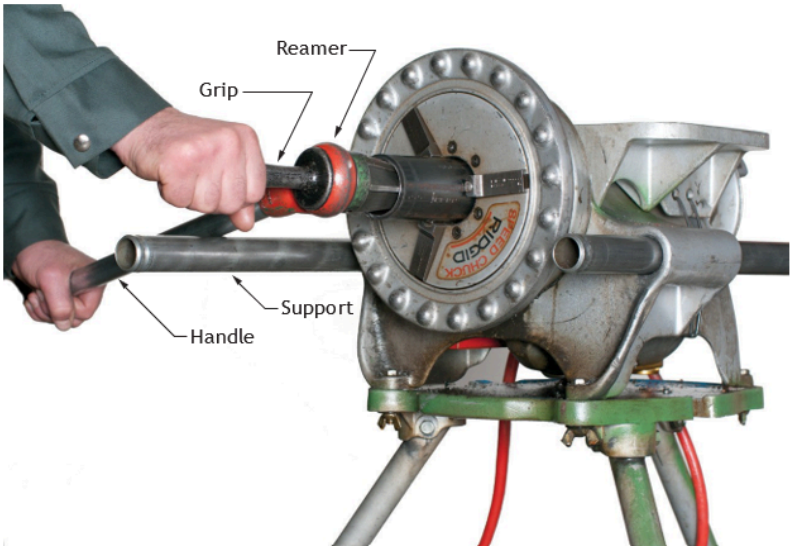

Figure 13 *Reaming pipe with a hand reamer using a power vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

3. Step on the foot switch and slowly push on reamer handgrip (same Figure 13), with right hand to ream pipe.
4. Release foot switch and remove reamer.

The straight reamer is a safe hand tool for manual use with power vises. Spiral reamers are not safe.

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

Reaming Pipe with a Power Drive Reamer or Threading Machine

Assume the correct operating position by standing on the switch side of the power drive, straddling the tripod leg. Use left foot to operate the foot switch.

1. Move the reamer arm down into the reaming position.
2. Extend the reamer by pressing the latch and sliding the knob toward the pipe until the latch engages the bar.
3. With the main switch in the forward position, step on the foot switch.
4. Position reamer into pipe and complete reaming by pushing carriage lever. Exert pressure on the hand wheel for the same action on a power threader.
5. Retract the reamer bar and return the reamer to out-of-the-way position.
6. Release the foot switch.

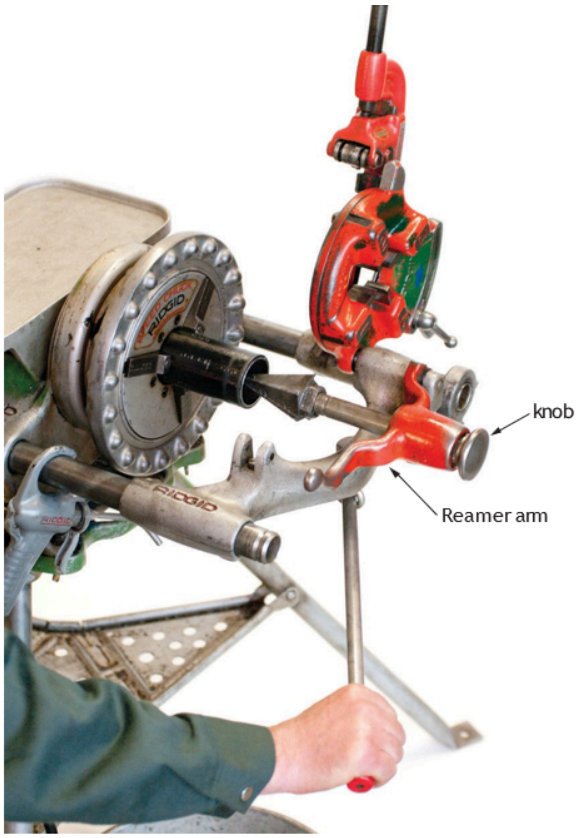

Figure 15 *Reaming pipe with power drive reamer* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Threading Pipe Using Power Vises or Threading Machines

A quick-opening die head is the standard drive mounted threading accessory. Depending on the pipe size, different die sets are installed which determine the number of threads per inch.

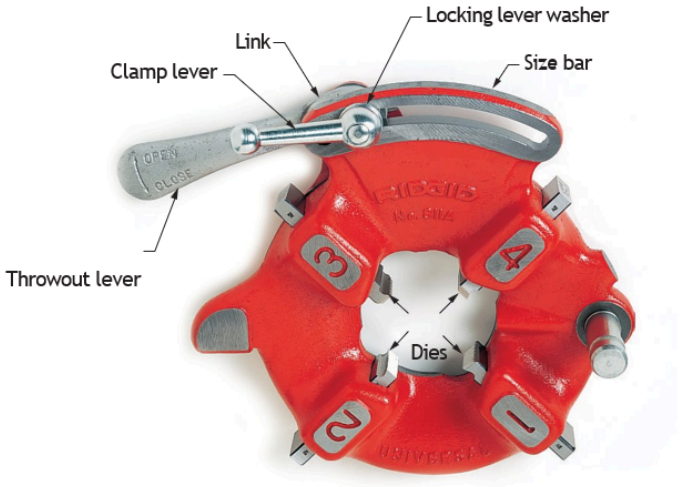

Figure 16 *Quick-opening die head (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Install a Die Set

1. Select the correct set of dies for the pipe size. The size is marked on either the back end or the face of the dies.
2. Lay the die head on the workbench with the numbers on the head facing up.
3. Flip the throw-out lever to the open position.
4. Loosen the clamp lever approximately three turns.
5. Lift the tongue of the locking lever washer up out of the slot under the size bar. Then slide the sizing mark all the way to the end of the slot.
6. Insert the dies to the line marked on the side of the dies, numbered edge up. Note that the die numbers 1 through 4 must correspond with the numbers on the die head slots.

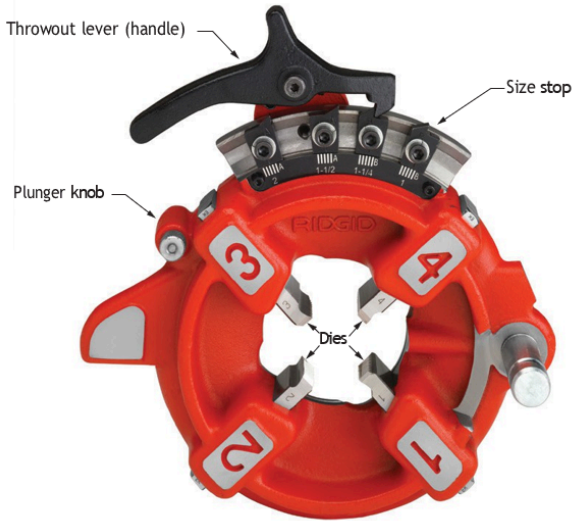

Figure 17 *Semi-automatic die head (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

7. Slide the throw-out lever back so that the tongue of the clamp lever washer will drop into the slot under the size bar.

Adjust the Die Head to the Size Desired

1. For standard threads, adjust the size bar of the die head until the index line on the link lines up with the proper size mark on the size bar.
2. Tighten the clamp lever.

Thread Pipe with Quick-Opening Die Head

1. Install the die set.
2. Swing the cutter and reamer to an out-of-the-way position.
3. Lower the die head into the threading position.
4. Apply thread cutting oil to the end of the pipe.
5. Ensure that the main switch is in the forward position.
6. Step on the foot switch.
7. Engage the dies with the pipe, using the carriage lever.
8. Use plenty of thread cutting oil until the thread is completed.

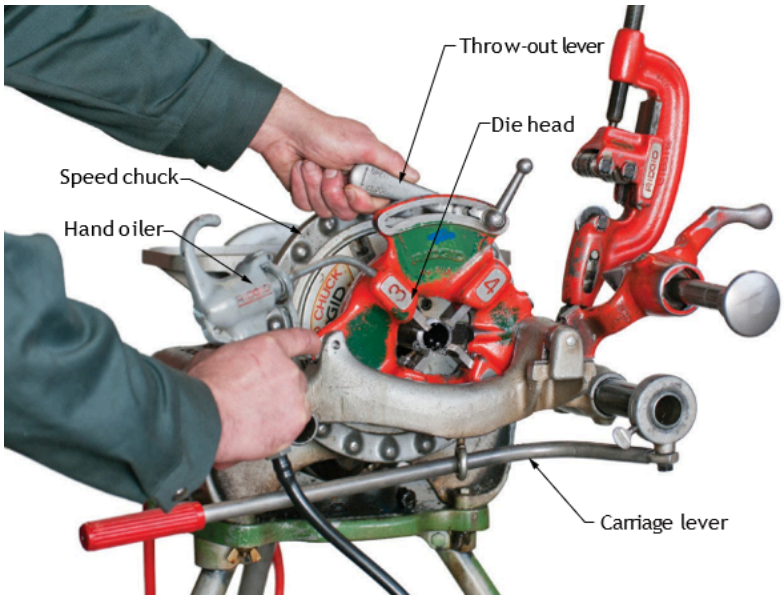

Figure 18 *Thread pipe with a quick-opening die head (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The thread is completed when the end of the pipe is flush with the numbered end of the ***dies***.

9. When the thread is completed, raise the throw-out lever to the open position.
10. Move the carriage lever away from the pipe end and return the die head to the up-and-out- of-the-way position.

Using a Geared Threader

In this section you will learn safe procedures for using a geared threader.

Install the Geared Threader on a Power Vise

1. Place the adjusted threader on the floor or on a workbench, with the drive shaft up.
2. Install the drive bar on the drive shaft of the threader and tighten the two set screws.

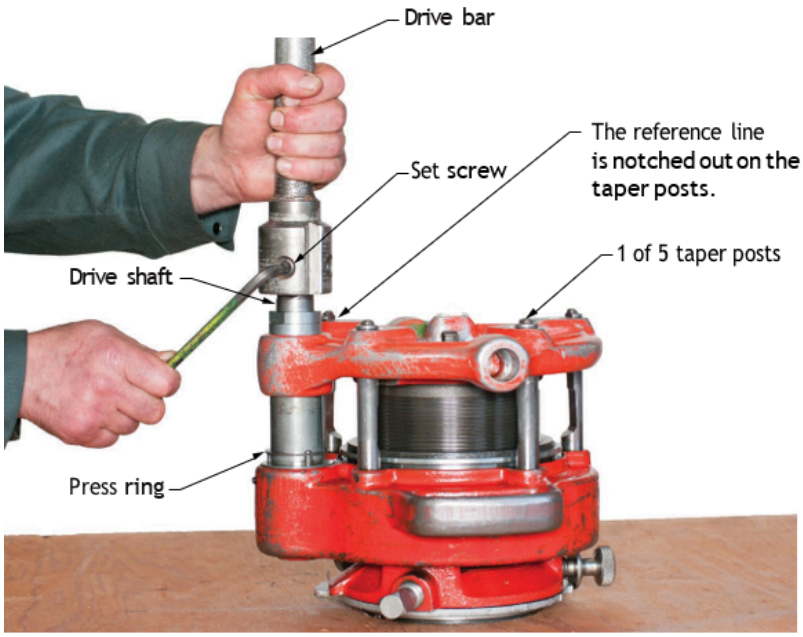

Figure 19 *Install the drive bar on a geared threader (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

3. Insert the drive bar into the chuck of the power vise. (This will likely require the assistance of another person to pick up the threader and drive bar.)
4. Tighten the jaws of the power vise chuck into the three V-shaped notches in the head of the drive bar. Be sure to allow about 18 mm ($\frac{3}{4}$„ in.) of the drive bar to be exposed in front of the chuck jaws. This will provide space for oiling.
5. Close the rear centring device on the shaft of the drive bar.
6. Pull out the support bar on the switch side of the vise and secure it in the extended position.
7. Slip the gear case loop over the support bar and secure it in the hole provided on the threader with the set screw.

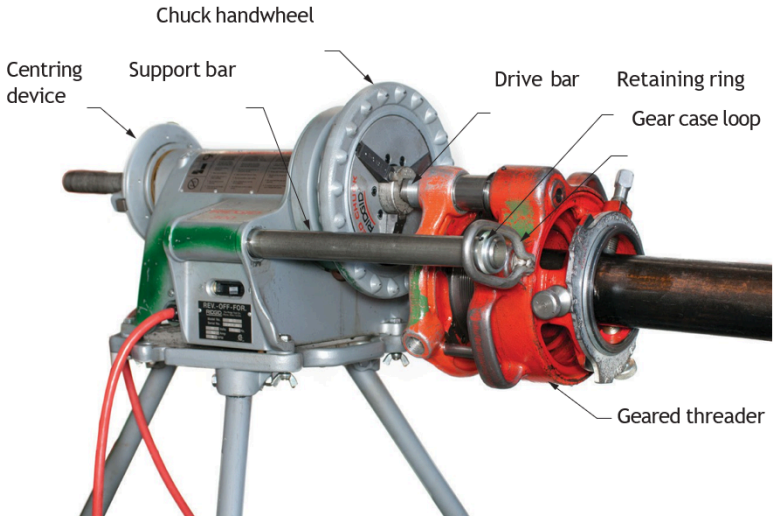

Figure 20 *Geared threader close-coupled to power drive (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Position the Pipe in the Threader

1. Set the sizing screws using the gauge plate.
2. Insert the pipe in the threader and centre the end of the pipe in the throat of the dies.
3. Turn the work holder with a socket wrench to centre the pipe and hold it in position.
4. Tighten the clamp screw, securely locking the pipe in the work holder.
5. Place the oiler directly under the threader. Long pieces of pipe must be supported by a pipe support, with the pipe free to rotate as it is threaded.

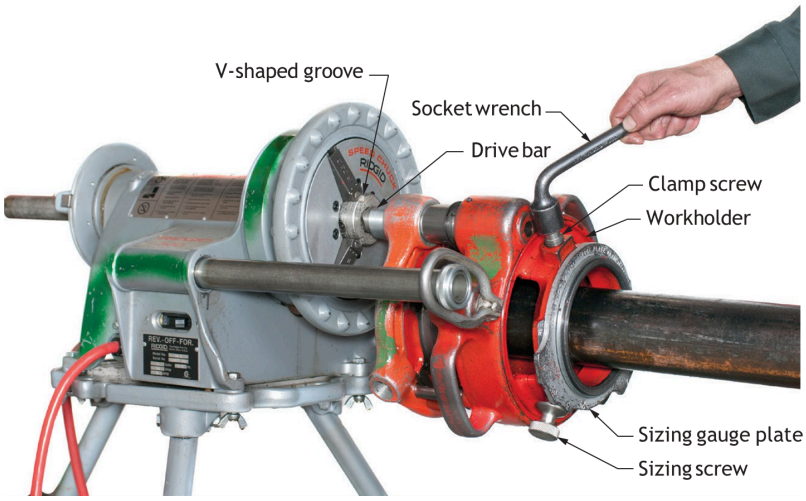

Figure 21 *Tightening work holder on the geared threader (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Cut Threads with a Geared Threader

1. After the geared threader and pipe are installed, put in the power cord.
2. Turn the power drive switch to the forward position.
3. Step on the foot switch.
4. Flood die with thread cutting oil during the threading operation to ensure the die's long life.
5. Release the foot switch when the red STOP line appears on the pinion sleeve (Figure 22). (The die head starts to press on the ring at the base of the pinion sleeve.)
6. Turn the power drive switch to off. When motion stops, turn the switch to reverse and press the foot switch to unscrew the dies from the pipe. Loosen the set screw and the work holder from the pipe.

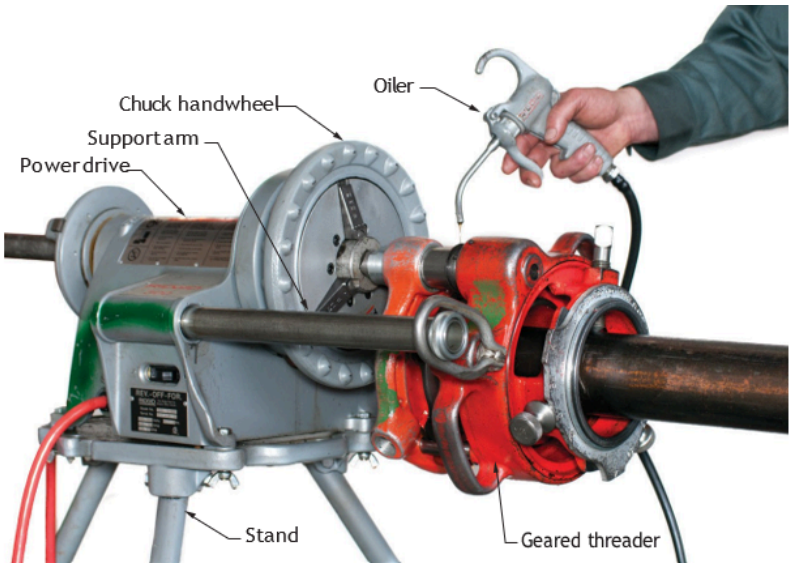

Figure 22 *Cut threads with a geared threader (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Using Nipple Chucks

A ***nipple*** is a short piece of pipe, 300 mm (12 in.) or less in length, threaded on both ends.

The size of a nipple is designated by its diameter and length. For example, a 13 mm × 15 cm ($\frac{1}{2}$ in. × 6 in.) nipple is made of 13 mm pipe, 15 cm long ($\frac{1}{2}$ in. pipe, 6 in. long.) A close nipple has threads along its entire length. The shoulder nipple has a short section of unthreaded pipe between the threads on each end.

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

The ***nipple chuck*** is used to hold nipples (or ***studs***) for threading when the nipple is so short that the jaws of the power vise would damage the threads. The nipple chuck is inserted into the jaws of a power vise or threader.

The nipple chuck accommodates pipe sizes up to 5 cm (2 in.). Adapters are used with 38 mm ($1\frac{1}{2}$ in.) pipe and the smaller sizes, according to the size of the pipe.

The nipple chuck provides a means of holding a nipple with threads on one end, while cutting, reaming, and threading the other end. It also provides an easy release so that the nipple can be removed without overcoming the binding torque applied while threading.

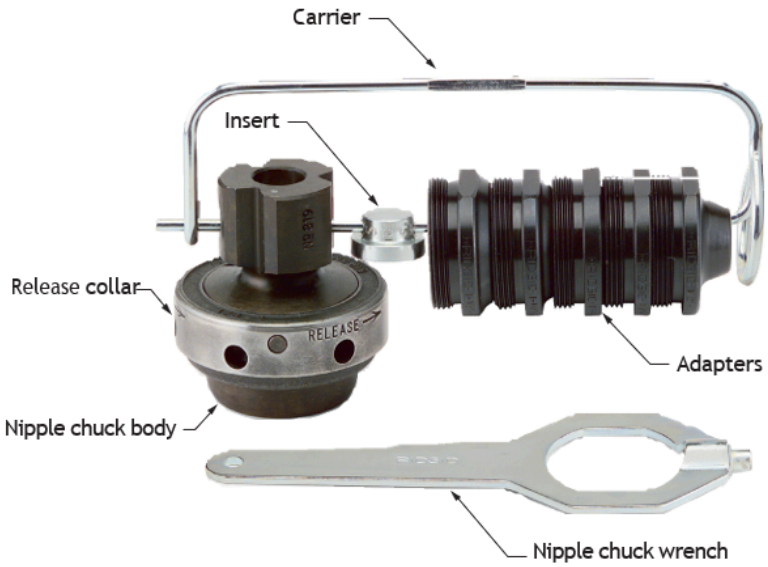

Figure 24 *Nipple chuck kit (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Procedure for Short or Close Nipple Threading with Power Threading Machine

1. Ream and thread one end of the pipe in the usual manner. Cut off the end to the desired length of the nipple.
2. Install the nipple chuck in the power vise so that the jaws fit into the grooves of the nipple chuck.

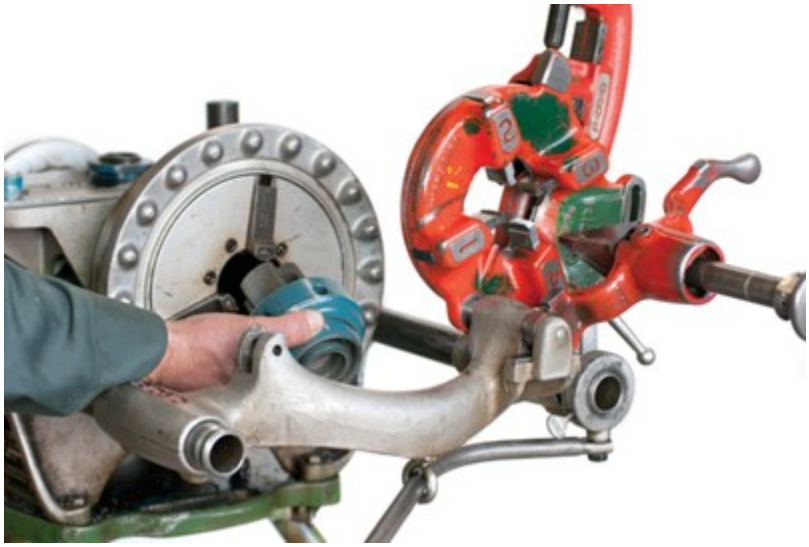

Figure 25 *Installing the nipple chuck* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

3. Position the insert. For pipe sizes 3 mm to 19 mm ($\frac{1}{8}$ in. to $\frac{3}{4}$ in.), the small end of the insert should face the adapter. For 25 mm (1 in.) pipe size, the large end should face the adapter. No insert is required for pipe sizes of 32 mm (1 $\frac{1}{4}$ in.) or larger.

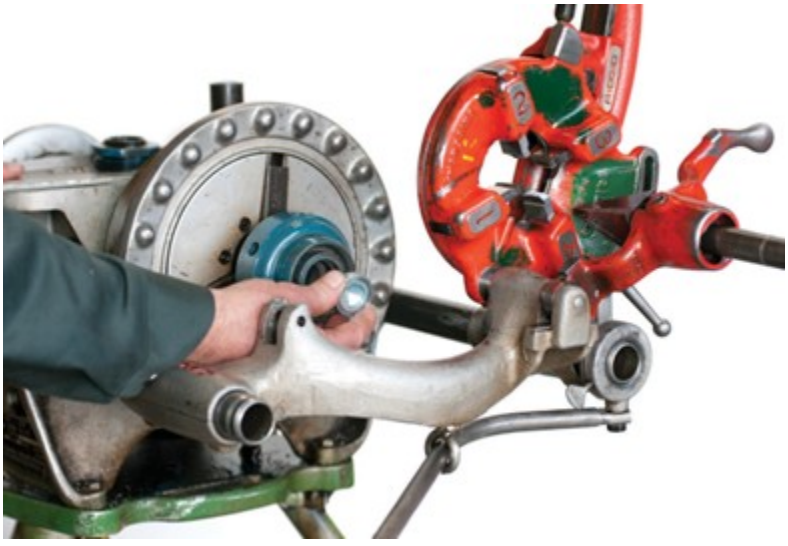

Figure 26 *Positioning the insert* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

4. Select the proper adapter and screw it into the nipple chuck.

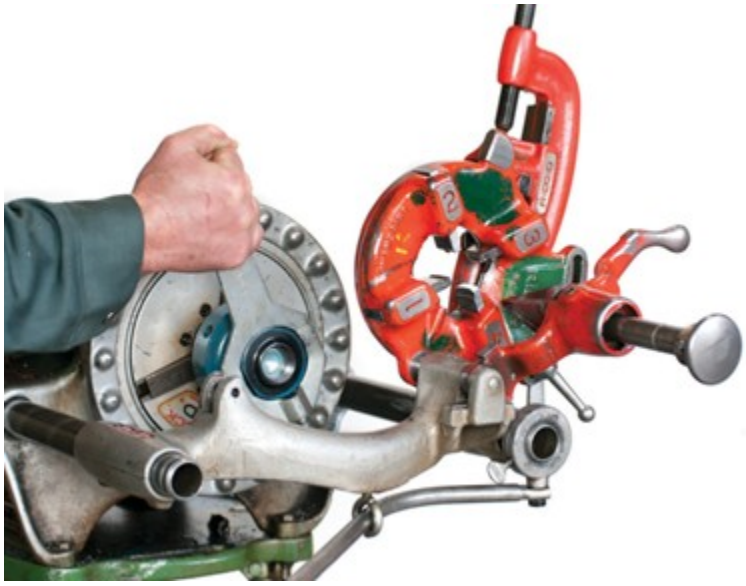

Figure 27 *Install the adapter* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

5. Insert the nipple, threaded on one end, into the adapter by hand.

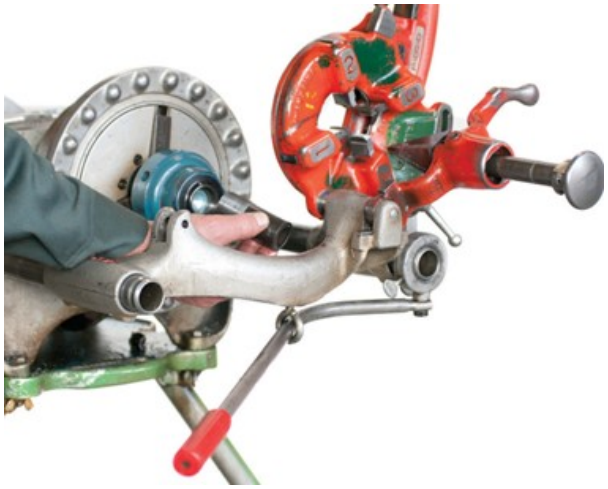

Figure 28 *Install nipple into the adapter* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

6. Ream and thread the unthreaded end of the nipple.
7. To release the nipple, insert the pin on the end of the wrench into one of the holes on the release collar. Turn the wrench approximately a one-quarter turn in the direction indicated by the arrow to release. The nipple may be removed by hand.

Figure 29 *Release the nipple (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Using Grooving Attachments

The ***roll groover*** forms grooves in standard pipe so that the pipe can be joined by mechanical couplings. Grooved pipe and fittings form a strong, leak-resistant conveyor for hot and cold fluids. They are easy to install and service and handle expansion and contraction without stress. They are ideal for use in heating and cooling systems, as well as in ***fire standpipe***, sprinkler, and storm and roof drainage systems.

A grooving operation produces results similar to a threading operation. Like threading equipment, grooves can be cut with hand tools having ratchet handles, or with groove cutters or groove rollers driven by a power drive. With some grooving equipment, the pipe remains stationary during the cutting process; with other equipment, the pipe rotates between the rolls.

The Model 925 roll groover may be mounted on a stand designed for the machine, or it can be attached to a bench. A support stand is used to hold pipe longer than one metre (3 feet).

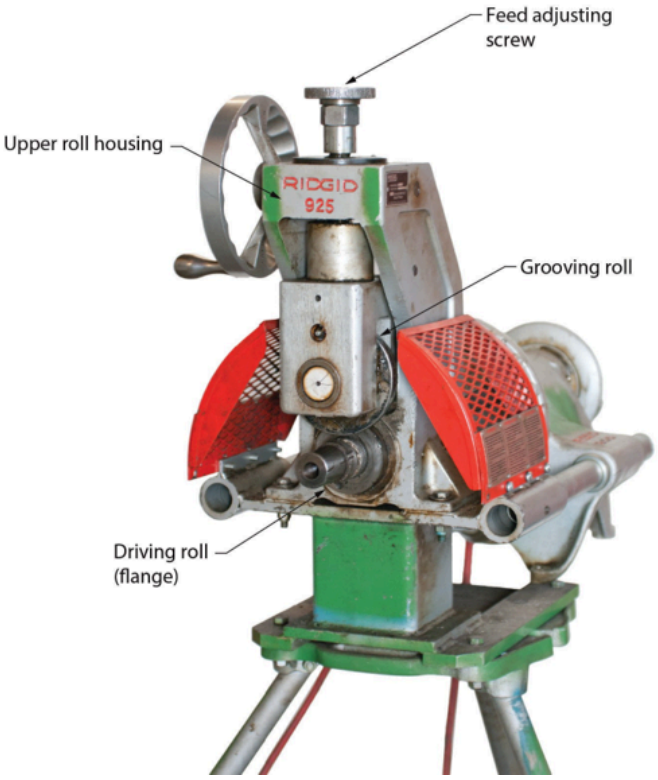

Figure 30 *925 roll groover (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

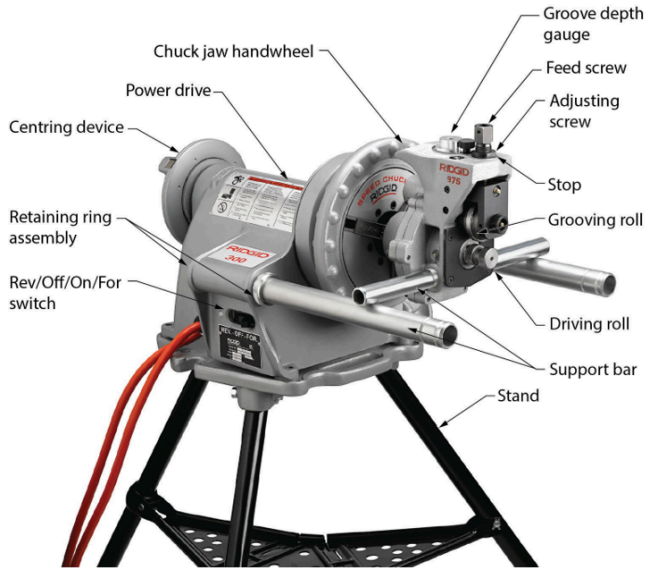

Figure 31 *Components of a 975 roll groover with power drive (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

For safety reasons, the roll groover should not be operated at a speed faster than 36 rpm; and if it is mounted on a stand, the stand should be firmly anchored to the floor. The machine should be grounded and secured tightly to the power drive.

Preparing Pipe for Grooving

The following procedure is for grooving pipe with a maximum diameter of 15 cm (6 in.). It is assumed that the proper stop, grooving roll, and driving roll are already installed on the machine.

1. Ensure that the pipe is cut to the correct length and the ends are square cut.
2. Ensure that both the internal and external surfaces of the pipe are smooth and uniform from the end to at least 50 mm (2 in.) back. Any internal or external weld beads or seams in this section must be ground down until they are flush with the pipe wall.
3. Remove burrs, coarse scale, rust and any other irregularities on the surface of the pipe with a reamer, a file, a grinder, a sander, or a wire brush. Do not create flat areas or recesses on the gasket seating surface.

Operating the 925 Roll Groover

1. Ensure that a pipe length longer than 1 m. (3 ft) is supported with a pipe stand. The pipe stand, with rollers to hold the pipe level, allow it to rotate, and prevent lateral movement at a distance $\frac{3}{4}$" of the pipe length away from the driving roll flange. Pipe longer than 6.5 m. (21 ft) should be supported by two stands.

2. Place the pipe end on the driving roll against the flange.

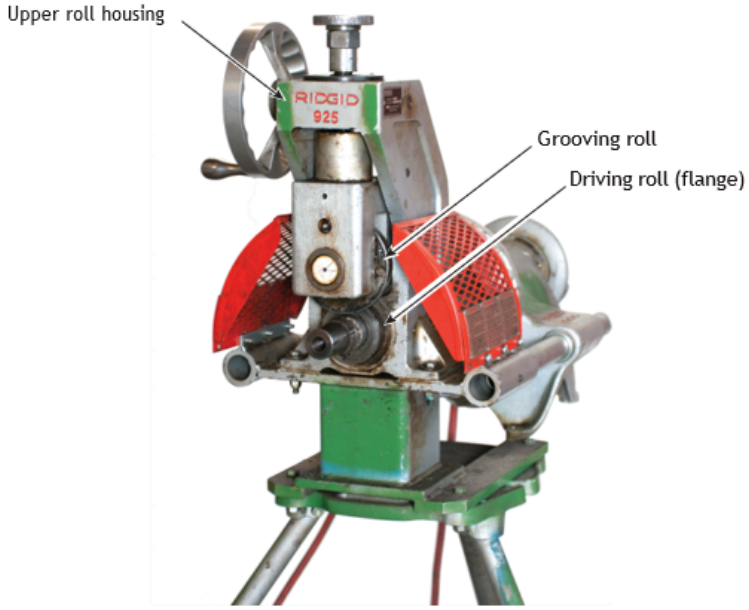

Figure 32 *Operating the 925 roll groover (BC Industry Training Authority, 2019).*
CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

3. Adjust the pipe (and pipe support stand) so that it comes in contact with the roll flange on one side only. To do this, face the groover and move the support stand holding the pipe to the right until the axis of the pipe is $\frac{1}{2}$ ° off the axis of the driving roll (Figure 33). For example, 10 ft from the groover, the pipe should be 25 mm (1 in.) to the right of centre.

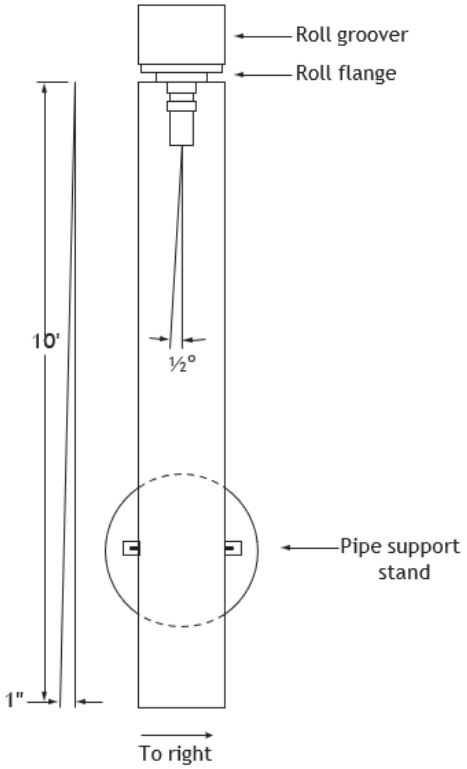

Figure 33 *Plan view of pipe alignment with groover (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

4. Turn the hand wheel clockwise to bring the grooving roll in contact with the pipe.
5. Turn the feed screw for grooving depth down against the upper roll housing (Figure 34).
6. Back off the feed screw by the number of marks required to obtain the proper groove depth for the pipe size. For example, an 8 cm (3 in.) pipe groove should be 2 mm (0.078 in.) deep. (This is about eight hundredths of an inch back off the feed screw 8 marks.)

Figure 34 *Adjusting the stop nut/feed screw on the Model 925 (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The manufacturer's manual for operators contains a chart specifying nominal groove depths for pipe sizes. Each mark on the 925's feed screw represents approximately 0.03 mm (0.01 inches).

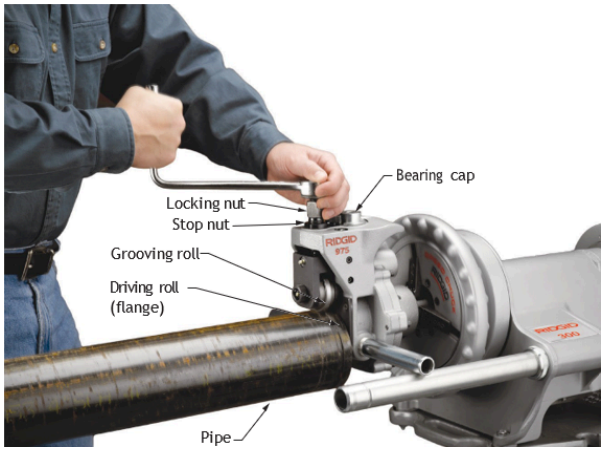

Figure 35 *Feeding grooving roll into pipe with hand wheel (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

7. Tighten the adjusting screw against the feed screw. Make sure the feed screw does not move.
8. Plug the power cord of the power vise into an electrical receptacle.
9. Turn the main switch of the power vise to the forward position.
10. Rotate the pipe slowly by jogging the foot switch (briefly pressing the foot switch). This will enable you to keep the pipe on the driving roll and against the flange. During the grooving operation, it is very important to keep the pipe against the flange of the driving roll. Serious injury could result if the pipe becomes disengaged from the drive shaft.
11. If the pipe moves away from the flange, turn the vise switch to the Off position, and back off the grooving roll using the hand wheel. Reposition the pipe, and again use the hand wheel to engage the grooving roll with the pipe. Then repeat Steps 9 and 10.
12. Continuously feed the grooving roll into the rotating pipe by turning the hand wheel clock wise.
13. When the stop nut bottoms against the bearing cap, allow the pipe to make two complete revolutions before releasing the foot switch.
14. Disengage the pipe and measure the diameter of the pipe groove, using an outside micrometer or a pie tape. Two readings, 90° apart, should equal the required groove diameter. (A mechanical coupling without the seal should just bottom when held completely closed in the groove.)
15. If the groove is not to specifications, adjust the stop nut accordingly and continue grooving until you obtain the correct groove diameter.

Using a Drill Press

A drill bit turning in a piece of metal exerts significant torque, which tends to cause the work to rotate. The twisting action increases when the drill bit breaks through the underside of the piece being drilled. A piece of work spinning on the end of a drill can cause serious bodily injury, break the drill bit, or spoil the work. Clamping the work or mounting it to prevent twisting avoids this hazard. A machine vise (Figures 36 and 37) can be used for holding smaller items. Large pieces should be secured with C-clamps.

Figure 36 *Drill press machine vise – top view (Camosun College/BCcampus) CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

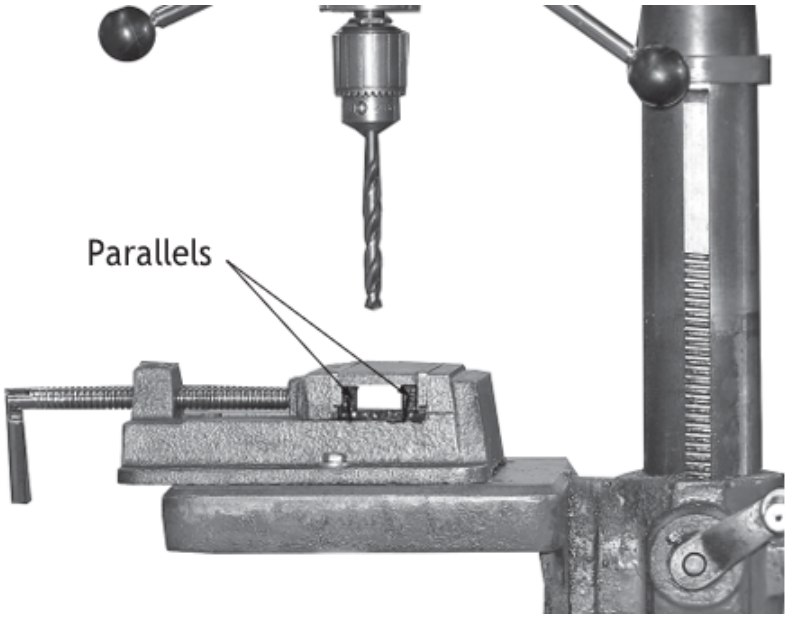

Figure 37 *Drill press machine vise (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Speed and Feed

The ***speed*** in any drilling operation is determined by the kind of material and the size of the hole. The smaller the drill bit, the greater the required speed in RPM. The speed should also be higher for soft materials than for hard materials.

On most drill presses, it is difficult to obtain the exact recommended speed, but you can come close by adjusting the drive belt on the step-cone pulleys. You will find instructions on adjusting the pulleys in the manufacturer's manual, or else ask your instructor to demonstrate this procedure. There is usually a chart in the manual or on a tag fixed to the machine that gives the various speed ratios for your particular drill press.

Feed is the amount of pressure you apply to control penetration. Too much pressure will force the tool beyond its cutting capacity and can result in rough cuts and jammed or broken bits. Too light a feed, particularly with metals or other hard materials, will cause overheating of the bit, and burning of the cutting edge. The best results will be obtained by matching the correct speed with a steady feed pressure that lets the bits cut easily at an even rate.

Safe Use of the Drill Press

Before proceeding with any drill press operation, you should understand the following safety pre- cautions:

- Never attempt to hold the work by hand. Use a vise or clamp to prevent the work from spinning.
- Use a face shield to protect yourself from flying chips.
- Never set speeds or adjust the work unless the machine is stopped.
- Keep away from revolving parts of a drill press to prevent your clothing from being caught.
- As the drill begins to break through the work, ease up on the drilling pressure and allow the drill to break through gradually.
- Always remove burrs from a drilled hole with a file or scraper, not with your hands.
- Never leave a chuck key in the drill chuck.
- Never attempt to grab work while the drill is still in motion; stop the machine first.
- Always position the table or the vise so that the drill bit will not damage either of them as it penetrates through the work.
- Before you start to drill, check the speed settings.

Self-Test B-2.4: Use Stationary Power Tools

Complete Self-Test 2.4 and check your answers.

If you are using a printed copy, please find Self-Test A-2.4 and Answer Key in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2792#h5p-6 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2792#h5p-6)

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Camosun College. (2015). Trades Access Common Core Competency C-2: Describe Common Power Tools and Their Uses. Victoria, B.C.: Crown Publications. Download for free from the B.C. Open Textbook Collection (https://open.bccampus.ca/browse-ourcollection/find-open-textbooks/).

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Self-Test B-2.1: Describe Portable Power Tools Used in the Pipe Trades

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

1. Which power drive requires a support arm when it is used with a drop head threader?

   _____

2. What power vise model can be mounted on a geared threader?

   _____

3. With a portable circular saw, what controls the depth of cut?
   a. Altering the speed of the motor
   b. Changing the size of blade
   c. Varying the cutting speed
   d. Raising or lowering the base
4. To make a bevel cut with a portable circular saw, you need to
   a. Tilt the lumber
   b. Use a special saw blade
   c. Tilt the base
   d. Raise the blade
5. The carbide metal used for carbide-tipped saws is hard and .
   a. Magnetic
   b. Very brittle
   c. Able to withstand rough treatment
   d. Virtually indestructible
6. Abrasive circular saw blades can be used to cut ferrous metals and what other material?
   a. Wood
   b. Plastic
   c. Non-ferrous metals
   d. Masonry products
7. What does a variable speed switch allow the drill operator to control?
   a. Direction of rotation
   b. Speed of rotation
   c. Danger or risk of jamming
   d. Size of the hole
8. The slowest speeds are normally found on what type of drills?
   a. ¼ in. drills
   b. 3/8 in. drills
   c. ½ in. drills
   d. Drills with forward-reverse switches
9. You must always wear eye protection when drilling.

a. True
b. False

10. What is the smooth round portion of the twist drill that fits into the chuck known as?

a. Body
b. Chuck-end
c. Shaft
d. Shank

11. Which twist drill is the largest?

a. #1
b. #60
c. #80
d. #100

12. Which of the following bits would you use for drilling deep holes in wood?

a. Auger bit
b. Spade bit
c. Spur bit
d. Carbide-tipped bit

13. What device supplies power to a pneumatic (air-powered) portable tool?

14. An air hose to a portable power tool must be free of water.

a. True
b. False

15. Why should regular hand-tool sockets not be used with a pneumatic impact wrench?

16. How is the size of an impact wrench designated?

17. Name three uses for a portable grinder.

18. At what speed does the fastener move in a low-velocity, powder-actuated tool?

19. At what speed does the pin move when a high-velocity tool is used?

20. What device does a low-velocity tool have that is not found in a high-velocity tool?

21. Which kind of powder-actuated tool is most commonly used in the piping industry?

22. Besides the captive piston, what are two safety features of the low-velocity, powder-actuated tool?

23. What cartridge colour produces the second strongest impact?

24. Cartridges are available in two shapes. What are they?

25. Some cartridges for powder-actuated tools are centre fired. How are other cartridges fired?

26. Name the colour of the Hilti cartridges from strongest to weakest.

27. When selecting a cartridge for a fastening job, what cartridge do you start with?

28. For fastening into concrete, the tip of the pin must be knurled.
    a. True

b. False

29. What must be remembered about the number code on the piston and the number code on the nail?.

Answer Key: Self-Test B-2.1 is on the next page.

Answer Key: Self-Test B-2.1

1. Portable Power Drive
2. Portable Power Drive
3. d. Raising or lowering the base
4. c. Tilting the base
5. b. Very brittle
6. d. Masonry products
7. b. Speed of rotation
8. c. ½ in. drills
9. a. True
10. d. Shank
11. a. #1
12. a. Auger bit
13. Air or pneumatic tools are operated by compressed air supplied by an air compressor.
14. a. True
15. They are not of a strong enough design to absorb the tremendous forces generated.
16. Impact wrench sizes are designated by the size of the drive on the nose of the tool.
17. Possible answers include: sharpening other tools, removing burrs, bevelling corners, and grinding welding beads.
18. Less than 100 m (330 ft.)
19. 460 m (1500 ft.) per second
20. Captive piston
21. Hilti low-velocity tool
22. (1) The tool is so designed that it will not fire if it is held at an angle of more than 7° off the work surface.
    (2) A built-in stop ring to absorb impact of firing the tool.

23. Red
24. Crimped and wadded
25. Rim fired
26. purple (strongest)
    red
    yellow
    green
    brown
    gray (weakest)

27. Start with the cartridge that has the weakest powder load.
28. b. False—the tip is smooth
29. The nail to be used with the tool must bear a number that matches the number code on the piston.

Self-Test B-2.2: Use Portable Power Tools

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

1. When should you ease up on the feed pressure when drilling?
    a. At multiple intervals
    b. As the drill breaks through the work
    c. As soon as the bit starts to cut
    d. When the bit will self-feed
2. The drill speed should be increased if the material being drilled is_____.
    a. Clamped to the drill press
    b. Very hard
    c. Soft
    d. Ferrous
3. The preferred cutting speed of a grinding wheel is at or just below what rate?
    a. 1725 feet per second
    b. The speed that causes sparking
    c. The maximum RPM rating
    d. 3000 RPM
4. If the portable system feeding compressed air to a nailer or stapler does not contain a lubricator, what rule about lubrication should you follow when you use these tools?

5. List the problems you will look for when you inspect the air-supply hose to a portable power tool.

6. How should you store the hose for a portable air supply system?

7. Dynamic air-line pressure is greater than static pressure.
    a. True
    b. False
8. How should you store the hose for a portable air supply system?

9. Name three uses for a portable grinder.

10. List three important safety considerations when using an air chisel.

11. At what speed does the pin move when a high-velocity tool is used?

12. Any Hilti tool will accept any kind of fastener.
    a. True
    b. False

13. When using a powder-actuated tool, approximately how much penetration is required for fastening into concrete?

14. When using a powder-actuated tool, where must a fastening be made in a concrete block?

15. When using a powder-actuated tool, what is the minimum thickness of steel that a fastener may be used on?

16. What penetration should the tool-operator look for when setting a fastener into steel?

17. What is the minimum distance you may set a powder-actuated fastener from a torch cut or weld?

18. What type of concrete products should not accept a powder-actuated fastener?

19. What is the rule about spalled areas?

20. List five materials that cannot be fastened onto concrete or steel.

21. If you use an extension cord with a non-double-insulated power tool, ensure that it is a three- wire type.
    a. True
    b. False

22. If the incorrect voltage is applied to a power tool, it can be damaged.
    a. True
    b. False

23. When you connect a power tool to a power supply, the switch on the tool must be in the _____position.
    a. On
    b. Off

24. List three things that can damage a power cord.

25. Clean plastic parts of a portable power tool with a soft cloth lightly moistened with:
    a. Thinner
    b. Alcohol
    c. Gasoline
    d. Soapy water

26. Wear eye protection when you use saws and other power tools that kick up particles and dust.
    a. Thinner
    b. Alcohol

Use the *sample regulations* provided to answer the following:

27. You can only use a high-velocity tool if a low-velocity tool will not complete the fastening task.
    a. True
    b. False

28. If a powder-actuated tool misfires, the operator must hold the tool firmly against the work surface for at least ____ _____seconds.
    a. 15

b. 10
c. 5
d. 0

29. A powder-actuated tool fastener must not be driven into steel within _____of an edge.

a. 26 mm
b. 20 mm
c. 16 mm
d. 13 mm

30. A low-velocity, powder-actuated tool fastener may not be driven into masonry materials within _____ of an unsupported edge.

a. 25 mm
b. 50 mm
c. 75 mm
d. 100 mm

31. A powder-actuated tool must not be used in an explosive or flammable atmosphere.

a. True
b. False

32. A powder-actuated tool fastener must not be driven into steel within _____of a weld.

a. 25 mm
b. 50 mm
c. 75 mm

33. A powder-actuated tool must not be pointed at any person.

a. True
b. False

Answer Key: Self-Test B-2.2 is on the next page.

Answer Key: Self-Test B-2.2

1. b. As the drill breaks through the work
2. b. Very hard
3. c. The maximum RPM rating
4. The manufacturer's instructions for each type of tool should be followed, since lubrication requirements of air tools are different.
5. Inspect air hoses for fraying, kinks, loose fittings and air leaks, and look for dust plugging the fittings.
6. When you store an air hose, coil it up and connect the connectors at the ends.
7. b. False
8. The water trap or separator should be drained on a daily basis when in regular use.
9. Air drills can be operated safely in wet areas, a condition that would make the operation of an electric drill hazardous.
10. Your answers should include the following: always remove the air hose before making a tool change, never allow anyone to stand in front of the hammer or chisel during operation, and always wear eye and hearing protection.
11. a. True
12. b. False—the tool uses only fasteners that are designed for it
13. About 25 mm (1 in.)
14. Into the solid part of the block and at least 75 mm (3 in.) away from the edge of the block
15. 5 mm (3/16 in.)
16. 12 mm (½ in.)
17. 50 mm (2 in.)
18. Precast concrete containing pre-stressed cables
19. Never use a powder-actuated tool on a spalled surface
20. Brick, ceramic tile, vitrified tile, glass, asbestos
21. a. True (to make sure that it is grounded)
22. a. True
23. b. Off
24. Heat, oil or solvents and sharp objects that can cut the cord
25. d. Soapy water
26. a. True
27. a. True
28. c. 5
29. d. 13 mm
30. c. 75 mm
31. a. True
32. b. 50 mm
33. a. True

Self-Test B-2.3: Describe Stationary Power Tools Used in the Pipe Trades

Complete Self-Test B-2.3 and check your answers.

1. Metal-cutting band saws may have downward pressure applied by means of hydraulics or what adjustable component?
    a. Feed screw
    b. Worm screw
    c. Counterweight
    d. Air-pressure regulator
2. To prevent overheating the work piece, what are some band saws equipped with?
    a. A blower system
    b. A mist spray
    c. Abrasive blades
    d. High-speed blades
3. When a metal-cutting band saw has cut through the workpiece it, will do which of the following?
    a. Sound a beeper
    b. Increase speed
    c. Unclamp the stock
    d. Automatically shut off
4. What is required to cut at an angle with a metal-cutting band saw?
    a. Adding angled blocks to the vise
    b. Rotating the vise
    c. Tilting the band saw
    d. Twisting the blade within its guides
5. When making a heavy cut with a band saw, how can you reduce heat build-up?
    a. Applying greater downward pressure
    b. Reducing the blade speed
    c. Increasing the blade speed
    d. Using a well-worn blade
6. Which of the band saw blades listed below is the least expensive to buy?
    a. Rake set
    b. Carbon steel
    c. Hook-tooth
    d. High-speed steel
7. Non-ferrous metals are easily and quickly cut with what type of blade?
    a. Hook-tooth
    b. Wavy set
    c. Regular-tooth
    d. Skip-tooth
8. What should thin or narrow sections of metal not be cut with?
    a. Abrasive cut-off wheels

b. Raker set teeth
c. Skip-tooth blades
d. Narrow blades

9. What is the best type of metal-cutting band saw blade for quickly cutting ferrous metals?

a. Regular-tooth, carbon steel
b. Hook-tooth, high-speed steel
c. Skip-tooth, high-speed steel
d. Skip-tooth, carbon steel

10. Skip-tooth and hook-tooth blades are available with what teeth spacing?

a. 1 to 3 per inch
b. 3 to 6 per inch
c. 6 to 24 per inch
d. 6 to 32 per inch

11. Which power vise can be used with hand tools or be converted for power drive tools

12. On what power vise model can you attach a roll groover?

13. How should you store the hose for a portable air supply system?

14. Identify the name and model number of this machine:

Figure 1 *Image for question 14.*

15. How does the power-threading machine differ from the power vise?

16. Name one safety feature common to all models of power vises.

17. What is the purpose of the grooving operation?

18. What model of Ridgid groover was designed to be used with a power drive for machine grooving, but it is also designed to manually groove pipe in place?

19. When groover is combined with the 300 power vise, what accessory may be required?

20. What is a side effect of mechanical bending

Answer Key: Self-Test B-2.3 is on the next page.

Answer Key: Self-Test B-2.3

1. c. Counterweight
2. b. Mist spray
3. d. Automatically shut off
4. b. Rotating the vise
5. b. Reducing the blade speed
6. b. Carbon steel
7. a. Hook-tooth blade
8. c. Skip-tooth blades
9. c. Skip-tooth, high-speed steel
10. b. 3 to 6 per inch
11. Model 300
12. Model 300
13. Power drive
14. No. 535 pipe and bolt threading machine
15. The cutter, reamer and threader are built into the power threading machine, while for the power vise, the tools are attached to the motor unit.
16. Foot switch
17. The purpose is to prepare pipe for grooved couplings and fittings.
18. Model 975 roll groover
19. Pipe support stand
20. Wall thickness changes: wall along the inner radius of the tube becomes thicker, and the outer wall becomes thinner.

Self-Test B-2.4: Use Stationary Power Tools

Complete Self-Test B-2.4 and check your answers.

1. The maximum distance from the face of a grinding wheel to the tool rest should be:
    a. 1 mm (1/16 in.)
    b. 3 mm (1/8 in.)
    c. 6 mm (¼ in.)
    d. 12 mm (1/2 in.)
2. To use a grinder safely you must wear:
    a. Leather pants
    b. A fireproof apron
    c. Eye and hearing protection
    d. A hard hat
3. To remove the nut on the left spindle of a stationary grinder, you must turn the nut:
    a. In a clockwise direction
    b. In a counter-clockwise direction
    c. Opposite the rotation of the motor
    d. Upward at the front
4. The purpose of the blotter paper disk on the sides of a grinding wheel is to:
    a. Prevent grinding on the sides
    b. Provide traction to the flanges
    c. Absorb excess moisture
    d. Reduce strain caused by the flanges
5. To correct out-of-roundness on a grinding wheel you must:
    a. Return the wheel to supplier
    b. Adjust the centre on the shaft
    c. Dress the face of the wheel
    d. Grind hard metals
6. To test a grinding wheel for cracks the wheel should be:
    a. Properly mounted on the grinder
    b. Standing or suspended on edge
    c. Rotating slowly
    d. Lying on a flat surface
7. State the safety precaution for checking the switches of a power vise before the machine is plugged in.

    _____

    _____

8. State the safety precaution for checking the switch of the Model 700 portable power vise before the machine is plugged in.

    _____

9. If you must use an extension cord with a power drive, what kind do you use?

10. It is never necessary to support a pipe when using a power vise.
    a. True
    b. False
11. Name the parts in the illustration below.

Figure 1 *Image for Question 11.*

a.

b.

c.

d.

e.

12. What must be done first before installing a length of pipe in a power vise?

13. How are the jaws of the chuck tightened on the pipe to be cut?.

14. After the pipe is installed, how is a hand cutter engaged with the pipe?

15. Which of the three ratchet reamers shown below is the safest hand tool to use with a power vise?

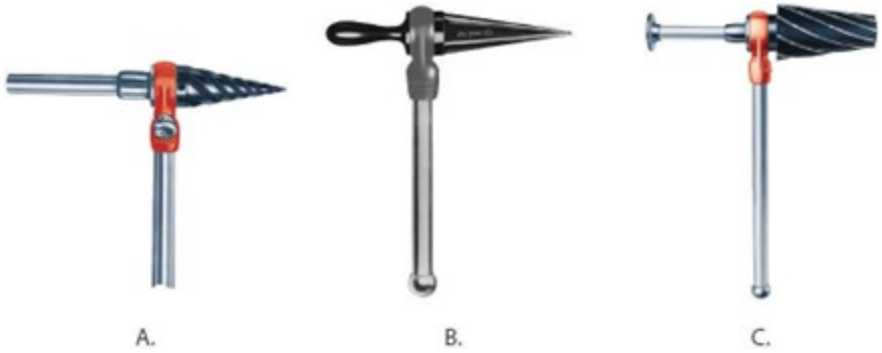

Figure 2 *Image for question 15.*

16. Name the steps for using a fluted hand reamer with a power drive.

a.

b.

c.

d.

e.

17. Name the steps for using a fluted hand reamer with a power drive.

a.

b.

c.

d.

e.

d.

e.

f.

g.

h.

18. A short nipple has threads along its full length.

a. True
b. False

19. A 5 cm (2 in.) nipple requires an adaptor to thread into a nipple chuck

a. True
b. False

20. A 25 mm (1 in.) nipple requires an insert and an adaptor in the nipple chuck.

a. True
b. False

21. Describe the steps for preparing pipe for grooving.

22. If a pipe stand is used to support a length of pipe, how is the stand positioned?

23. What mut you remember to do when placing a pipe end on the driving roll of the groover?

Answer Key: Self-Test B-2.4 is on the next page.

Answer Key: Self-Test B-2.4

1. b. 3 mm (1/8 in.)
2. c. Eye and hearing protection
3. a. In a clockwise direction
4. d. Reduce strain caused by the flanges
5. c. Dress the face of the wheel
6. b. Standing or suspended on edge
7. Check to make sure that the switch is in the Off position, and that the foot switch operates freely.
8. Before plugging in the machine, push down on the switch button a couple of times to make sure that the spring of the switch button returns to the Off position.
9. a. Three-wire extension cord, which has a three-prong grounding plug that fits into a three-pole receptacle
10. b. False—for long, heavy work, a floor pipe support must be used.
11. a. Cutter
    b. Reamer
    c Quick or self-opening die head
    d. Carriage w/lever
    e. Lever arm
12. Measure and mark the length of the pipe being worked.
13. The jaws are tightened with a snap-spin of the hand wheel in a counter clockwise direction. The snap-spin is repeated until the operator is sure the pipe is held securely.
14.
    1. Engage the pipe cutter with the pipe, and align the cutter wheel with the mark you have made when measuring the pipe.
    2. Rest the frame of the pipe cutter on the support bar. Tighten the screw feed handle.
15. b. The straight reamer
16.
    a. Turn the switch to the Forward position.
    b. Insert the reamer into the end of the pipe, holding the handle and handgrip firmly.
    c. Step on the foot switch.
    d. Slowly push on the reamer handgrip with one hand.
    e. Release the foot switch, remove the reamer, and turn the switch to the Off position.
17.
    a. Move the reamer arm down to the reaming position.
    b. Extend the reamer by pressing the latch and sliding the knob toward the pipe until the latch engages the bar.
    c. Turn the switch to the Forward position and step on the foot switch.
    d. Position the reamer into the pipe and complete the reaming operation by pushing the carriage lever with your hand.
    e. Pull the reamer bar back and return it to its out-of-the-way position.
    f. Release the foot switch and turn the switch to the Off position.
    g. Release the speed chuck hand wheel and the centring head from the pipe.
    h. Remove the pipe.
18. False
19. False
20. True
21. Check the pipe to make sure that:
    1. The ends are squarely cut
    2. The pipe fits smoothly on the driving roll

3. Steps have been taken to grind down any internal or external weld beads or seams that may interfere with the grooving operation
4. Burrs, coarse scale, rust, and other irregularities have been removed.

22. The stand is positioned in line with the axis of the driving roll and three-quarters of the pipe length away from the driving roll flange.
23. First, fit the pipe on the driving roll so that the end of the pipe is against the flange of the driving roll. Next, after making adjustments to the support stand (if used), adjust the pipe so that it is in contact with the roll flange on one side only.

PART III

B-3 USE ACCESS EQUIPMENT

Plumber Apprenticeship Program – Level 1

Men on Brown Scaffolding (https://www.pexels.com/photo/men-on-brown-scaffolding-2209529/) (Darya Sannikova/pexels) Pexels License (https://www.pexels.com/license/)

B-3 Use Access Equipment Introduction

Safe access equipment is essential in plumbing and pipe trades work, where tasks are often performed above ground level. Ladders and elevated work platforms allow workers to reach work areas safely, but they must be selected, set up, and used correctly to prevent accidents and injuries. Understanding the different types of access equipment and the safety requirements for their use is an important part of working safely on construction sites. In this section, you will learn about common types of ladders and elevated platforms, their key features, and the proper procedures for using them safely and effectively.

Learning Objectives

After completing this section, you should be able to:

- Describe ladders and elevated platforms.
- Use ladders and elevated platforms.

You will be required to reference publications and videos available online at WorkSafeBC. (https://www.worksafebc.com/en)

Terminology

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

- **allround system:** A modular scaffold system made of vertical posts and horizontal supports that connect at fixed points using special locking joints. The design allows scaffold sections to be assembled quickly and safely in many different shapes and heights. (Section B-3.1)
- **casters:** Small wheels attached to equipment so it can roll or move easily. (Section B-3.1)
- **cleats:** Flat wooden strips used as steps on some job-built ladders. (Section B-3.1)
- **coupling pins**: Metal pins used to connect and secure scaffold frames or sections together. They fit into

holes in the scaffold frames to keep the sections aligned and prevent them from separating during use. (Section B-3.1)

- **fillers:** Pieces of material used to fill gaps between parts so everything fits tightly and securely. (Section B-3.1)
- **guardrail:** A protective rail along an edge that helps prevent people from falling. (Section B-3.1)
- **hydraulic**: A system that uses liquid pressure to move or lift objects or equipment. (Section B-3.1)
- **ladder-jack scaffold:** A temporary work platform supported by brackets attached to ladders. (Section B-3.1)
- **levelling screw jacks**: Adjustable metal supports placed at the base of a scaffold that can be turned to raise or lower the scaffold frame. They are used to level the scaffold on uneven ground and provide a stable foundation. (Section B-3.1)
- **mudsill:** A strong board placed on the ground to spread the weight of a scaffold and keep it from sinking. (Section B-3.1)
- **out-of-plumb:** Not perfectly vertical or straight up and down. (Section B-3.1)
- **overlap:** The part where two sections of a ladder slide over each other to make the ladder longer and stronger. (Section B-3.1)
- **plan brace (gooser bar)**: A metal support bar used on scaffolding to keep the scaffold frame square and stable. It connects parts of the scaffold to prevent the structure from twisting or shifting out of alignment. (Section B-3.2)
- **pneumatic:** A system that uses air pressure to move or lift things. (Section B-3.1)
- **rungs:** The round bars on a ladder that you step on when climbing. (Section B-3.1)
- **scaffold:** A temporary structure that allows workers to safely reach high work areas. (Section B-3.1)
- **scissor lift:** A machine that raises workers straight up using folding supports that move like scissors. (Section B-3.1)
- **self-supporting:** Able to stand on its own without leaning against another structure. (Section B-3.1)
- **slip-resistant safety feet**: Rubber or textured ends attached to the bottom of a ladder that help prevent it from sliding and keep it stable on the ground. (Section B-3.2)
- **spreaders:** Bars on a step ladder that hold the legs apart so the ladder stays stable. (Section B-3.1)
- **sway brace:** A support bar that helps keep a scaffold stable and prevents it from wobbling. (Section B-3.1)
- **toe-board:** A small board along the edge of a platform that prevents tools or materials from falling off. (Section B-3.1)
- **tolerance:** The small amount a measurement can vary from the exact value and still be acceptable. (Section B-3.1)
- **tube-and-clamp system**: A type of scaffold built from metal tubes connected with adjustable clamps. The tubes can be arranged in many different ways, allowing the scaffold to be built to fit different shapes and sizes of work areas. (Section B-3.1)

B-3.1 Describe Ladders and Elevated Platforms

The safe use of ladders and working platforms is required in all types of construction. Ladders and elevated work platforms must meet applicable Canadian Standards Association (CSA) or American National Standards Institute (ANSI) standards. Workplace regulations have set minimum standards for the production, assembly, and use of ladders and working platforms.

WorkSafeBC publishes Occupational Health and Safety regulations concerning ladders and elevated platforms in Part 13 (https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation/part-13-ladders-scaffolds-and-temporary-work-platforms), which can be found in the OHS Guidelines (https://www.worksafebc.com/en/law-policy/occupational-health-safety/ohs-guidelines) on the WorkSafeBC website. WorkSafeBC also publishes guidelines to help workers understand and comply with these regulations. It is your responsibility to be familiar with these regulations.

Types of Ladders

There are three basic types of ladders: step ladders, single (straight) ladders, and extension ladders. Step ladders and extension ladders are usually manufactured. Single ladders may be manufactured or built on the job site.

CSA Ladder Rating Scale

Table 1: CSA Ladder Rating Scale

Grade	Projected Use	Load Rating
1	Construction/Industrial	Heavy
2	Light Maintenance/Farm	Medium
3	Household	Light

Step Ladders

Step ladders are ***self-supporting***, meaning that they do not need to lean against a structure. They must be placed on a level surface, and must not be used as a means to access other platforms or landings.

Step ladders are available in a wide range of sizes, styles, and materials. The longest step ladder readily available is 6 m (20 ft). They are hinged at the top, and can be folded flat for easy transport.

When using step ladders, take the following precautions:

- Fully spread the legs of the step ladder.
- Lock the ***spreaders*** at each side so that the legs cannot open or close during use.
- Never stand on the top two steps.
- Never use the fold-down shelf near the top of the ladder as a step.

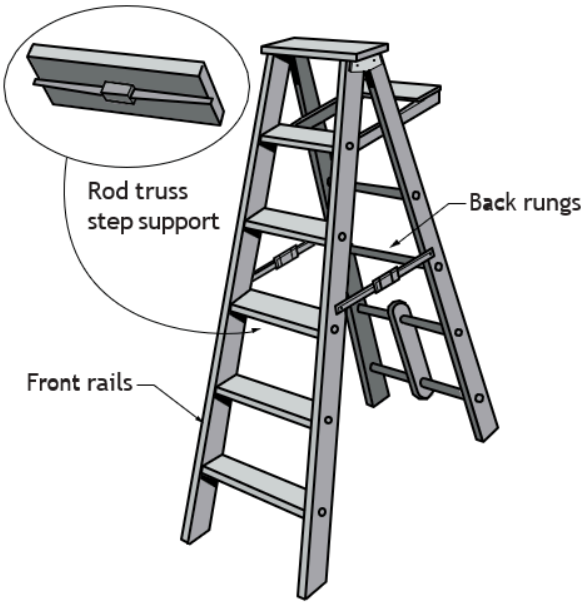

Figure 1 *Step ladder (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Single (Straight) Ladders

Manufactured single ladders have ***rungs*** (a round cross-piece, typically metal). Job-built ones have ***cleats*** (typically a flat strip of wood). Before using a job-built ladder, make yourself familiar with the relevant workplace regulations.

Whether the ladder has rungs or cleats, the following regulations typically apply:

- Lumber for all components must be construction grade, No. 2 grade, and better.
- Plywood must not be used for any ladder component.
- Side rails must be 38–89 mm (2–4 in.) for ladders up to 5 m (16 ft) long.
- Side rails must be 38–140 mm (2–6 in.) for ladders up to 7.3 m (24 ft) long.
- Cleats must be 19–64 mm (1–3 in.) for ladders up to 5 m (16 ft) long.
- Cleats must be 19–89 mm (1–4 in.) for ladders over 5 m (16 ft) to 7.3 m (24 ft) long.
- Do not notch the side rails to receive cleats.
- Nail the cleats to the narrow edges of the side rails.
- Fill the spaces between the cleats with close-fitting, well-secured ***fillers***, of the same thickness as the cleats (Figure 2).
- The distance between side rails must be between 380 mm (15 in.) and 500 mm (20 in.).
- Space the cleats at 300 mm (12 in.) centres.
- Nail cleats made of 19 × 64 mm (1 in. – 3 in.) material with two 57 mm ($2\frac{1}{4}$ in.) nails at each end.
- Nail cleats made of 19 × 89 mm (1 in. – 4 in.) material with three 57 mm ($2\frac{1}{4}$ in.) nails at each end.

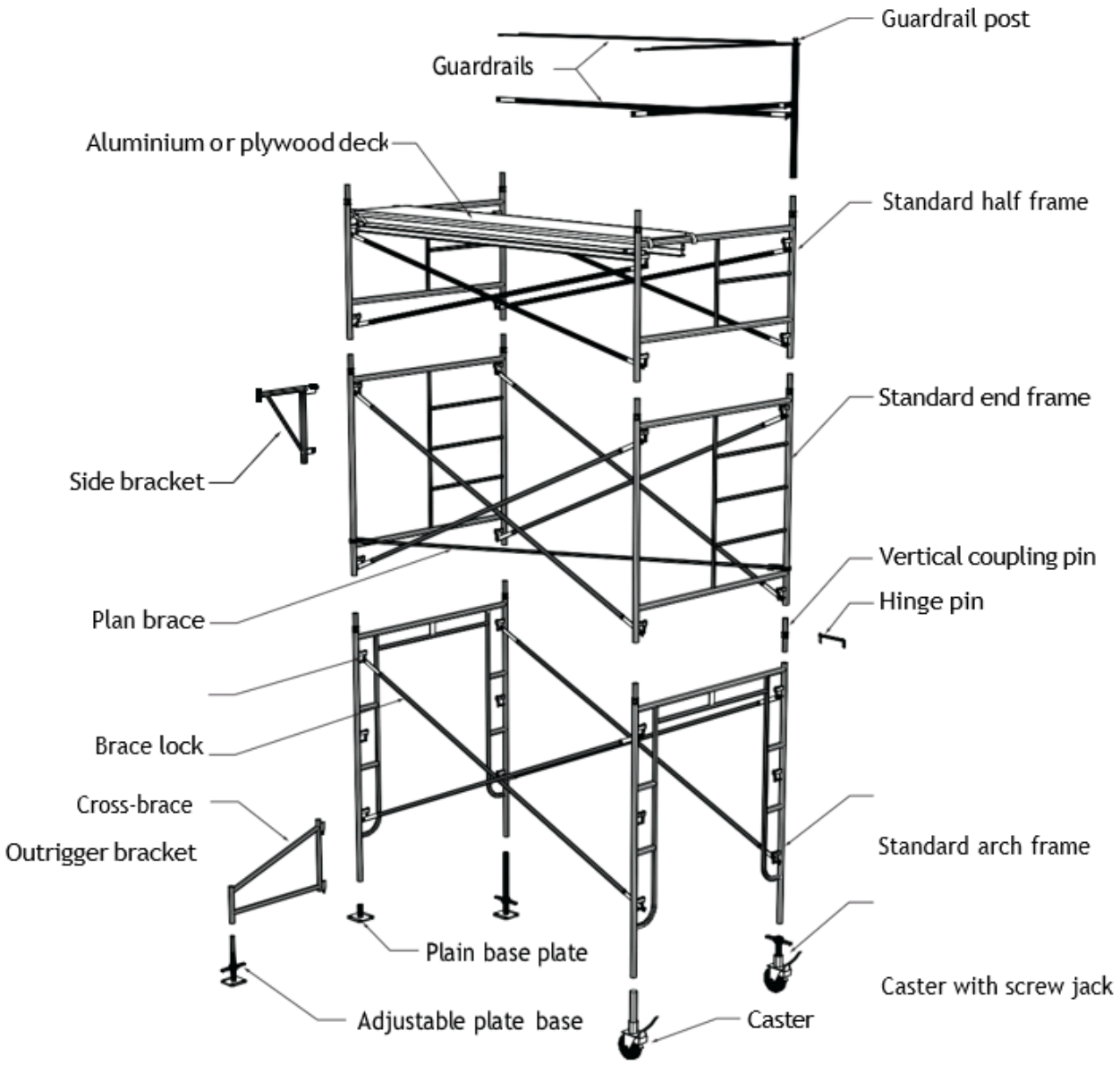

Figure 2 *Welded steel frame scaffold (Courtesy WorkSafeBC). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Extension Ladders

An extension ladder is similar to a single ladder. However, the extension ladder has two or three sections that ***overlap***, allowing it to reach variable heights.

Brackets that rest on the rungs of lower sections support the higher extending sections. The area where the sections are still in contact with one another is referred to as the overlap section. Longer extension ladders require a longer overlap for strength.

- Grade 1 extension ladders with two sections may be up to 18 m (60 ft) long.
- Grade 1 extension ladders with three sections may extend up to 22 m (72 ft).
- Minimum required overlap is 1 m (39 in.) for ladders extending up to 11 m (36 ft).
- Minimum required overlap is 1.2 m (4 ft) for ladders extending to between 11 m (36 ft) and 15 m (48 ft).
- Minimum required overlap is 1.5 m (5 ft) for ladders extending to between 15 m (48 ft) and 22 m (72 ft).

Watch this WorksafeBC (2026) video *Choose the Right Ladder and Use It Safely | WorkSafeBC* [2:45] on YouTube.

> *One or more interactive elements has been excluded from this version of the text. You can view them online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2851#oembed-1 (#oembed-1)*

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

Types of Elevated Platforms

A safely erected ***scaffold***, for example, provides a stable platform for workers to complete their work. Powered platforms, such as ***scissor lifts***, must only be used by trained personnel.

Scaffolds

Workplace regulations do not give specifications for scaffolding accessories such as welded scaffold brackets and ***ladder-jack scaffolds***. Many scaffolding accessories available have been tested in accordance with CSA standards and are approved for use as construction work platforms. Accessories that are custom built must be designed by a registered professional engineer and certified as safe for use.

It is the employer's responsibility to ensure that scaffolds used by workers are in safe condition and able to withstand the load, regardless of who erected the scaffold.

Scaffold Construction and Use

Only trained workers should construct and dismantle scaffolds. Do not use damaged materials or weakened scaffold parts when erecting a scaffold. When dismantling a scaffold, carefully remove each component. Pass the removed parts down to a co-worker by hand and use a tool bag to safely raise or lower small components from higher elevations to the ground. Remove any nails or other fasteners that might create a hazard.

Employers must ensure that all scaffolds are safe before use, but workers must also inspect scaffolds prior to use.

Take care not to overload the scaffold. Scaffolds are designed to support only workers and a suitable amount of material. Stockpiling materials is not recommended unless the scaffold is specifically designed to support the additional load.

Knowing how to assemble and use a steel scaffold safely does not guarantee freedom from accidents. Watch your step and be prepared to hold onto something if you lose your balance.

Erecting Scaffolds

Scaffolds are not permanent structures. Scaffolds must be assembled and disassembled quickly. Despite the temporary nature of scaffolds, they are structures, so they must be erected on proper foundations, laid out correctly, and built within spec*ific* ***tolerances***.

- **Foundations**—Scaffolds are used to access many different work areas, some of which are very large or high. Like any structure, a scaffold needs an adequate foundation. A scaffold is a temporary structure, so there are usually no excavation or concrete footings. The foundation for a scaffold is usually a heavy wooden plank, called a ***mudsill***.
- **Layout**—Larger scaffolds require approved plans and specifications to follow during construction. Build smaller wooden scaffolds according to the specifications laid out in the OHS Regulation. In any case, the layout of the scaffold base is critical. The scaffold will be unstable if the base is not square or does not meet the required dimensions.
- **Tolerances**—The tolerances for the construction of a scaffold are the same as for other structures. For prefabricated scaffolds, the overall dimensions are set by the dimensions of the scaffold frames or components. Tube-and-clamp or job-built wooden scaffolds can be constructed to any dimension. The dimensions of these scaffolds should meet the tolerances specified in their design plans.

The usual tolerance for ***out-of-plumb*** is 6 mm in 3 m ($\frac{1}{4}$ in. in 10 ft) to a maximum of 38 mm (1 $\frac{1}{2}$ in.) overall.

Mudsills

When erecting scaffolds supported by the ground, the vertical supports must rest on a solid base. Where the ground is soft or the bearing pressure is high, spread the load over a larger area of the ground with a wood "*mudsill*" under each vertical support. If a mudsill is placed under a single upright, it should be built from plywood with dimensions of 38 mm × 300 mm × 300 mm (2 in. × 10 in. × 10 in.). It is preferable to have continuous sills, but if this is not possible, use a sill supporting two uprights or, as a last option, a single sill. Sills must be level.

Plumb and Level

Horizontal scaffold supports must be level, and vertical scaffold supports must be plumb. This is required for both aesthetic and structural reasons. A scaffold that looks good and is straight is a mark of a professional tradesperson and is usually safer.

Scaffold Stability

A free-standing scaffold that is more than three times higher than its minimum base dimension must be fastened to the building or supported by other means.

Guardrail and Toe-Boards

A standard ***guardrail*** (Figure 4) must be installed if the working surface of the scaffold is more than 3 m (10 ft) above the surrounding ground.

The standard guardrail shown in Figure 4 is for a steel-frame scaffold, but the dimensions relating to this type of guardrail apply to all scaffolds. Fibre or wire rope may not be used as guardrails or intermediate rails unless permission has been granted by the Workers' Compensation Board prior to their erection.

Toe-boards prevent tools, materials, or equipment from falling off the scaffold platform. Figure 5 shows how they are installed around the open sides of scaffolds. Toe-boards must extend 100 mm (4 in.) above the work platform and must have no more than 13 mm ($\frac{1}{2}$ in.) clearance between their low edges and the work platform. Toe-boards may be omitted at access openings.

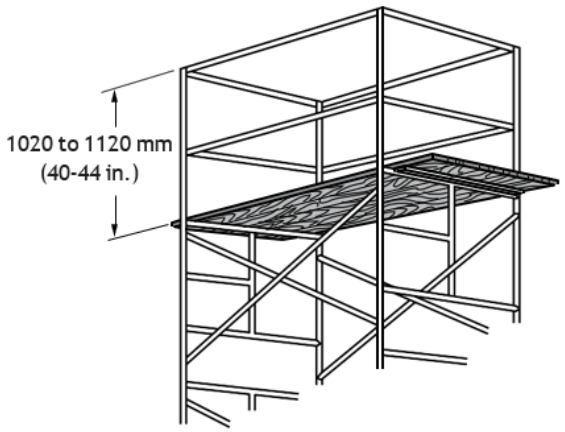

Figure 4 *Standard guardrail (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

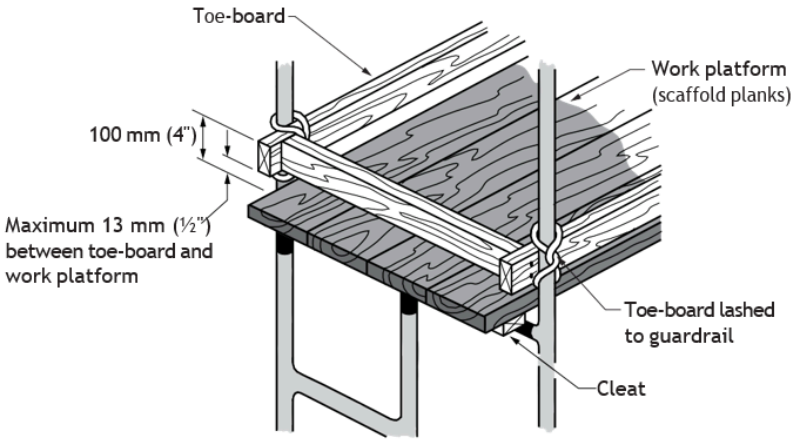

Figure 5 *Toe-board on a steel frame scaffold (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Scaffold Planks

Scaffold planks are the work surface of the scaffold, and they must be treated with care. Before being installed, each scaffold plank, new or old, must be inspected. If the strength of any planks is in question, they must be tested.

Lumber Grades, Types, and Sizes for Scaffold Planks

Most regulations require that sawn-wood scaffold planks be "select structural scaffold plank" lumber meeting National Lumber Grades Authority grading rules or an equivalent standard. These planks must show the appropriate grade stamp. However, most sawmills no longer produce planks of this grade; therefore, strict compliance with this regulation is often no longer possible.

Most workplace regulations allow the following alternatives instead of using select structural scaffold plank lumber:

For a 3 m (10 ft) span:

- A double layer of 38–235 mm (2–10 in.) dressed planks (one placed on top of the other, with no need to nail or glue them together), graded No. 2 or better.
- Precautions must be taken where scaffold planking overlaps for continuous runs, as the 75 mm (3 in.) height difference may create a tripping hazard.

Alternatively, a single thickness of rough-sawn plank having actual dimensions of 48–251 mm ($1\ \frac{7}{8}$ in. – $9\ \frac{1}{4}$ in.), graded No. 2 or better, may be used.

For a 1.8 m (6 ft) span:

- A single thickness of 38–235 mm (2–10 in.) dressed lumber, graded No. 2 or better.

- Hand-pick scaffold planks for minimal knots and straight grain to ensure they are suitable for scaffold use.

Use only the following species of lumber for scaffold planks:

- Douglas fir-larch
- Hem-fir
- Spruce-pine-fir
- Coast Sitka spruce

Rough lumber is stronger and provides a more slip-resistant surface. However, rough lumber is usually not graded and must therefore be inspected visually for defects before use. All planks must be of uniform thickness.

Manufactured Planks

Manufactured scaffold planks must be CSA-approved. Job-built planks are not approved by WCB unless a registered professional engineer certifies them.

A single manufactured extension staging (painter's plank, the type often used with a ladder-jack scaffold) may be used, provided that it supports only one worker.

Testing Scaffold Planks

If scaffold material is not certified as "tested" prior to shipment to the job site, it must be field-tested before use. To test scaffold planks, follow the procedures described in applicable local workplace regulations.

Plank Platforms

The minimum work-platform width is two planks or 500 mm (20 in.). Openings must not be wider than the width of one plank. If the work platform is sloped, it must be slip-resistant. The maximum slope is 600 mm (2 ft) vertical in 3 m (10 ft) horizontal, which is a 1:5 slope ratio.

Plank Support

Scaffold plank supports must be placed at intervals of at least every 3 m (10 ft) for light work, and at intervals of at least every 2.1 m (7 ft) for heavy work, such as bricklaying and masonry. The planks must extend no less than 150 mm (6 in.) and no more than 300 mm (12 in.) beyond the supporting members.

Scaffold Types

There are three basic types of tubular steel and aluminum scaffolding:

- Welded steel-frame system
- ***Allround system***
- ***Tube-and-clamp system***

Allround and tube-and-clamp system scaffolding requires a professional scaffolder for installation.

Welded Steel-Frame Scaffold Parts

On construction sites, welded steel-frame scaffolds are the most widely used. They are often rented by the contractor for a specific job. When a large amount of scaffolding is required, there may be a separate contract for the erection and dismantling of the scaffolds. Figure 6 shows a typical welded steel frame scaffold.

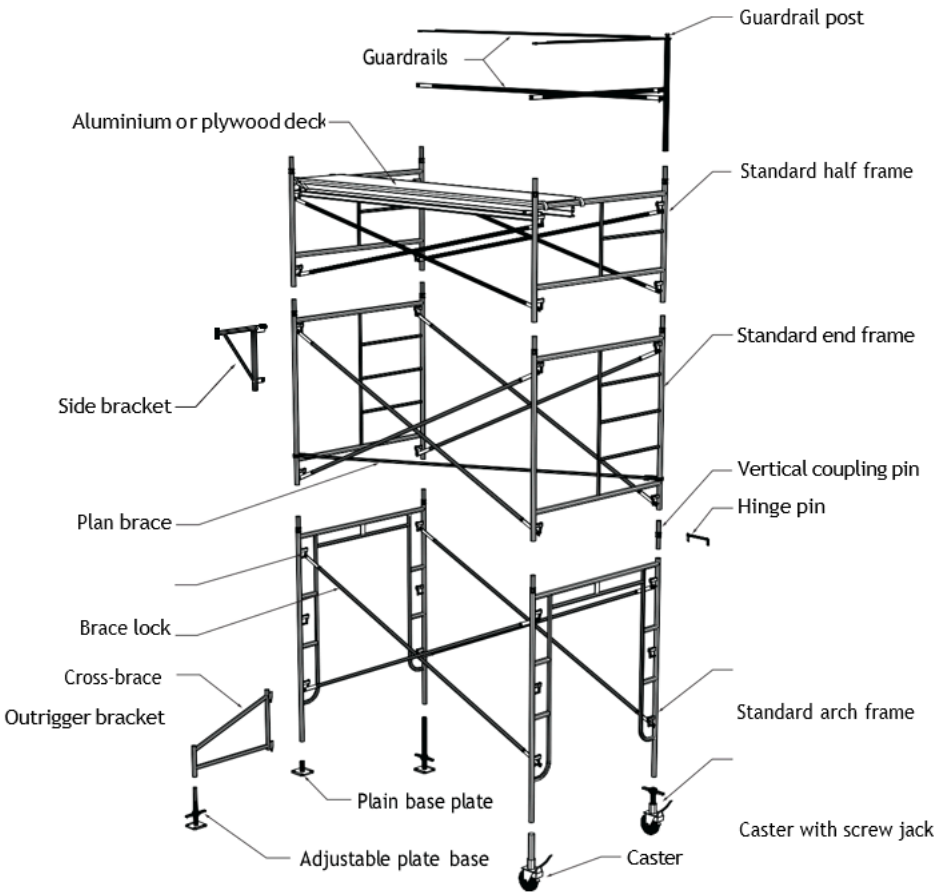

Figure 6 *Welded steel frame scaffold (Courtesy WorkSafeBC)*

A welded steel scaffold has two parts: the end frame and the cross-brace (Figure 7).

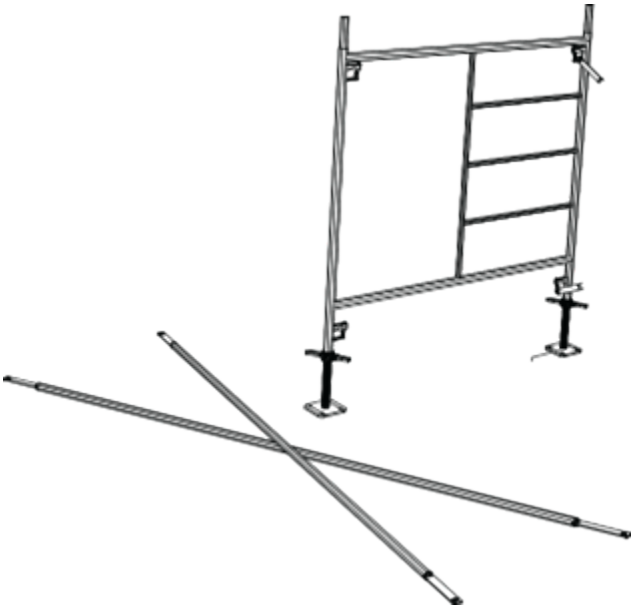

Figure 7 *End frame and cross-brace*
(Courtesy WorkSafeBC)

Assembling two end frames and two cross-braces forms a single basic unit, as shown below.

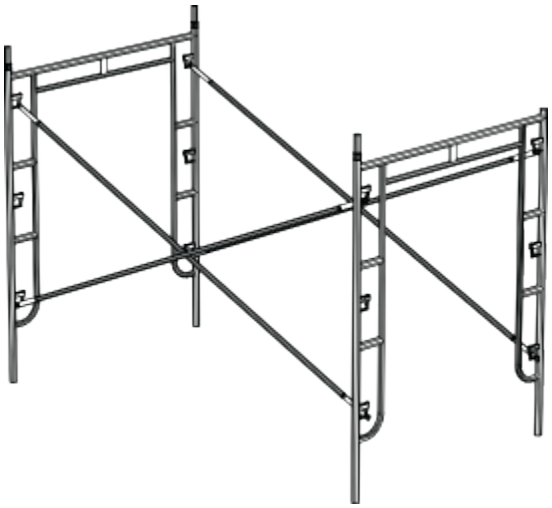

Figure 8 *The basic unit of a welded steel scaffold*
(Courtesy WorkSafeBC)

The scaffold can be expanded upward or sideways by assembling several basic units adjacent to each other. Use ***coupler pins*** to align and secure the units.

The scaffold frames must be level in both directions. Use ***levelling screw jacks*** if required.

When the scaffold is more than one unit high, the basic units are secured to each other by coupler pins inserted through the end frames. Bolts may be needed to secure the pins in place. The entire scaffold should be capable of being lifted by a crane without the frames separating.

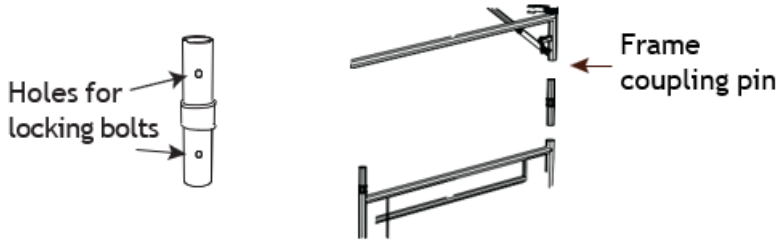

Figure 9 *Coupler pin / frame coupling*
(Courtesy WorkSafeBC)

Cross-bracing helps to keep the scaffold rigid. Basic units placed next to each other can be connected by cross bracing to form longer or higher units. Cross braces do not provide the required protection and therefore cannot be used as a guardrail. If the work platform is above 3 m (10 ft) from the surrounding grade, guardrails that meet the OHS Regulation must be installed.

Secure steel scaffolds to the building structure at horizontal intervals of 6.4 m (21 ft). The first vertical attachment to the building must be within three times the minimum base dimension, usually 4.6 m (15 ft), and then at intervals of 6 m (20 ft) after that.

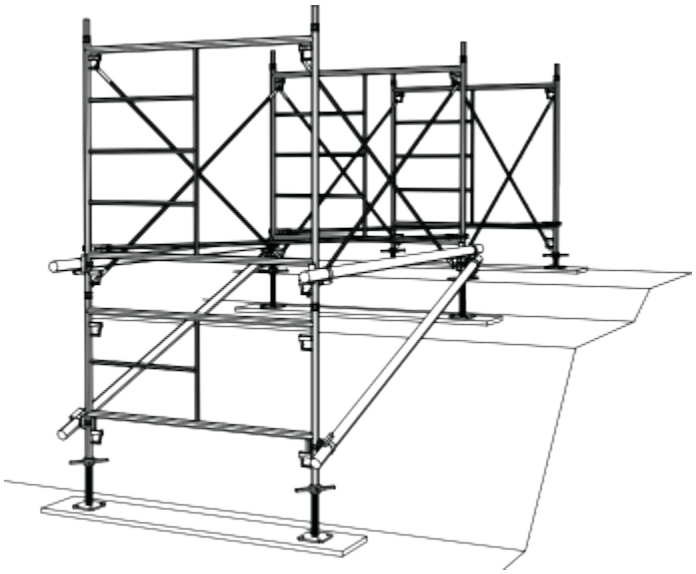

Figure 10 *Frames connected by bracing to form a long scaffold*
(Courtesy WorkSafeBC)

There is a danger of electric shock when using metal scaffolds near energized electrical equipment. The structure must be grounded or equipped with resilient, nonconductive tires.

Adjusting For Ground Conditions

Whenever scaffolds are erected, they must be level and placed on a firm base. Soil should be well-compacted to remove cavities.

Uneven Ground

If the ground is uneven, use screw jacks or ***adjustable base jacks*** to level the scaffold. Never use bricks, pallets, boxes, or building blocks to level the base of a scaffold.

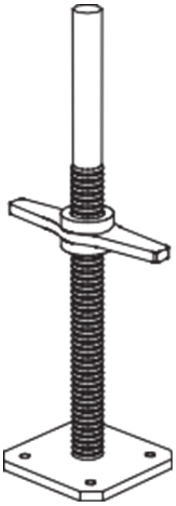

Figure 11 *Screw jack (Courtesy WorkSafeBC)*

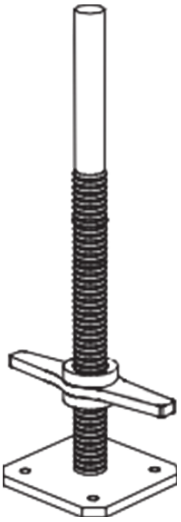

Figure 12 *Adjustable base jack (Courtesy WorkSafeBC)*

Soft Ground

To prevent the vertical legs of the scaffold from sinking into soft surfaces, support them with mudsills. For long mudsills, use lumber no smaller than 38 × 235 mm (2 × 10 in.). If a mudsill is placed under a single upright, it should be built from plywood with dimensions of 38 × 300 × 300 mm (1 $\frac{1}{2}$ × 12 × 12 in.). Use a base plate to spread the weight of the scaffold over the mudsill.

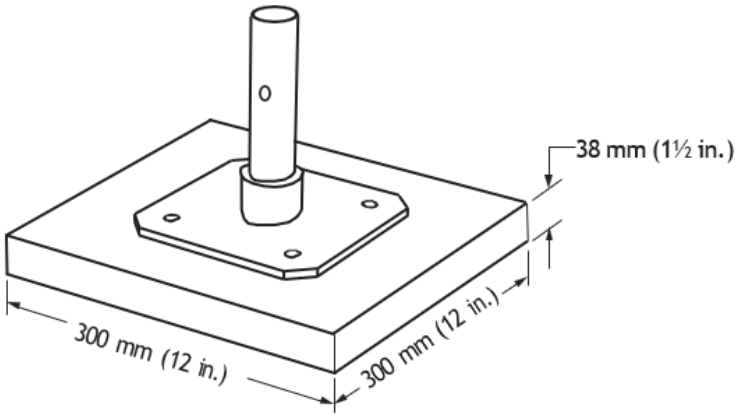

Figure 13 *Base plate on mud sill (Courtesy WorkSafeBC)*

Frozen Ground

Do not place mudsills directly onto frozen ground. Dig out the frozen ground until a firm bearing layer is reached, or have an engineer approve the foundation conditions.

Platforms

Planks used for a work platform on a manufactured scaffold are often manufactured to match the steel scaffolding. The plank shown below hooks over the horizontal bars of the end frames, and usually has a minimum width of 508 mm (20 in.). Manufactured planks must be designed to meet workplace regulations.

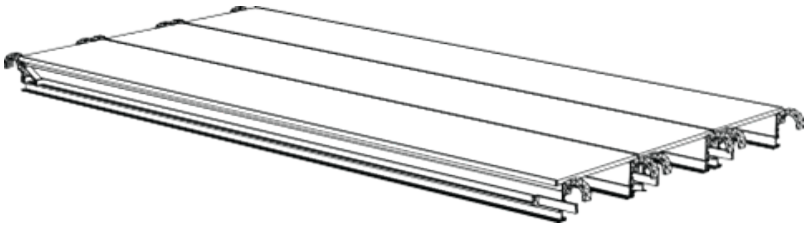

Figure 14 *Manufactured scaffold plank (Courtesy WorkSafeBC)*

If lumber planks are used instead of manufactured ones, they must be fitted with cleats to prevent them from sliding off the steel frames. Lumber planks must extend beyond the supports by at least 150 mm (6 in.) but no more than 300 mm (12 in.).

Guardrails

Whenever the work platform is more than 3.0 m (10 ft) above the ground, guardrails are required on all open sides of the scaffold platform. The guardrail unit consists of a top rail, an intermediate rail, and a toe-board. The top rail is placed 1020–1120 mm (40–44 in.) above the platform, and the intermediate rail is set halfway between the top rail and the toe-boards. Guardrails can be erected at the top of steel scaffolding using manufactured guardrail posts and metal guardrails.

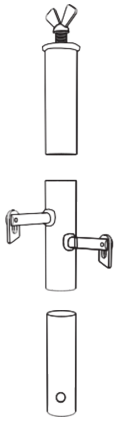

Figure 15 *Guardrail post*
Courtesy of WorkSafeBC

Figure 16 *Metal guardrail*
Courtesy of WorkSafeBC

When manufactured guardrail components are not available, an additional unit of scaffolding may be added to the top of the scaffold. Attach wooden guardrails to this added section. Guardrails must be installed at the ends of the platforms as well as along the sides.

Rolling Scaffolds

A rolling scaffold is a steel scaffold fitted with ***casters*** so that it can be moved easily. With casters, even a heavy unit two or three frames high can be moved easily. Rolling scaffolds must be used only on floors that are within three degrees of level and must be free of depressions and obstructions.

Casters must be installed on steel scaffolds so that they cannot fall out if one end of the scaffold is lifted. All casters must be bolted to the frame. Casters must be fitted with locking devices or brakes when workers are on the scaffold more than 3 m (10 ft) above floor level. Because the casters allow the basic unit to shift from corner to corner, a horizontal cross brace, called a ***sway brace***, is installed to give the unit rigidity.

The most common violation by users of rolling scaffolds is failure to install locking pins to secure the wheels in place. The pins are required to hold the wheels in place. Accidents have occurred because one of the wheels fell out when the scaffold was rolled over a depression in the floor or ground. All vertical frames must also be equipped with locking pins at the top and bottom of the couplers.

The height of a rolling scaffold must not exceed three times its base dimension. Use outriggers to increase the base dimension and allow for a higher free-standing scaffold.

Moving Rolling Scaffolds

If the height of the platform exceeds $1\frac{1}{2}$ times the minimum base dimension of a rolling scaffold, a worker on the work platform must not move the scaffold while remaining on it.

If the height of the platform exceeds two times the minimum base dimension of a rolling scaffold, a worker must not remain on the scaffold while it is being moved from below.

Always cover floor openings and use curb protection when using rolling scaffolds. Follow the manufacturer's instructions precisely when erecting manufactured scaffolds, to reduce the risk of accidents.

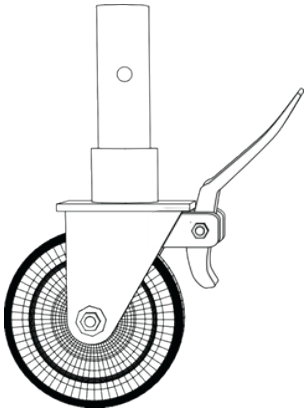

Figure 17 *Caster wheel (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

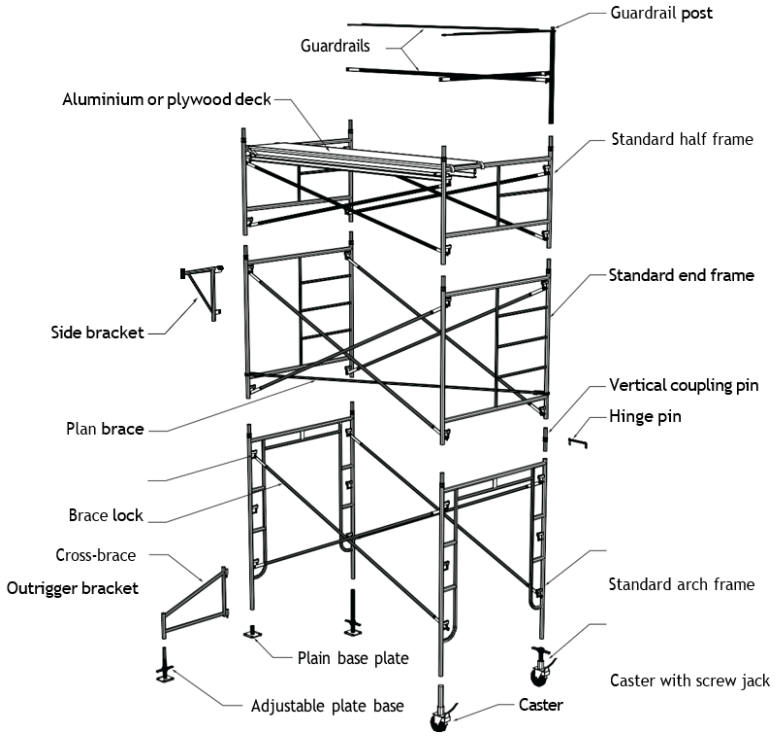

Figure 18 *Rolling scaffold (Courtesy WorkSafeBC)*

Powered Elevated Work Platforms

Power-elevated work platforms are useful because they provide mobility and access to different elevations. These types of lifts allow workers to reach elevated work areas and operate the equipment from the platform.

Scissor Lifts

A scissor lift is a type of elevated platform that can be used to access high work areas while supporting multiple workers and equipment. Most scissor lifts used in construction are mounted on rubber tires, either solid or ***pneumatic***, which allow the lifts to be transported to worksites on trailers.

The largest advantage of scissor lifts is their ability to quickly move a load vertically. Linked, folding supports connected in a crisscross pattern provide vertical movement of the platform.

The upward motion is achieved by applying pressure to the outside of the lowest set of supports, lengthening the crossing pattern and propelling the work platform vertically. The platform may also have an extending platform bridge to allow closer access to some work areas.

The driving force of the scissor action is most often ***hydraulic***, but it may also be pneumatic or mechanical (using a lead screw or rack-and-pinion system). Depending on the power system employed on the lift, it may require no power to enter "descent" mode, but rather a simple release of hydraulic or pneumatic pressure.

Figure 19 *TL 2000 scissor lift (Edmolift AB/Wikimedia Commons CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0/)*

Figure 20 *Scissor lift (elevated work platform) (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

This is the main reason that these methods of powering the lifts are preferred, as they allow a fail-safe method of returning the platform to the ground by release of a manual valve.

Boom Lifts

Boom lifts are often mounted on rubber pneumatic tires capable of operating on rough terrain.

Also known as ***cherry pickers***, they are widely used for maintenance and construction applications, including extensive use in the pipe trades. As with all power-operated elevated work platforms, proper training in safe operating procedures is required for all employees who will operate this equipment.

You must perform safety checks and log critical information daily. Consult local workplace regulations for additional requirements.

The ***bucket*** is designed for a person to stand in and work from. Often the person in the bucket has a duplicate set of controls available at grade level, allowing them to position the platform. The lifting arms of some cherry pickers are capable of telescoping to adjust the reach of the device, usually with automatic safety controls to prevent tipping. Articulated boom lifts (a highly manoeuvrable design) are more appropriate than ***stick booms*** when operating in tight spaces or when it is necessary to clear nearby obstacles.

Figure 21 *Articulating Boom Lift (Billy McCrorie/Wikimedia Commons) CC BY-SA 2.0 (https://creativecommons.org/licenses/by-sa/2.0)*

Self-Test B-3.1: Ladders and Elevated Platforms

Complete Self-Test 3.1 and check your answers.

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2851#h5p-32 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2851#h5p-32)

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WorkSafeBC. (2026, April 17). *Choose the right ladder and use it safely* [Video]. YouTube. https://www.youtube.com/watch?v=8HdzqCOayCA

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- **Figure 20** Articulating Boom Lift (https://commons.wikimedia.org/wiki/File:Articulating_Boom_Lift,_Stranraer_-_geograph.org.uk_-_7271692.jpg) by Billy McCrorie on Wikimedia Commons is used under a CC BY-SA 2.0 (https://creativecommons.org/licenses/by-sa/2.0) license.

B-3.2 Use Ladders and Elevated Platforms

Portable Ladder Safety

Portable ladder safety requirements are governed by workplace regulations. In British Columbia, these requirements are outlined in WorkSafeBC's Occupational Health and Safety Regulation, Part 13: Ladders, scaffolds and temporary work platforms (https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation/part-13-ladders-scaffolds-and-temporary-work-platforms), available on the WorkSafeBC website.

The following rules apply to all portable ladders:

- Inspect all portable ladders before use.
- Do not use ladders with loose, broken, or missing rungs, split side rails, or other dangerous defects.
- Ensure that aluminum ladders have all members straight and properly aligned.
- Remove from use any aluminum ladder with bends, kinks, or other damage.
- Have damaged ladders repaired by an appropriate and reputable firm before putting them back into service.
- Do not use metal ladders or wire-reinforced wooden ladders near energized electrical equipment.
- Use only transparent protective coatings or preservatives on wooden ladders, so that possible defects remain visible during inspection.
- Never reach more than one arm's length beyond the side of the ladder.
- Do not carry heavy or bulky items while climbing up or down ladders.
- Always face the ladder when climbing up or down.
- Ensure that all ladders bear the appropriate Canadian Standards Association (CSA) label.

Carrying, Setting Up, and Using Ladders

Single and extension ladders have the same basic requirements for safe use:

- Rest the foot of the ladder on a firm, level base.
- Choose a ladder of sufficient length to project at least 1 m (3 ft) above the level of the ***landing*** to which it provides access.
- Do not stand on the top two ***rungs*** or ***cleats***.
- See the illustration for Figure 1: It shows a side-elevation view of a ladder leaning against a building. If dimension A is 4 m (13 ft), then B should be approximately 1 m (3 ft), and C should extend approximately 1 m (3 ft) above the level of the landing.

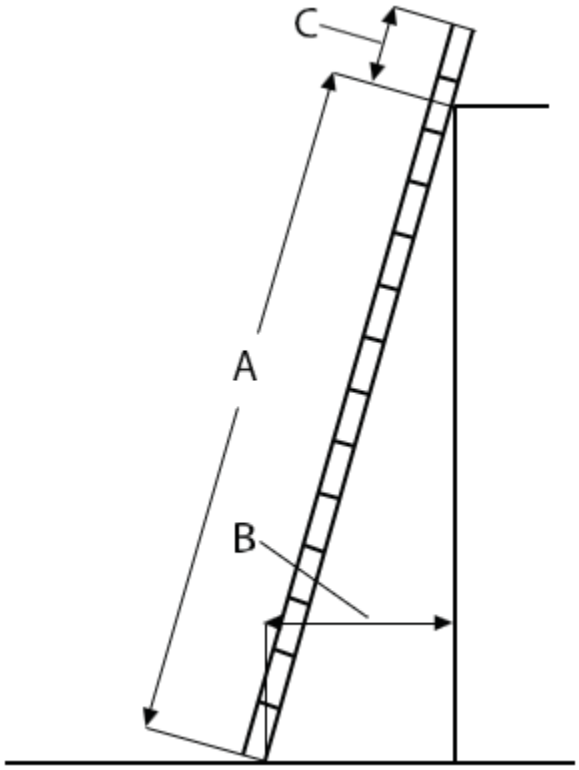

Figure 1 *Correct ladder slope (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

- Ladders must have ***slip-resistant safety feet*** or be secured to prevent slipping during use.

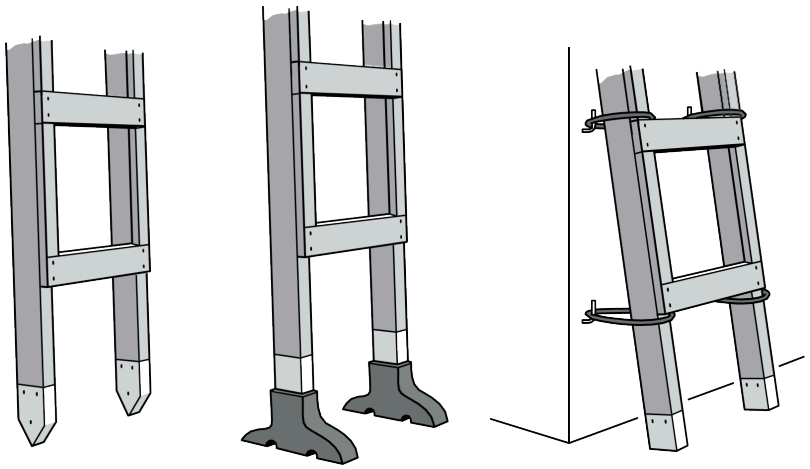

Figure 2 *Securing the base of single or extension ladders (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Setting Up Single and Extension Ladders

It is important to use the correct methods for setting up ladders to avoid injury to the person or damage to the ladder. Check for overhead wires or other hazards before lifting the ladder.

Setting Up Alone

The following steps should be followed when setting up or taking down a ladder when you are alone.

1. Lay the ladder on the ground with the base resting against the wall and the top pointing away from the wall.
2. Starting at the top of the ladder, lift the end over your head and walk under the ladder toward the wall, moving your hands from rung to rung as you go (Figure 3).
3. If you find you are unable to raise the ladder enough, set it back down and get help.
4. Adjust the slope of the ladder so that the distance from the wall at the base is one-quarter of the height of the landing being accessed.
5. If necessary, secure both the top and bottom to prevent dislodgment.
6. Reverse this process to take down the ladder, and remember that you will be walking backwards, so check your path for obstacles before you start.
7. Lower the ladder slowly so that you keep it under control and prevent it from falling on you.

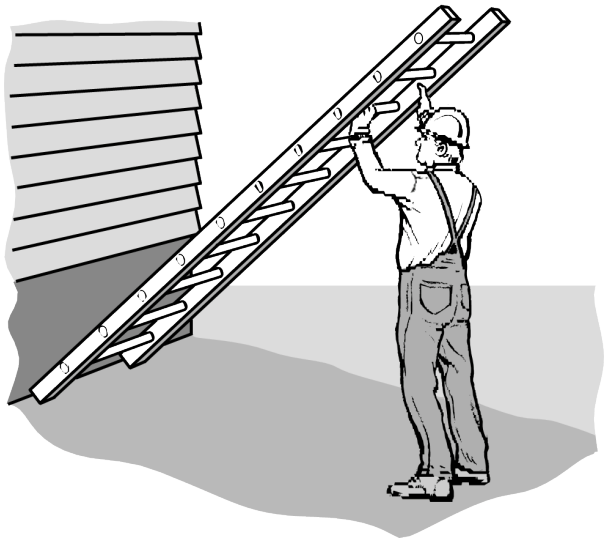

Figure 3 *Setting up a ladder alone (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Setting Up with a Helper

The following steps should be followed when setting up or taking down a ladder with someone else's help:

1. Lay the ladder flat on the ground, with its feet at the point where they will be placed during use, and with its

length parallel to the surface against which it will be placed.
2. With the helper holding the base of the ladder in place, lift the top of the ladder over your head.
3. Walk down the length of the ladder, lifting as you go and moving your hands from rung to rung, while your helper bears some of the ladder's weight (Figure 4).
4. When the ladder is straight up, lower the top gently against the wall.
5. If necessary, secure both the top and bottom to prevent dislodgment.

Follow these steps in reverse to take down the ladder. Remember to check your path for obstacles because you will be walking backwards. Gravity will cause the ladder to fall if not controlled at all times.

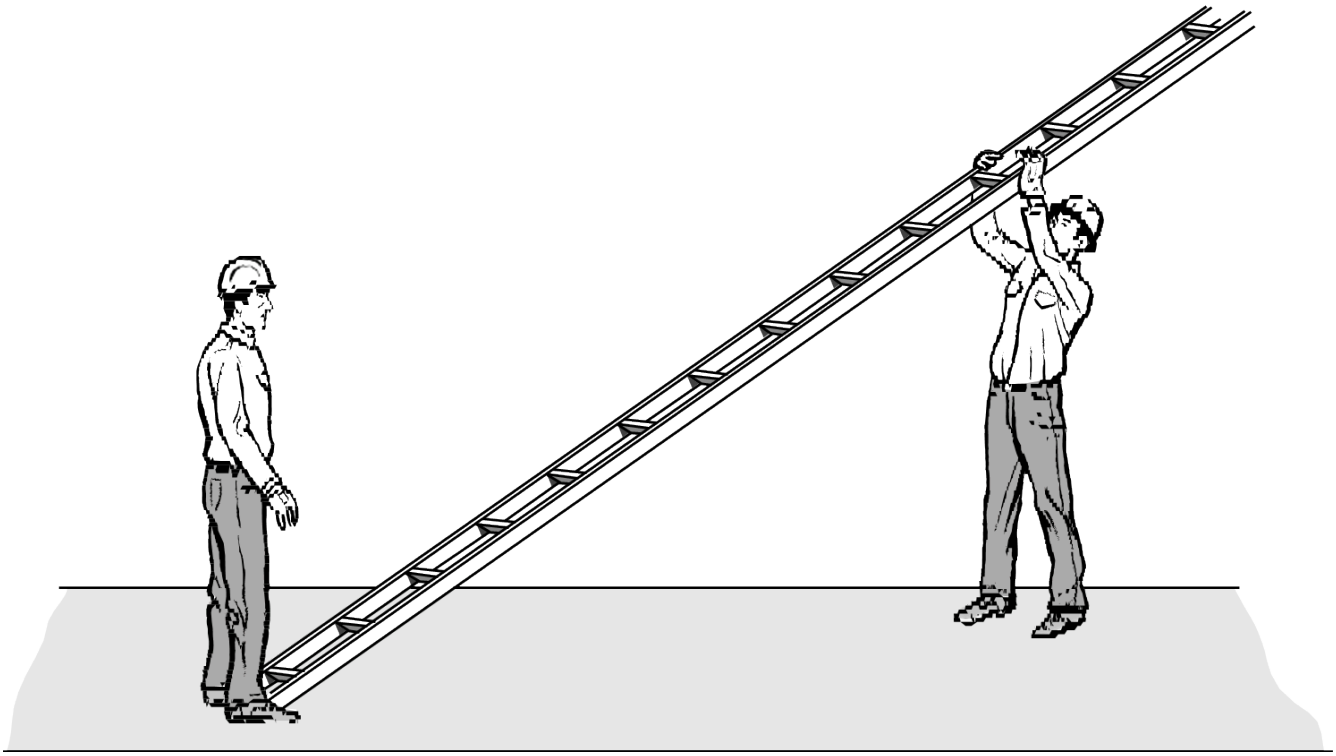

Figure 4 *Setting up a ladder with a helper (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Ladder Maintenance and Storage

In addition to a routine inspection before use, proper maintenance and storage of a ladder will help ensure that it is safe to use. The following steps highlight important practices for maintaining ladders:

- Wipe the ladder clean to keep it free of oil, grease, or grime.
- Replace frayed or worn ropes on extension ladders.
- Treat wood ladders with a clear finish or penetrating preservative. NEVER paint a wood ladder because paint can hide damage.
- Clean and lubricate pulleys on an extension ladder.
- Store ladders away from heat, moisture, weathering, and sunlight. Ultraviolet (UV) rays damage fibreglass, and heat and moisture can cause wood ladders to rot.

- Properly store ladders on a rack; do not store materials on ladders.

General Requirements for Scaffolds

The following specifications apply to all scaffolds:

- Scaffolds shall be erected, maintained, and dismantled under the direct personal supervision of an experienced, competent worker.
- Use a spirit level to set standards and ledgers accurately in both horizontal and vertical alignment at each lift.
- All wood planks shall be unpainted and regularly inspected for defects.
- Place the inner row of standards as close as possible to the wall. If they are more than one plank width from the wall, install an inside guardrail and midrail. The work platform must be fully planked.
- Standards shall be spaced no more than 2.1 m (7 ft) apart for heavy work and 3 m (10 ft) apart for light work.

Erecting Welded Frame Scaffolds

Scaffolds should be erected by two or more people. The following instructions are provided as a general guideline; always follow the manufacturer's or supplier's specifications. These steps describe the assembly of a scaffold that is one frame high. Additional frames should be added after Step 5 and before installing the guardrail system. Before erecting a scaffold, ensure you are familiar with OHS Regulation Part 11: Fall Protection (https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation/part-11-fall-protection) and applicable Workers' Compensation Board (WCB) requirements available on the WorkSafeBC website.

1. Select and prepare the ground area. Select the equipment you need and place it near your work area. Place suitable ***sills*** and make sure there are no holes under the sills. Put the adjustable ***base plates*** onto the sills to match your approximate scaffold dimensions, but don't secure them to the sills yet. Adjust the base plate jack nuts so they are approximately level, starting with the jack nut at the highest level and setting it relatively low—about 7.5–15 cm (3–6 in.) from the top of the sill.

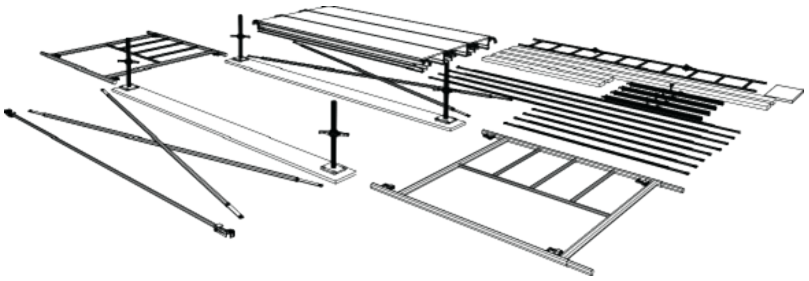

Figure 5 *Lay out components (Courtesy of WorkSafeBC)*

If you are erecting a rolling scaffold, you will not install sills or base plates because you will be working on a hard, level surface. In this case, you can start by installing the four wheels onto the first two frames.

2. Place the first frame onto the base plates, then connect a ***cross brace*** to the frame. Allow the frame to lean slightly forward and rest on the sill while you prepare to install the next frame.

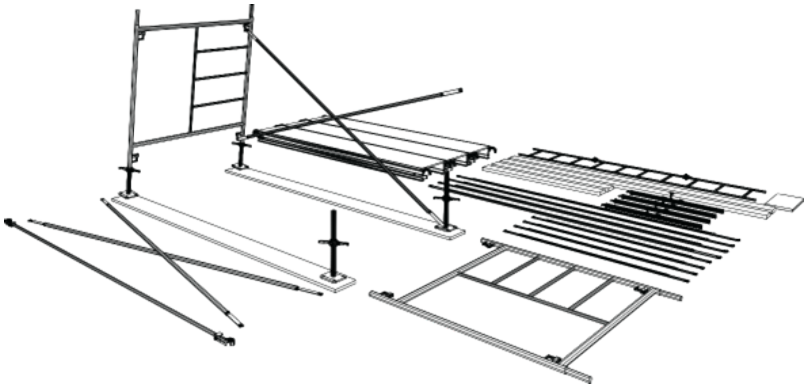

Figure 6 *First frame installation*
(Courtesy of WorkSafeBC)

3. Install the second frame onto the base plates and secure the previously connected cross brace to the second frame.

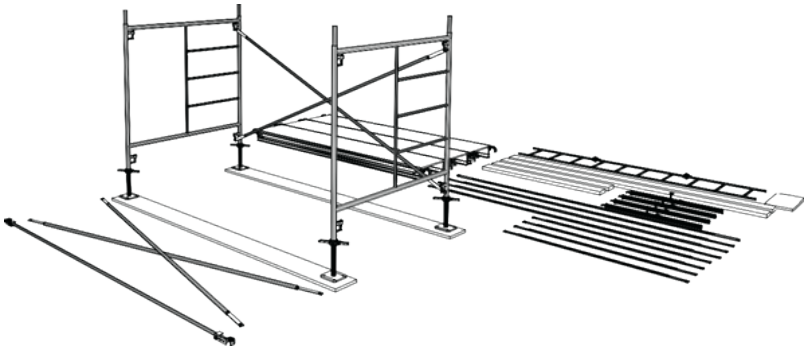

Figure 7 *Second frame installation*
(Courtesy of WorkSafeBC)

4. Install the second cross brace to both frames, then level the scaffold using the jack screws. If possible, always bring the highest corner down. Install the ***plan brace (gooser bar)*** to keep the scaffold square. Fasten the base plates to the sills.

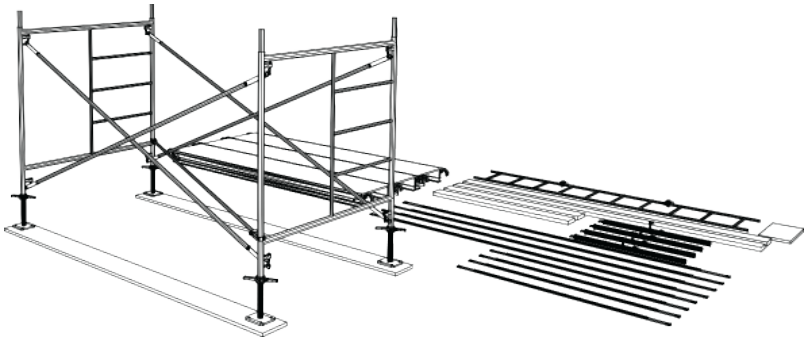

Figure 8 *Complete basic unit*
(Courtesy of WorkSafeBC)

5. Install the decking, which may be metal or wood planks, or aluminum and plywood decking units.

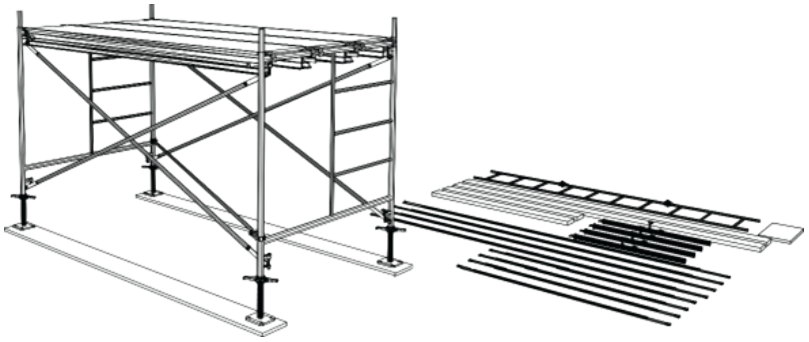

Figure 9 *Install decking*
(Courtesy of WorkSafeBC)

6. Select the appropriate guardrail system. If your system is purpose-made for frame scaffolds, install the four posts into the vertical coupling pins on top of the frames. Make sure all coupling pins have two locking pins or spring clips to prevent separation.

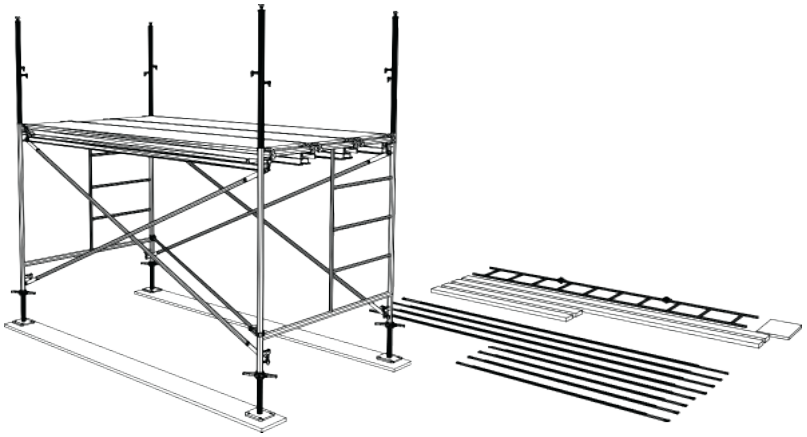

Figure 10 *Install guardrail posts*
(Courtesy of WorkSafeBC)

7. Attach the guardrails and midrails to the posts on all exposed sides.

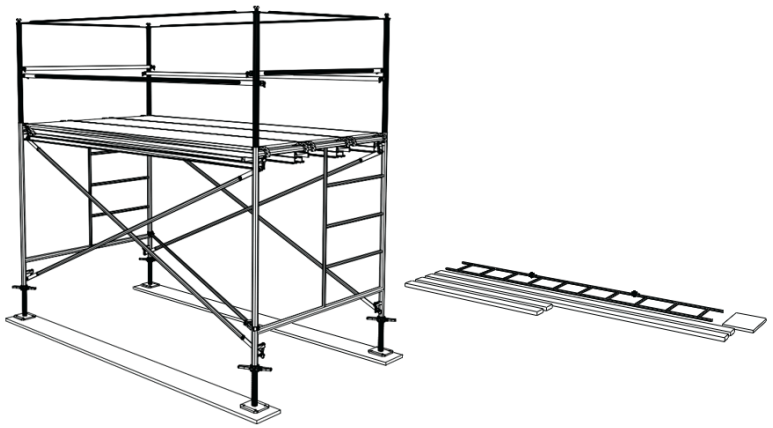

Figure 11 *Install guardrails*
(Courtesy of WorkSafeBC)

8. Install toe-boards as required.

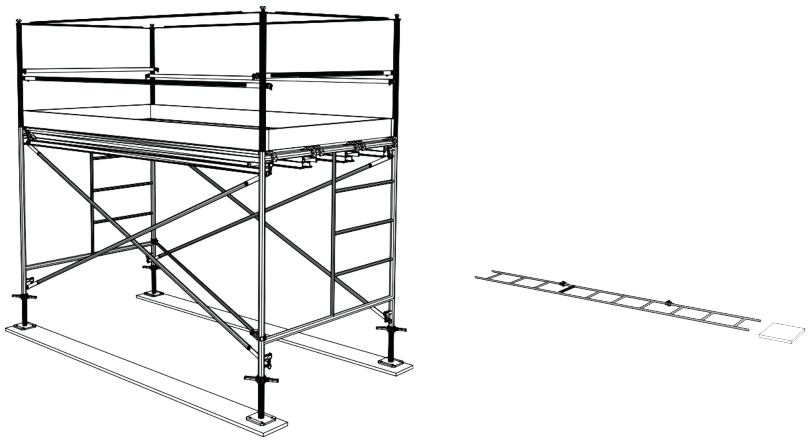

Figure 12 *Install toe-boards (Courtesy of WorkSafeBC)*

Self-Test B-3.2: Use Ladders and Elevated Platforms

Complete Self-Test 3.2 and check your answers.

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2853#h5p-7 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2853#h5p-7)

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- **Figures 5-12** are courtesy of WorkSafeBC and are used with permission.

Self-Test B-3.1: Describe Ladders and Elevated Platforms

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

1. Which organization publishes the Occupational Health and Safety regulations related to ladders and scaffolds in British Columbia?

a. Canadian Standards Association (CSA)
b. American National Standards Institute (ANSI)
c. WorkSafeBC
d. National Building Code

2. Which of the following is NOT one of the three basic types of ladders?

a. Step ladder
b. Extension ladder
c. Single (straight) ladder
d. Platform ladder

3. A Grade 1 ladder is designed primarily for:

a. Household use
b. Construction or industrial use
c. Office use
d. Recreational use

4. A step ladder is described as self-supporting. What does this mean?

a. It must be secured to a wall before use
b. It can stand on its own without leaning against a structure
c. It can only be used indoors
d. It must be used with scaffolding

5. When using a step ladder, which safety practice must always be followed?

a. Stand on the top step to gain extra height
b. Lock the spreaders before climbing
c. Lean the ladder against a wall
d. Use the shelf near the top as a step

6. Manufactured single ladders usually have:

a. Cleats
b. Platforms
c. Rungs
d. Spreaders

7. On a job-built ladder, the climbing steps are called:

a. Spreaders
b. Cleats
c. Guardrails
d. Platforms

8. For safe ladder setup, the distance between the ladder base and the wall should be approximately:

a. One tenth of the ladder height
b. One quarter of the ladder height
c. One half of the ladder height
d. The same as the ladder height

9. A worker must access a platform that is 4 m high. Approximately how far should the ladder base be from the wall?

a. 0.5 m
b. 1 m
c. 2 m
d. 4 m

10. In an extension ladder, the overlap section refers to:

a. The part where ladder feet touch the ground
b. The section where ladder parts slide over each other
c. The rung spacing on the ladder
d. The guardrail attachment point

11. A temporary structure used to provide a working platform at height is called a:

a. Cleat
b. Scaffold
c. Spreader
d. Guardrail

12. Who is responsible for ensuring scaffolds used by workers are safe and able to withstand loads?

a. The worker using the scaffold
b. The manufacturer
c. The employer
d. The safety inspector

13. Before using a scaffold, a responsible worker must:

a. Inspect the scaffold
b. Paint the scaffold
c. Remove guardrails
d. Install additional planks

14. A scaffold is being erected on soft ground. What should be used to spread the load and provide support?

a. Toe-boards
b. Mudsills
c. Cleats
d. Coupler pins

15. The term out-of-plumb refers to a structure that is:

a. Not level horizontally
b. Not perfectly vertical
c. Not supported properly
d. Too tall for its base

16. Guardrails must be installed when a scaffold work platform is more than:

a. 1 m above ground
b. 2 m above ground
c. 3 m above ground
d. 5 m above ground

17. The purpose of toe-boards on scaffolds is to:

a. Support the scaffold frame
b. Prevent tools or materials from falling off the platform
c. Secure the scaffold to the building
d. Connect scaffold braces

18. What is the main function of a scissor lift?

a. To move workers horizontally
b. To raise workers vertically using folding supports
c. To stabilize scaffolding
d. To secure ladders

19. Casters on a rolling scaffold allow the scaffold to:

a. Increase height
b. Move easily across a surface
c. Attach to a building
d. Support heavier loads

20. The platform where a worker stands on a boom lift is called the:

a. Guardrail
b. Bucket
c. Cleat
d. Coupler

Answer Key: Self-Test B-3.1 is on the next page.

Answer Key: Self-Test B-3.1

1. c. WorkSafeBC
2. d. Platform ladder
3. b. Construction or industrial use
4. b. It can stand on its own without leaning against a structure
5. b. Lock the spreaders before climbing
6. c. Rungs
7. b. Cleats
8. b. One quarter of the ladder height
9. b. 1 m
10. b. The section where ladder parts slide over each other
11. b. Scaffold
12. c. The employer
13. a. Inspect the scaffold
14. b. Mudsills
15. b. Not perfectly vertical
16. c. 3 m (10 ft.)
17. b. Prevent tools or materials from falling off the platform
18. b. To raise workers vertically using folding supports
19. b. Move easily across a surface
20. b. Bucket

Self-Test B-3.2: Use Ladders and Elevated Platforms

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

1. The type of finish for a wooden ladder is:
    a. Oil-based paint
    b. Latex paint
    c. Solid colour stain
    d. Clear finish

2. Which of the following ladders is freestanding?
    a. Extension
    b. Step
    c. Single
    d. Fixed
3. A full body harness attached to a lifeline must be used when working on a scaffold higher than
    a. 2.1 m (7 ft.)
    b. 2.4 m (8 ft.)
    c. 3 m (10 ft.)
    d. 4.9 m (16 ft.)

4. The correct slope for single or extension ladders is:
    a. 1 up the slope of the ladder to 4 horizontal
    b. 2 up the slope of the ladder to 4 horizontal
    c. 3 up the slope of the ladder to 1 horizontal
    d. 4 up the slope of the ladder to 1 horizontal

5. Minimum size for the side rail of a 3 m (10 ft.) job-built single ladder is
    a. 38–38 mm (2–2 in.)
    b. 38–64 mm (2–3 in.)
    c. 38–89 mm (2–4 in.)
    d. 38–140 mm (2–6 in.)

6. The minimum distance that a single or extension ladder is required to project above the level to which it gives access, is
    a. 500 mm (20 in.)
    b. 600 mm (2 ft)
    c. 900 mm (3 ft)
    d. 1200 mm (4 ft)

7. What is the minimum width of a wooden scaffold plank?
    a. 140 mm (5½ in.)
    b. 184 mm (7¼ in.)
    c. 235 mm (9¼ in.)
    d. 286 mm (11½ in.)

8. What is the minimum height of a guardrail?

    a. 600 mm (24 in.)
    b. 750 mm (30 in.)
    c. 900 mm (36 in.)
    d. 1020 mm (40 in.)

9. At what maximum height does a scaffold require a guardrail?

    a. 1200 mm (4 ft)
    b. 2100 mm (7 ft)
    c. 2400 mm (8 ft)
    d. 3000 mm (10 ft)

10. Bolts or pins must be placed through the end frames and coupler pins when the scaffold is higher than one unit.

    a. True
    b. False

11. Casters for steel scaffolds must have:

    a. Rubber tires
    b. Ball bearings
    c. Leveling screws
    d. Brakes

12. What is the maximum height of a rolling scaffold?

    a. 2 times its minimum base dimension
    b. 2½ times its minimum base dimension
    c. 3 times its minimum base dimension
    d. 3½ times its minimum base dimension

13. Steel scaffolds fitted with casters also require:

    a. Sway braces
    b. Screw jacks
    c. Base plates
    d. Mud sills

Answer Key: Self-Test B-3.2 is on the next page.

Answer Key: Self-Test B-3.2

1. d. Clear finish
2. b. Step
3. c. 3 m (10 ft.)
4. d. 4 up the slope of the ladder to 1 horizontal
5. c. 38 × 89 mm (2 × 4 in.)
6. c. 900 mm (3 ft.)
7. c. 235 mm (9-1/4 in.)
8. d. 1020 mm (40 in.)
9. d. 3000 mm (10 ft.)
10. a. True
11. d. Brakes
12. c. Three times its minimum base dimension
13. a. Sway braces

PART IV

B-4 USE RIGGING, HOISTING, LIFTING AND POSITIONING EQUIPMENT

Plumber Apprenticeship Program – Level 1

Yellow crane hook against blue sky (https://www.pexels.com/photo/yellow-crane-hook-against-blue-sky-in-para-brazil-33346841/) (Julia Nobre/pexels) Pexels License (https://www.pexels.com/license/)

B-4 Use Rigging, Hoisting, Lifting and Positioning Equipment

Rigging, hoisting, lifting, and positioning are important skills in the plumbing and pipe trades, where workers often need to move heavy materials, tools, and equipment safely on construction sites. Understanding how loads behave, selecting the correct lifting equipment, and communicating clearly during lifting operations are critical for preventing injuries and damage. In this section, you will learn the basic principles of lifting and hoisting, become familiar with common hoisting, lifting, and rigging equipment, and understand the communication practices used during lifting operations. You will also learn how to select appropriate slings, tie common knots, bends, and hitches, and safely use rigging equipment when lifting and positioning loads, including when working with cranes.

Learning Objectives

After completing this section, you should be able to:

- Describe the principles of lifting and hoisting.
- Describe hoisting, lifting and rigging equipment.
- Describe lifting and hoisting communication.
- Select slings and tie knots, bends, and hitches.
- Using hoisting, lifting and rigging equipment.
- Using rigging loads for cranes.

You will be required to reference publications and videos available online at WorkSafeBC. (https://www.worksafebc.com/en)

Supplementary Video Series: Trades Access Common Core — Tools and Equipment

To support your learning in this section, you may find the following video series helpful. These short instructional videos were developed by Camosun College and shared through BCcampus as part of the Trades Access Common Core learning resources.

1. Knots and Hitches – BCcampus (https://media.bccampus.ca/media/Knots%20and%20Hitches/0_1zyju8c0)
2. Truckers Hitch – BCcampus (https://media.bccampus.ca/media/Truckers%20Hitch/0_x4iyzc34)
3. How to Whip the End of a Rope – BCcampus (https://media.bccampus.ca/media/How%20to%20Whip%20the%20End%20of%20a%20Rope/0_rhafq2j5)

Terminology

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

- **boom truck:** Frequently used on construction sites to lift and position pipe, equipment, and materials at height. Plumbers often work directly with boom truck operators during installations. (Section B-4.2)
- **boom radius:** Also referred to as the operating radius, this is the horizontal distance from the centre of rotation to the hook and is a function of boom angle and length. This concept is crucial to understanding safe crane capacity. (Section B-4.6)
- **centre of gravity:** The point in an object where its weight is balanced. (Section B-4.1)
- **chain hoist (chain fall):** Commonly used in mechanical rooms, shops, and construction sites to lift and position heavy pipe, pumps, or mechanical equipment. (Section B-4.2)
- **come-along (puller):** A very common hand tool used by plumbers to pull pipe into alignment, tension materials, or position equipment before fastening or welding. (Section B-4.2)
- **dog everything:** A safety instruction used in lifting and hoisting operations that means to secure or lock all controls and equipment so that no movement can occur. It ensures the load and machinery remain safely in place before workers approach or handle the load. (Section B-4.3)
- **drop stops**: Safety devices installed on lifting equipment, such as trolleys or hoists, that prevent the load or trolley from accidentally falling or running off the end of a beam or track. (Section B-4.2)
- **effort (input force):** The force a person applies to move or lift an object. (Section B-4.1)
- **lift plan**: A written or discussed plan that explains how a load will be safely lifted and moved. It includes details such as the weight of the load, the equipment being used, the lifting path, possible hazards, and how workers will communicate during the lift. (Section B-4.1)
- **lifting point:** The place on a load where the lifting equipment is attached. (Section B-4.1)
- **load integrity**: The condition in which a lifted load remains secure, stable, and properly contained so that individual items do not shift, separate, or fall during lifting, moving, or positioning operations. (Section B-4.1)
- **mechanical advantage (MA):** How much a machine increases the force you put into it to make work easier. (Section B-4.1)
- **outrigger:** A support member that projects beyond the natural outline of a crane to provide additional support and to prevent toppling. (Section B-4.6)
- **pallet jack (manual forklift):** Widely used in warehouses, shops, and job sites to move skids of pipe, fittings, and equipment. (Section B-4.2)
- **peening:** Damage that occurs when wire rope repeatedly strikes or rubs against a hard surface, causing the wires or strands to flatten, distort, and become brittle over time. (Section B-4.5)
- **pick and carry**: A lifting operation in which a crane or lifting machine raises a load and then moves it horizontally to another location while the load remains suspended, usually carried low to the ground for safety. (Section B-4.1)
- **pulley:** A wheel with a rope or cable that helps lift or move heavy loads. (Section B-4.1)
- **resistance (load force):** The force that must be overcome to move or lift a load. (Section B-4.1)
- **rigging:** The equipment and methods used to attach and lift loads safely with cranes or hoists. (Section B-4.1)

- **safety factor:** A margin of safety used to ensure equipment can handle more than the expected load. (Section B-4.1)
- **signal person:** A trained worker who gives hand signals or radio instructions to a crane operator during lifting operations. (Section B-4.1)
- **sling:** A strong strap, rope, or chain used to lift heavy objects. (Section B-4.1)
- **snatch block:** Important for rigging setups because it allows workers to change the direction of a pull or increase pulling power when moving heavy materials. (Section B-4.2)
- **snub line**: A rope or line attached to a load to help control its movement and prevent it from swinging while it is being lifted or moved by a crane. (Section B-4.1)
- **tag line**: A rope attached to a suspended load that workers hold to guide and steady the load, helping control its direction and rotation during lifting or positioning. (Section B-4.1)
- **thimble**: A metal fitting placed inside the eye (loop) of a wire rope or fibre rope to protect it from wear and crushing. The thimble helps the rope keep its shape and prevents damage when the rope is attached to hooks, shackles, or other rigging hardware. (Section B-4.4)
- **unstable load:** A load that shifts, tilts, or moves unexpectedly when lifted. (Section B-4.1)
- **whipping:** A method of tightly wrapping twine or wire around the end of a rope to prevent it from fraying or unraveling. (Section B-4.4)
- **working load limit (WLL):** The maximum weight a piece of lifting equipment can safely carry. (Section B-4.1)

B-4.1 Describe the Principles of Lifting and Hoisting

Mechanical Advantage

The ***mechanical advantage (MA)*** of a mechanism is the factor by which input effort is multiplied to produce greater output force. Mechanical advantage describes how much a machine increases applied force. The mechanical advantage of a device can be used to determine how well it performs and whether it can perform a given job.

Most ***simple machines*** operate using the principle of MA, and it can be calculated using the following formulas.

- **Levers**: MA = length of effort arm ÷ length of resistance arm.
- **Pulleys**: All pulleys have a fixed MA, depending on the type. A single fixed pulley has an MA of 1:1. A single movable pulley has a MA of 2:1. A pulley with six ropes (block-and-tackle system) has an MA of 4:1.
- **Wheel and Axle**: MA = radius of wheel ÷ radius of axle
- **Inclined Plane**: MA = length of slope ÷ height of slope

Understanding mechanical advantage helps workers safely lift and move loads using rigging and hoisting equipment.

Pulleys

Single fixed ***pulleys*** can change the direction in which a force is applied and can transmit rotational motion into linear motion. However, they do not provide mechanical advantage, because the amount of force required is equal to the force of the load.

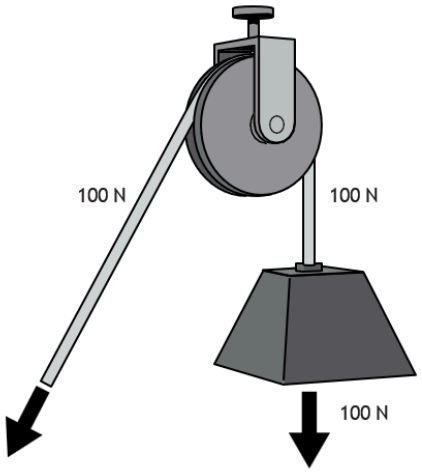

Figure 1 *Fixed pulley (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Movable and multiple pulleys can be used to provide significant mechanical advantage. In this case, there is a trade-

off between force and distance: less force is required, but the distance required to do the work increases. (**Note, the product of force × distance remains the same.**) In Figure 2, although the effort is cut in half, the length of rope required will be twice the distance that the load travels.

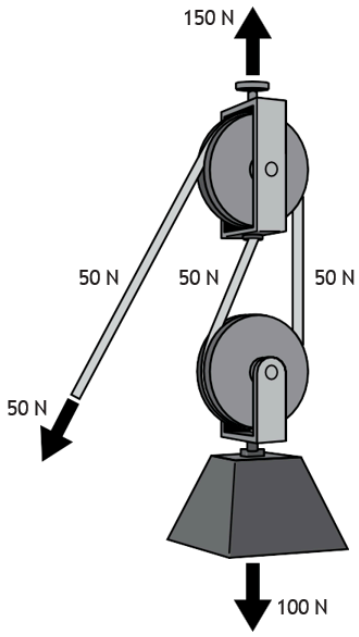

Figure 2 *Compound (movable) pulley (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Balance Points and Load Stability

Properly ***rigging*** a load of material (supporting or fastening it for lifting or transport) helps keep the load level and stable as it is lifted into the air by a ***crane*** or hoisting device. A poorly rigged load may shift and could cause the load to fall. To maintain stability, workers must consider the centre of gravity, ***sling*** locations, and sling types.

Centre of Gravity

The ***centre of gravity*** of an object is the point at which the object will balance, regardless of whether the object is upright, on its side, top, bottom, or end.

A suspended object will always move so that its centre of gravity is located directly below its point of support.

You must consider the location of the centre of gravity whenever you rig a load to be lifted by a crane. Estimate the location of the centre of gravity for the object to be lifted. Although the centre of gravity can be calculated using complex formulas, workers in the piping trades often determine it using careful judgment and short trial lifts. Complex or critical lifts should always be rigged by a competent, certified rigger. Use a sling arrangement that positions the lifting hook directly above the centre of gravity.

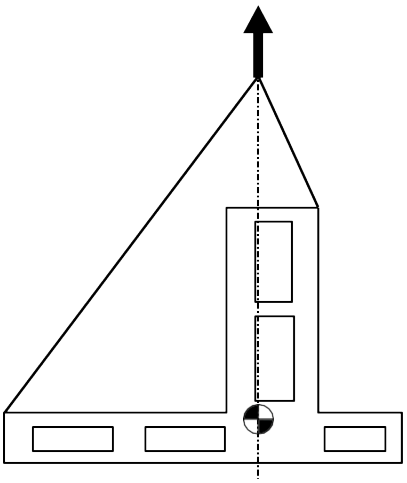

Figure 3 *Stable load (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

A load with the hook to the side of the centre of gravity will shift or tilt when lifted. This shift will continue until the centre of gravity rests directly below the hook.

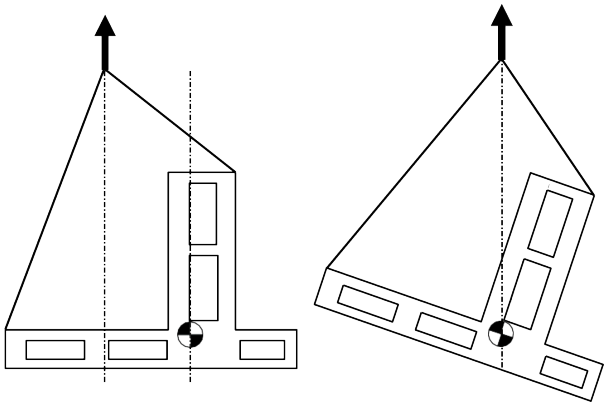

Figure 4 *Movement of unstable load (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

NEVER rig a load with the centre of gravity above the lifting point (or points). Doing so may cause the load to turn over. The natural position for the centre of gravity is below the point of attachment.

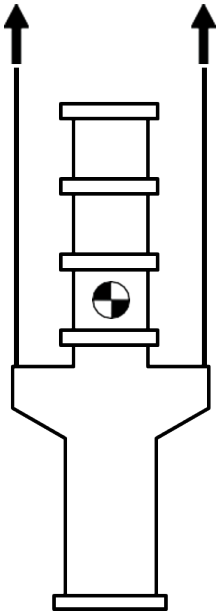

Figure 5 *Incorrect position of the load (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Sling Locations

The position of the ***sling*** attachment to the load is very important.

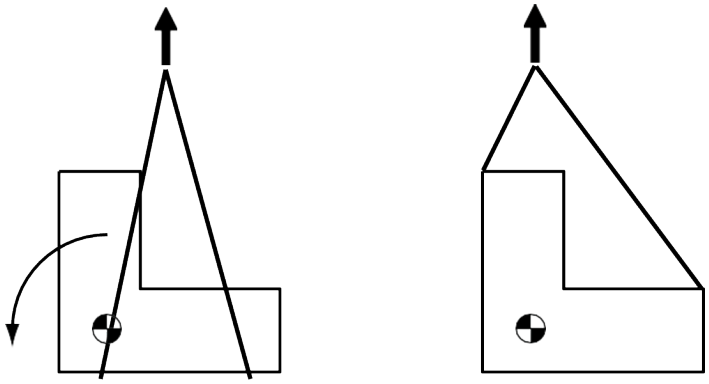

Figure 6 *Sling application (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

When using a sling, as shown here, ensure that the centre of gravity is located between the two slings. If the centre of gravity is beyond the slings, the load may topple over at the start of the lift. Rigging loads with their centre of gravity

close to one sling is considered poor practice because of the increased risk of tipping. Always use a sling arrangement that places the centre of gravity below the sling's point of attachment to the load.

When you are lifting loads with a crane, start the initial lift very slowly, and watch the load for signs of tilting or shifting. If the load tilts more than 5°, lower the load and rearrange the rigging.

Steps to a Safe Lift

Certification Requirements

The OHS Regulation Part 15: Rigging (https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation/part-15-rigging) states that "Rigging and slinging work must be done by, or under the direct supervision of, qualified workers familiar with the rigging to be used and with the code of signals authorized by the Board for controlling hoisting operations."

Training standards are often site-specific, where employers define what constitutes a qualified worker, with the OHS Regulation as the minimum requirement.

Labour organizations, private third-party training companies, and equipment manufacturers also offer training. The Canadian Standards Association Group (CSA Group) provides a rigging certification course developed with United Association Canada (UA) and the National Association of Union Schools and Colleges (NAUSC).

Lift Plan

A ***lift plan*** is a process that includes calculating load weight, identifying the lift-route, recognizing potential hazards (such as weather or overhead powerlines), selecting equipment and safety protocols, and establishing communication procedures. Lift plans can range from a quick, informal chat between a worker acting as a signal-person and a boom-truck operator to a formal process for a critical lift, requiring signed documentation from riggers, supervisors, engineers, and crane operators. This distinction between non-critical and critical lifts is often set by employers or crane companies.

Factors that may classify a lift as critical include:

- The proximity of the lift to power lines
- The need for two or more lifting devices
- Load weight exceeding 75% of the crane's capacity
- Uneven ground or side loading on the crane

Calculations of Weight

Knowing the approximate weight of the load and rigging hardware is crucial for proper equipment selection. Load weights may be obtained from reliable sources such as shipping documents and forms, manufacturers' specifications,

or design plans (drawings). Weights of common material can be sourced from publications such as the IPT Pipe Trades Training Manual (https://iptbooks.com/product/pipe-trades-manual/?v=5435c69ed3bc). Other scenarios may require calculations using standard weight of common material and applying the formulas for area and volume.

Equipment Selection

Approved hoisting equipment has a rated load called its *rated capacity* or ***working load limit (WLL)***. This indicates the maximum safe load the equipment can handle. This is based on the ratio of the ultimate breaking strength to the safety factor. Rigging load calculations are based on a design safety factor of 5:1 for material and 10:1 for critical or personnel lifts. This means that if a 1-inch wire rope has an ultimate breaking strength of 41,000 kg, with a safety factor of 5, the WLL would be 8,200 kg.

Communication

During a lift, the crane operator and ***signal person*** work together to execute the lift safely. Only an experienced, trained operator should control lifting equipment and ensure that movements are planned, slow, and thoughtful. Signal persons must know the proper hand signals or radio communication procedures and should have a pre-lift consultation with the operator to clarify the lift plan and communication. **Clear communication is essential for safe lifting operations**!

Load Security

Load integrity is considered if multiple objects are hoisted at once, as in the case of pipe bundles, or if a ***pick-and-carry*** operation is required. If the load consists of many like objects, use the proper sling arrangement for security or carry the load in a basket. During a pick-and-carry lift, the load is carried low to the ground and a ***snub line*** is used in addition to ***tag lines*** to control swing.

Self-Test B-4.1: Describe the Principles of Lifting and Hoisting

Complete Self-Test 4.1 and check your answers.

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2877#h5p-10 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2877#h5p-10)

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B-4.2 Describe Hoisting, Lifting and Rigging Equipment

The following rigging accessories and lifting devices are commonly used in the pipe trades and must be selected and used correctly to ensure safe lifting operations.

Lifting and Hoisting Accessories

Rigging loads requires the use of various hardware items for lifting. Correct selection, inspection, and assembly of these hardware items is critical to ensuring a safe lift. Common rigging hardware includes:

- Turnbuckles
- Eyebolts
- Shackles
- Cable clips and thimbles
- Hooks
- Slings and hitches
- Spreader bars

Turnbuckles

Turnbuckles are used to adjust the lengths of slings so that loads can be lifted in a level position.

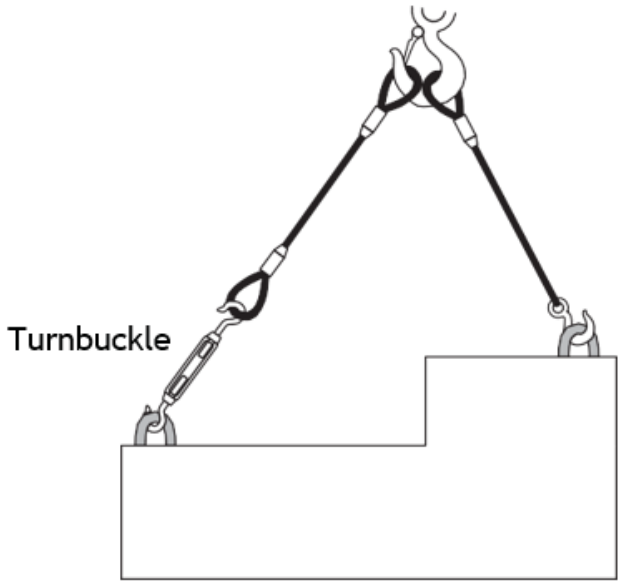

Figure 1 *Adjusting leg length with a turnbuckle (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

They are metal sleeves with left-hand internal threads at one end and right-hand internal threads at the other. Threaded metal rods are fitted into each end.

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

The ends of these threaded rods are available as eyes, jaws, or hooks. All hooks on turnbuckles must have a safety catch (Figure 3).

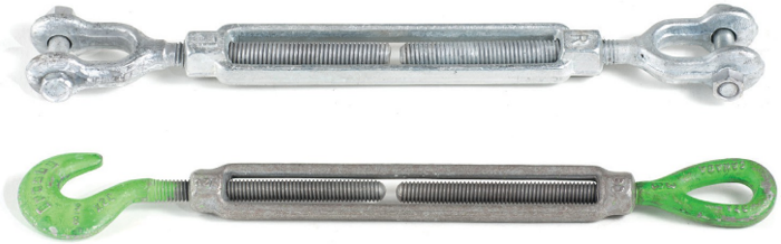

Figure 3 *Turnbuckle ends (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

It is important to prevent turnbuckle ends from rotating. Rotation can be caused by vibration or by tension on the rope attached to the turnbuckle. If there is any chance that the ends of the turnbuckles could rotate within the sleeve, the ends should be secured to the sleeve using lock wire, as shown.

Figure 4—Turnbuckle end with lock wire (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Eyebolts

Eyebolts are used to provide a secure point of attachment for hoisting operations. There are two types: shoulder and shoulderless eye bolts. Shoulderless eye bolts must not be used in overhead lifting, because force applied from the side at any angle will break the stem of the bolt.

Shoulder-type eye bolts are able to withstand pulls up to 45° from vertical, providing the pull is applied along the plane of the eye. Pulling at an angle that is not in the same plane will bend or break the eye. Always make sure that the eye bolt is properly installed so that the shoulder sits tightly against the load. Do not use an eye bolt if there is any space between the shoulder and the load, because it will act like a shoulderless eye bolt and may break under stress.

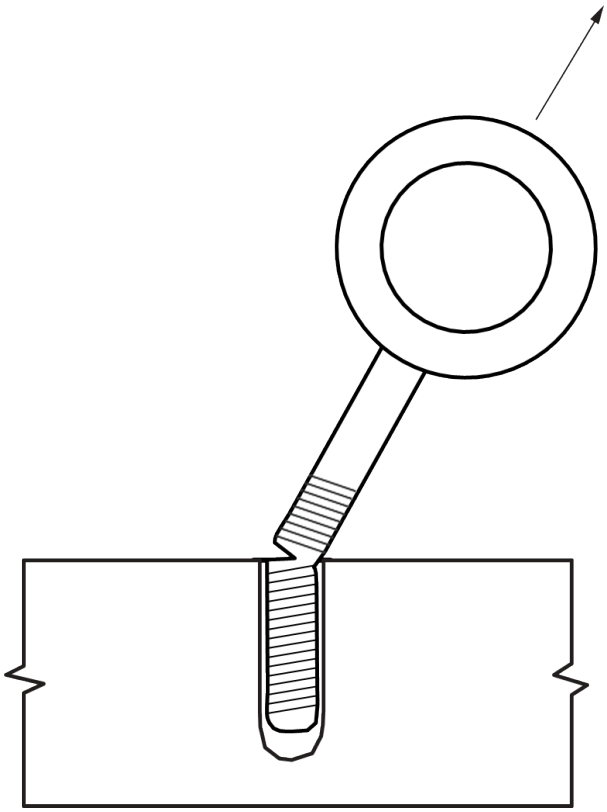

Figure 5 *Shoulder-less eye bolt* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

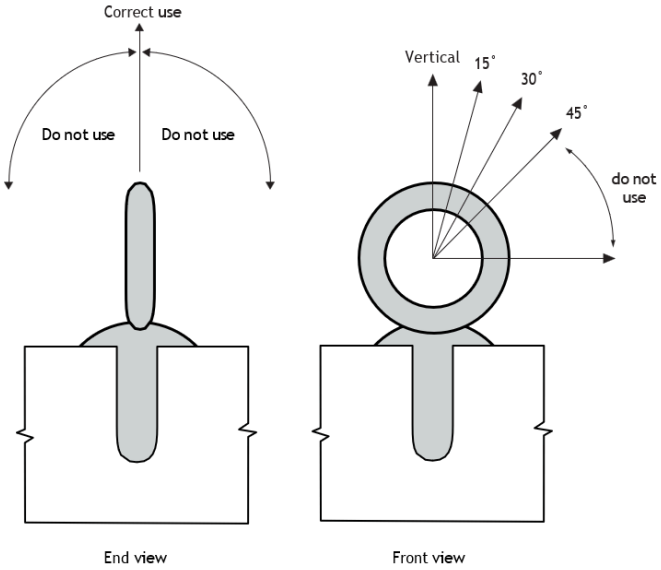

Figure 6 *Angle of pull-on eyebolts (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The Working Load Limit (WLL) for eye bolts are given for vertical pulls. When lifting at an angle, you must reduce the WLL of the eye bolt as follows:

- Vertical pull = No reduction in WLL
- 15° from vertical = 45% reduction in WLL
- 30° from vertical = 65% reduction in WLL
- 45° from vertical = 75% reduction in WLL
- Over 45° from vertical = NOT RECOMMENDED

Shackles

Shackles (Figure 7) are used to connect a sling to a load. They should be used whenever two or more ropes are placed over a hook (Figure 8). The shackle should have a throat large enough to avoid crowding and pinching the ropes. The working load limit (WLL) of a shackle must be shown as a stamped or embossed number on the body of the shackle. Never use shackles that do not display a load rating.

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

Never replace the pin of a shackle with an ordinary bolt. Shackle pins are made of hardened steel, while ordinary bolts may bend under load and damage the shackle. In many applications, the shackle pin must be secured for safety. The pin may be wired off to prevent it from turning loose, or the pin may be seized in place.

Figure 8 *Wire ropes on shackle over hook (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 9 shows a shackle attachment that could cause the screw pin to become loose.

Figure 9 *Incorrect shackle attachment (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Never attach a shackle so that the load is applied to the sides of the shackle. This condition is called ***crossbow loading***. Always apply the load to the pin and the curved body of the shackle. To prevent crossbow loading, never use a shackle with slings where the sling angle will exceed 45° between the two slings at the shackle.

Figure 10 shows the correct method for attaching a shackle to a lifting hook. Note that if the width of the shackle's opening is considerably greater than the thickness of the hook, packing washers should be used to centre the hook on the shackle.

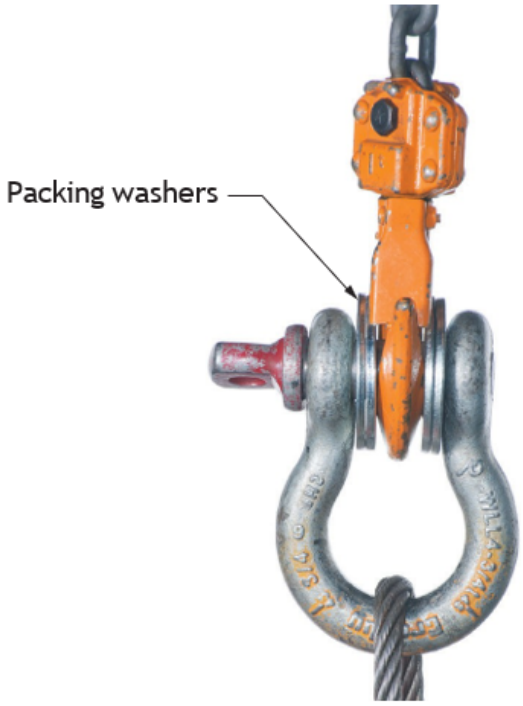

Figure 10 *Apply load to pin (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Shackles may be used to form a ***choker hitch***, but you must make sure the pin is not bearing on any moving part of the rope. The rope could cause a screw pin to turn and become loose.

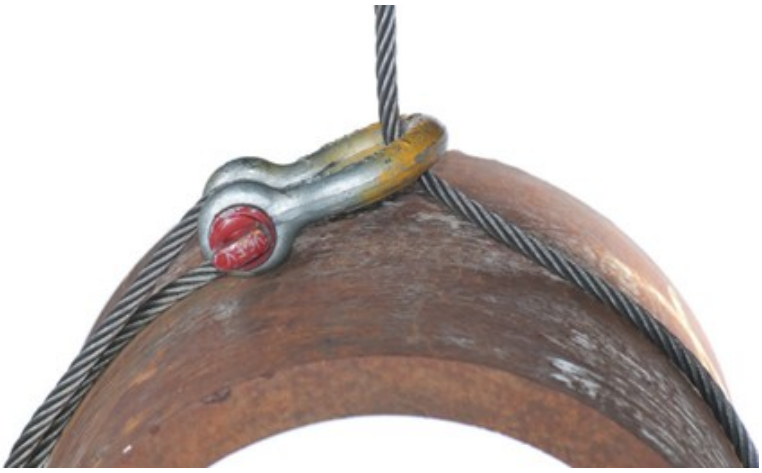

Figure 11 *Using a shackle for a choker hitch (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

There are three basic types of pins available for shackles:

- *Screw pins
- Round pins
- Safety type pins

*The screw pin shackle is the most commonly used.

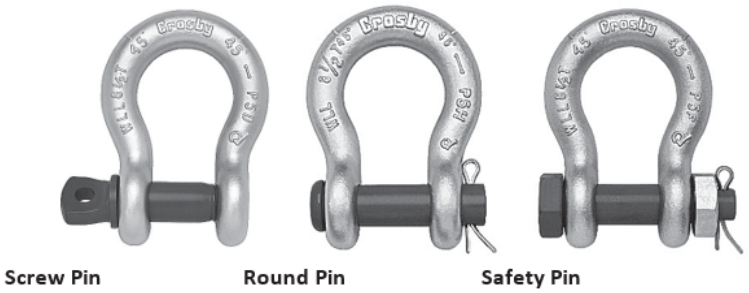

Figure 12 *Pin types for anchor shackles (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Cable Clips and Thimbles

Cable clips are used to fasten the end of a wire rope back onto its standing part to form a loop. Cable clips provide a relatively quick and easy method for tying wire rope. However, the crimping action of cable clips significantly reduces the breaking strength of wire rope (by up to 20%).

The two most popular types of cable clips are the U-bolt clip and the ***double saddle (fist grip) clip***, shown here. The U-portion must be installed on the dead end of the rope.

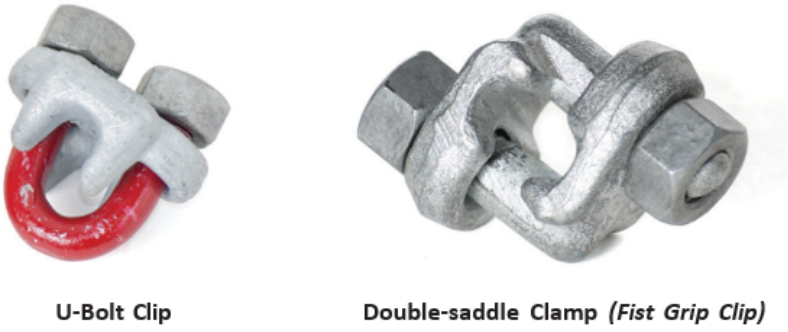

Figure 13 *Cable clips (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The space between cable clips is usually equal to six or seven rope diameters. The distance from the rope end to the first cable clip should also be six or seven rope diameters. To figure out how many clips are required to make the loop, multiply the rope diameter by three and round up to the next whole number.

Wire rope has a tendency to stretch a small amount when first put into service. Wire rope reduces in diameter as it stretches. Tighten all cable clips after the first hour of service for a new connection. If the cable clip connection is under heavy strain, check the tightness of the nuts at regular intervals until no further loosening is observed.

The correct procedure for installing cable clips is as follows:

1. Calculate the length required for the loop (number of clips required multiplied by six rope diameters). Install the first clip six rope diameters from the rope end. Tighten the nuts to the recommended torque using a torque wrench.

Figure 14 *Installing first cable clip* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

2. Install the second clip as near the ***thimble*** as possible. Tighten the nuts securely but do not apply final torque yet.

Figure 15 *Installing second cable clip* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

3. Install all other clips at equal spacing. Apply tension to the rope and then tighten all nuts to the recommended torque.

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

Correctly installed cable clips reduce the breaking strength of wire rope by approximately 20%; incorrectly installed, they can reduce the breaking strength by up to 50%.

Hooks

Hooks are commonly used to connect lifting devices to loads. Common types include:

- Standard eye hooks
- Slip hooks
- Grab hooks
- Sorting hooks

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

The standard safety eye hook is commonly used to lift loads that have been rigged, as is the variation that includes a swivel base.

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

All hoisting hooks, except grab and ***sorting hooks***, must have ***safety catches***. Open hooks must not be used to lift a bucket, cage, or skip if there is a possibility the load could injure people.

Hooks are usually made of alloy steel, and their working load limit (WLL) should be stamped on them. It is important to remember that the working load limit applies only when the load sits in the saddle of the hook. If the load is off-centre or sits between the saddle and the tip, the working load limit is significantly reduced (see illustration).

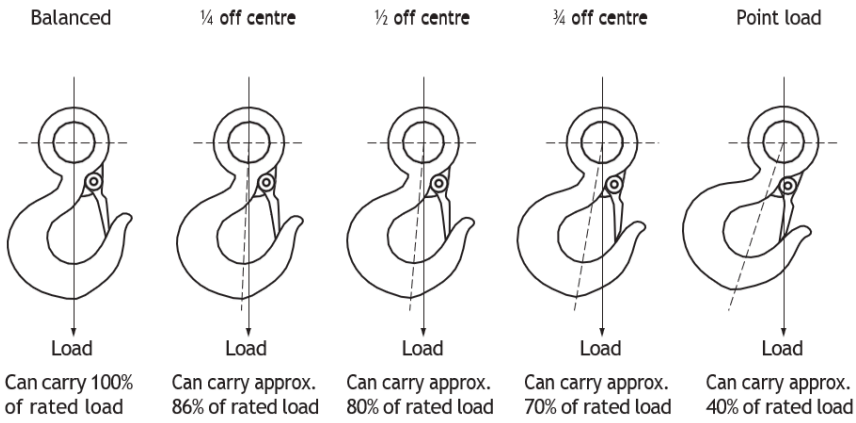

Figure 19 *Effect of off centre loads on hook capacity (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Slip and grab hooks are generally attached to the ends of chains to pick up or pull a load. *Sorting hooks* are also referred to as *shake-out hooks and* are primarily used at the end of slips for picking up steel plate and other structural shapes. The long, thin hook can slide between closely stacked steel shapes. When sorting hooks are used to lift heavy loads, you must ensure that the load sits squarely in the bottom (***saddle***) of the hook.

To protect chains from the stress of twisting while under load, all hoisting chains should be equipped with ***swivels***, such as those shown here.

Figure 20 *Chain swivels (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Choker Hooks

Choker hooks are fittings attached to the end of a sling. The width of the hook protects connected ropes from sharp bends. When the hook is attached back onto its sling, it forms a choker hitch.

The standard choker hook shown here is attached to the end of the sling. The sling is passed around the load, and the wide surface of the hook is hooked over the standing part of the sling.

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

A variation of the standard choker hook, called the ***adjustable or sliding choker hook*** (below) is mounted on a sling that has a loop at each end. The sling is passed around a load, and the end loop is hooked over the choker hook.

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

Slings and Hitches

Most items that require hoisting have no provisions for attaching a hoisting line to them. Slings are used to connect the load to the lifting device. Slings may be made of fibre rope, wire rope, chain, or webbing, and they may be attached to loads in a variety of ways.

To protect both the load and the sling, place padding between the sling and any sharp corners on the load (called ***softeners***). The following simplified diagrams may not show softeners being used, but they should be applied whenever possible in the field.

Identification

All slings must have an identification tag in accordance with ANSI/ASME and CSA guidelines. This tag provides the following information:

- Name of the manufacturer
- Diameter, width, and length of the sling
- Materials
- Rated load for the given type of hitch
- Lift angle upon which the load rating is based

Sling Design Factor

One must apply a safety factor of 5:1 to every lift. This is to account for overloading, abrasion, crushing, kinking, and impact loading of slings. Some engineered lifts may have safety factors of 6:1, 8:1, 10:1 or higher.

Synthetic Web Slings

Synthetic web slings (typically made from woven nylon) are available in a variety of shapes and widths. They are softer and wider than most other slings so better protect the load against marring or scratching. The shapes most commonly found are illustrated below.

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

Some web slings have metal end fittings instead of sewn eyes. Two types are available (see Figure 24). A basket web sling has metal triangles of equal size at each end of the webbing. A choker web sling has a larger triangle containing a slot at one end and a smaller triangle at the other end. The smaller triangle can be passed through the slot of the larger triangle to form a choker hitch.

Figure 24 *(left) Basket web sling (right) choker web sling (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Metal Mesh Slings

Loads that are too abrasive or too hot for synthetic webbing yet require the wide bearing surface of a web belt are rigged with slings made of metal mesh. These metal mesh slings are usually equipped with triangle ends that permit the use of either a basket or choker hitch.

Chain

Chain slings have certain applications as they do not kink, are able to withstand rough handling, and are resistant to abrasion and corrosion. However, they have no elasticity and due to their nature, chains are less reliable than wire rope or synthetic slings and can fail without warning. The term 'weak link' illustrates that a single chain link can cause catastrophic failure, whereas wire rope will break progressively over time and show signs of stress or damage upon inspection.

Chain sling identification will indicate the manufacturer's approval for hoisting. It will also show the chain's size, WLL, length and manufacturer.

Chain slings require documented annual inspections. For a sound inspection of chain slings, clean the chain first then

inspect for wear or stretching. Any stretch over 5% requires the sling to be removed from service (OHS Regulation Part 15: Rigging (https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation/part-15-rigging)). Any cracks require the entire chain to be removed from service.

Rules for safe chain use include:

- Only use alloy chain slings for hoisting.
- Always use softeners for rectangular loads.
- Avoid shock loading.
- Never repair or weld links and never shorten a chain by tying a knot or bolting two links together.
- If links bind together, this indicates stretching, and further inspection is required.
- When a chain is used for a basket hitch, always hook to the ***master link***, not the chain itself.
- Store chain in a dry place.

Identification

Synthetic web slings must bear an identification tag indicating the WLL (working load limit, also known as the **safe working load**). This tag must never be removed or tampered with.

Figure 25 *Sling identification tag (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Inspection

Web slings should be inspected for:

- Worn or distorted fittings
- Cuts
- Holes
- Punches (or punctures)
- Tears
- Frayed material
- Broken stitching
- Burns caused by acid, caustic chemicals, or heat

Inspect the slings carefully before use and make a decision about their safety. If you are not sure that the sling is safe, tag

it so that it will not be used by another worker and notify your supervisor. Your supervisor should make the necessary arrangements to have the sling inspected for safety and approved before it is returned to service.

Never use a sling for lifting unless it has a tag clearly indicating its working load limit!

Single Vertical Hitch

The single vertical hitch consists of a single leg of sling material with a hook or an eye at each end. The eyes on fibre or wire-rope slings should be lined with thimbles to protect the strands.

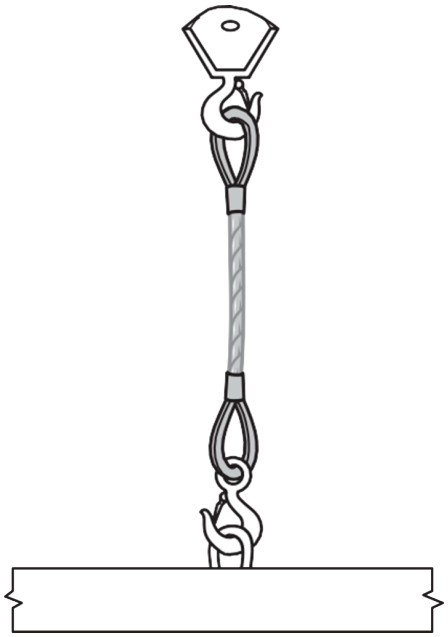

Figure 26 *Single vertical hitch (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Bridle Hitch

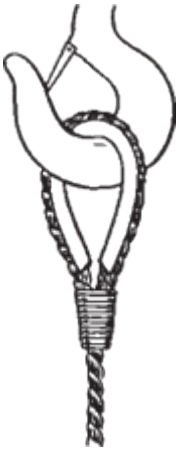

Figure 27 *A thimble protecting the eye (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Two, three, or more legs may be used together to form a ***bridle hitch***. Bridle hitches are generally used on loads that have suitable attachment points. To keep the load stable, the attachment points must be located above the load's centre of gravity.

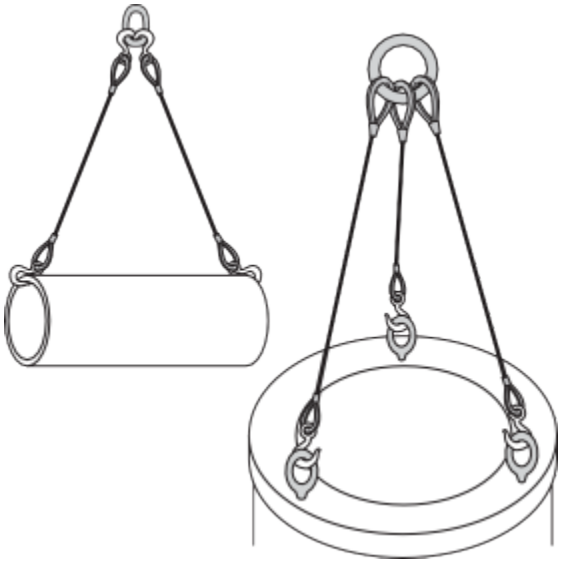

Figure 28 *Bridle hitches (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

When a bridle hitch has more than two legs, do not assume that all legs are sharing the load equally. Regardless of the total number of legs, the full weight of the load might be shared by only two legs. The other legs may simply be balancing the load (see below). For this reason, each sling in a multi-leg bridle hitch must be sized so that any one sling can safely support half of the load.

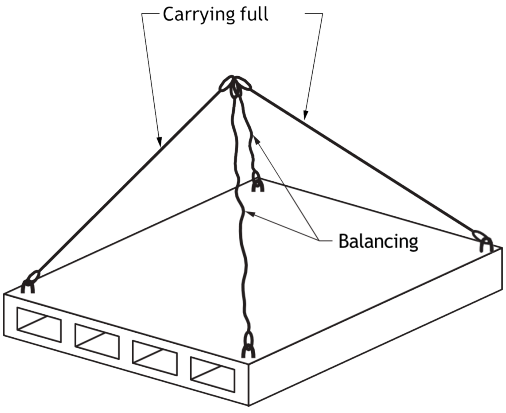

Figure 29 *Load sharing (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Single Basket Hitch

A ***single basket hitch*** is made from a single length of sling material passed through an opening in the load, with both ends of the sling attached to the main lifting hook.

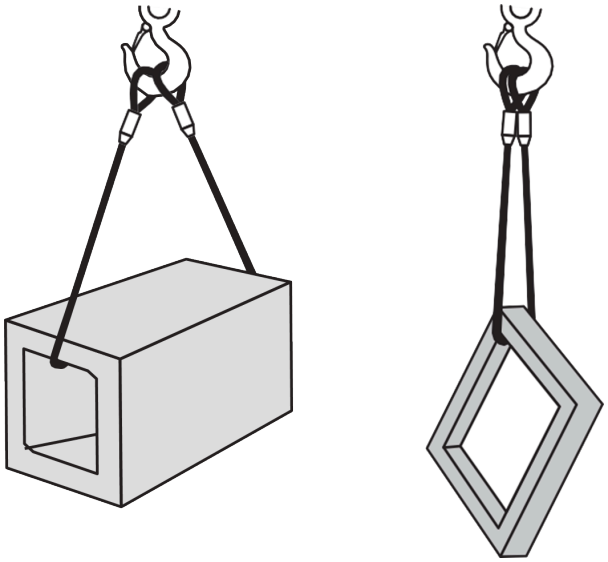

Figure 30 *Single basket hitches (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Single basket hitches must not be used on loads that could tilt or slide out of the hitch.

When a sling is wrapped around a square object, sharp corners must be padded or protected to prevent damage to both the sling and the load.

Double Basket Hitch

Loads that require support from underneath can be lifted with a ***double basket hitch***. The double basket hitch must be positioned so the load is balanced between the two points of support. The two points must be far enough apart to prevent the load from tipping or sliding out of the hitch.

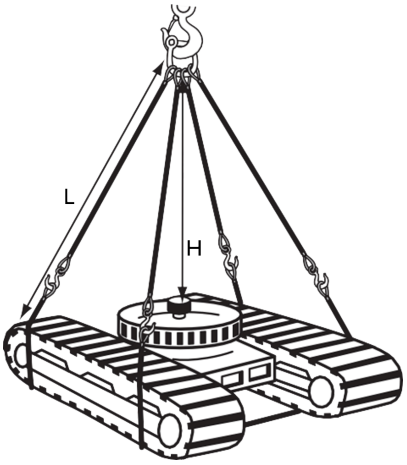

Figure 31 *Double basket hitch (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The legs of a double basket hitch should be inclined at an angle of at least 60° from the horizontal to prevent the legs from sliding toward each other. By using longer slings, you can spread the legs further apart while maintaining the 60° angle. Note that the slings may slide toward each other under load, and the load may tip out of the slings unless steps are taken to secure them in place, such as placing blocks of wood to prevent movement when lifting metal pipes.

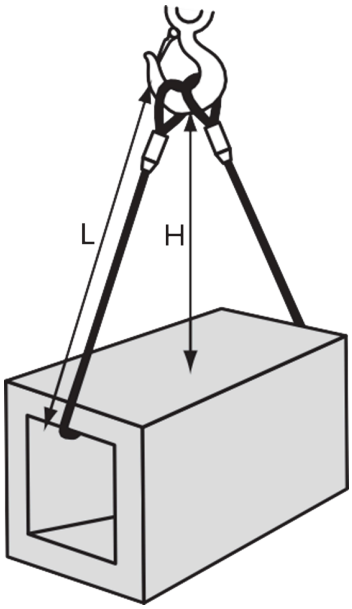

Figure 32 *Necessary incline angle (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Double-Wrap Basket Hitches

Loose loads can be securely rigged for hoisting with double basket hitches by wrapping the sling completely around the load (Figure 33). This double wrapping compresses all the components together so that even the top pieces will not slide out of the rigging.

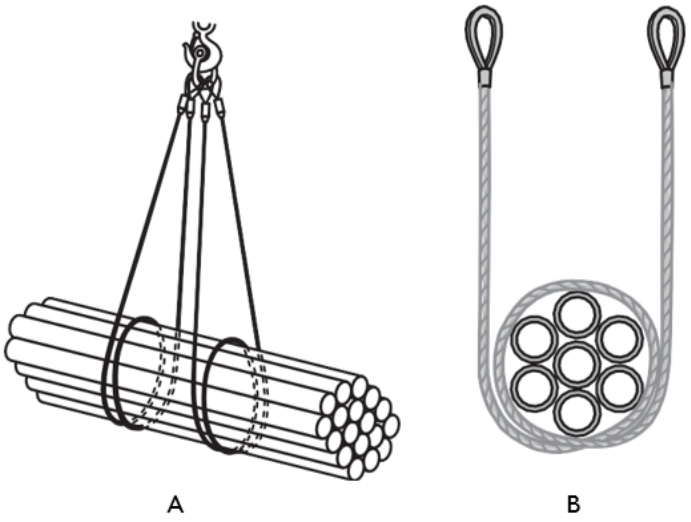

Figure 33 *Double-wrap basket hitch (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Single choker hitches (below) are made by hooking a single length of sling material back onto itself just above the load. Although there are several methods for securing the sling back onto itself, none will fully secure the top of loose loads. (see Figure 34).

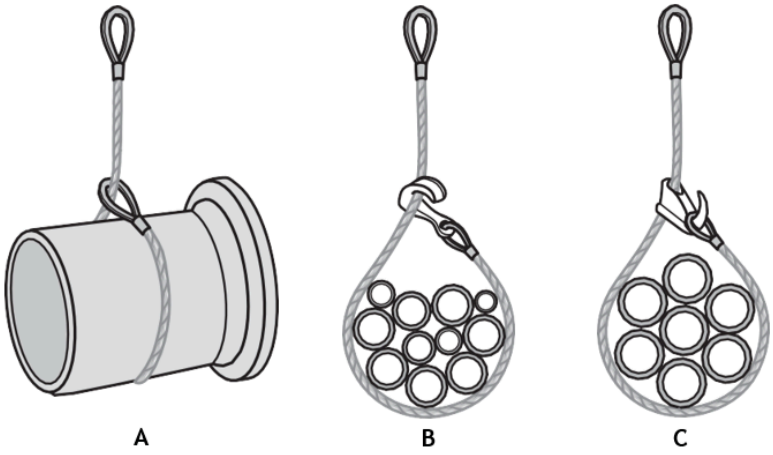

Figure 34 *Single choker hitches (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Double Choker Hitch

Double choker slings must be used on all horizontal loads made up of two or more pieces of material that are over 3 m (10 ft) in length.

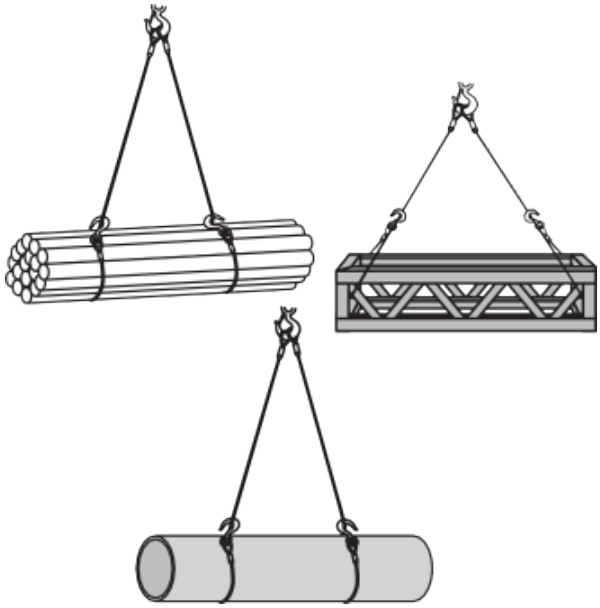

Figure 35 *Double choker hitches (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Double-Wrap Choker Hitch

The double-wrap choker hitch is similar to the double-wrap basket hitch in that both squeeze the load from all sides. Double-wrap choker hitches may be used singly or in pairs.

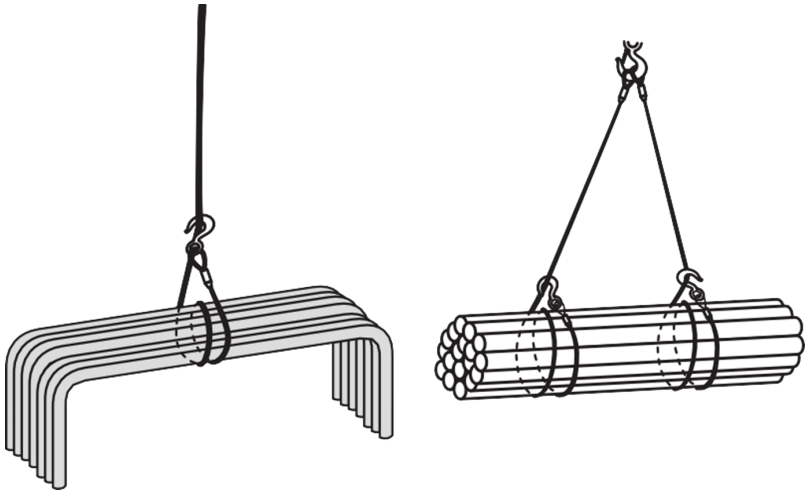

Figure 36 *Double-wrap choker hitches (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Endless Slings

Endless slings (also known as grommet slings) can be used in a variety of configurations. They are simply continuous loops of the same material.

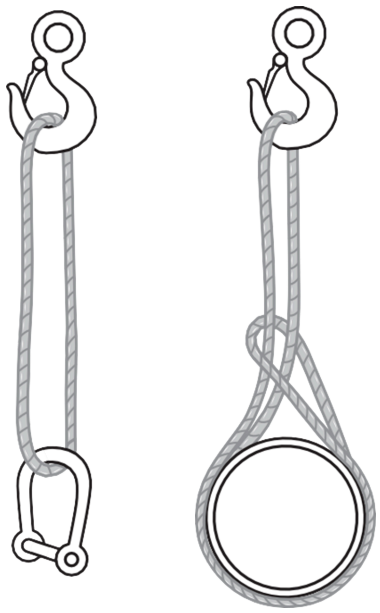

Figure 37 *Endless slings* (*BC Industry Training Authority*, 2019). *CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Endless slings are usually made of fibre rope or synthetic webbing. They are light to handle and do not damage the loads, but because they are subjected to sharp bends, they tend to deteriorate more rapidly than most other types of slings.

Spreader Bars

Long loads are often attached to [*pb_glossary id="5056"]spreader bars (beams)[/pb_glossary]* before hoisting to prevent the load from tipping or sliding out of their rigging. ***Equalizer bars*** ensure that the load is distributed evenly between the legs of a sling or between hoist lines when more than one is used. The following figures show spreader and equalizer bars and how they are used to keep loads evenly balanced.

Equalizer bars, spreader bars, and all lifting devices must be professionally designed and manufactured. They must be certified by a registered professional engineer, stamped with the certification, and marked with a safe working load. Homemade lifting devices, such as S-hooks, are not permitted.

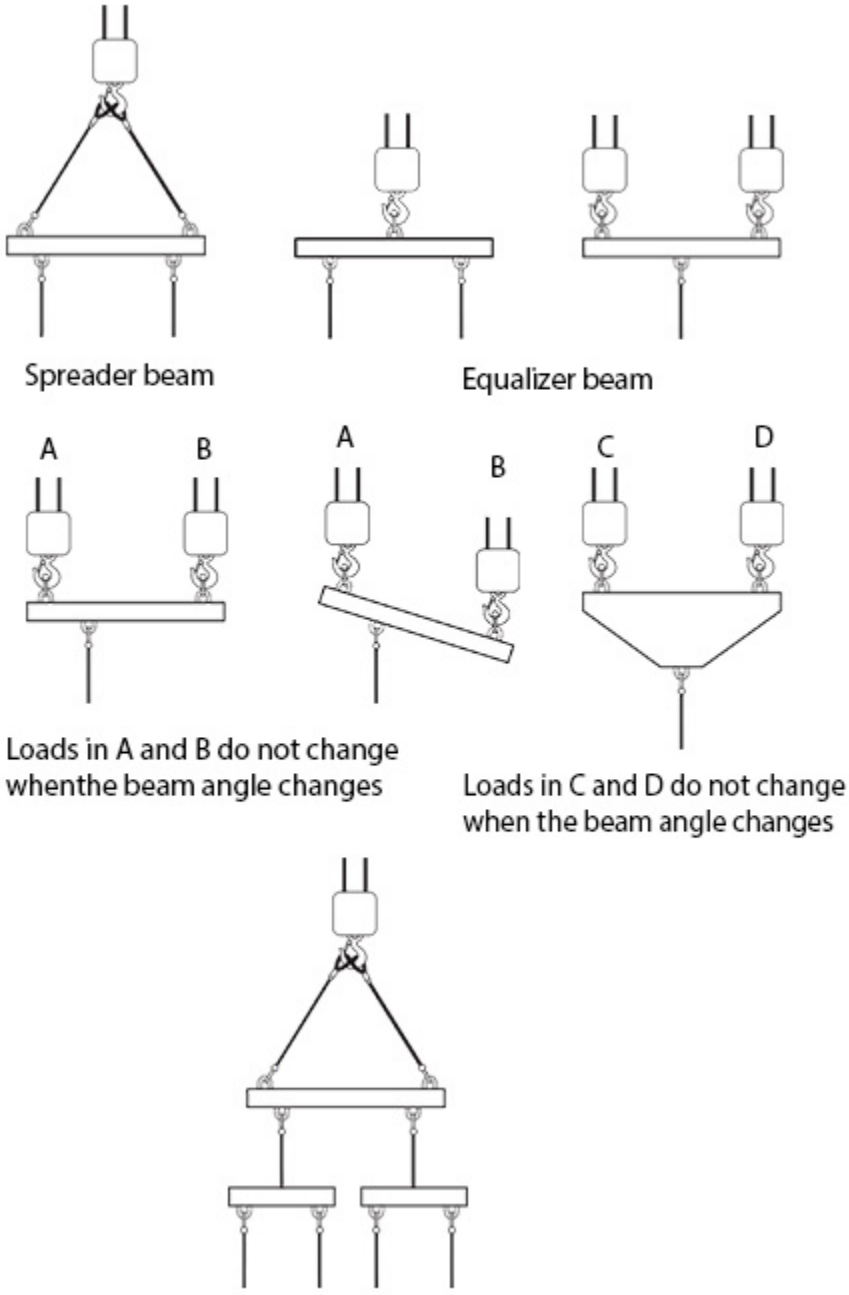

Figure 38 *Spreader and equalizer beams* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Lifting and Hoisting Equipment

No person may operate lifting or hoisting equipment without proper training. All training must be provided by a qualified instructor who has received training from the original equipment manufacturer in the safe operation of the specific equipment. Only the manufacturer's operations manual may be used for training purposes.

Manual Lifting Devices

Manual lifting devices include:

- Block and tackle
- Chain hoists
- Come-alongs
- Tirfor jacks

Block–and–Tackle

A ***block-and-tackle*** uses fibre ropes rather than wire rope. It is capable of increasing lifting capacity. This increase can be calculated by counting the number of ropes leaving the travelling block or by counting the number of ***sheaves (grooved wheels)***. For example, a with four sheaves, two on the fixed block and two on the movable block, can lift a 1000 kg load by exerting a pull of only 250 kg. This is important because the load being lifted may exceed the rope's breaking strength.

A block-and-tackle has no braking device or safety system. It cannot support a load unless the line is anchored.

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

Snatch Blocks

A ***snatch block*** is a pulley block with a side plate that swings open. Because the side plate opens, the cable does not need to be threaded through the block opening; instead the side plate is opened and the bight of the cable is placed over the pulley.

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

Chain Hoists

Chain hoists (also known as chain falls or endless chains) are dependable and economical devices for vertical lifting. Both manually operated and electrically powered models are available. They are designed to move loads either up and down or sideways, but never both at the same time.

Chain hoists are most often used for vertical lifts but can also be used for horizontal pulls. They are hand-operated and available in a wide range of capacities, from 450 kg to 9000 kg ($\frac{1}{2}$ ton to 10 tons). The lifting capacity of a chain hoist must be clearly marked on the hoist, and must never be exceeded.

Movement is relatively slow, and the lifting distance is limited by the length of the lifting chain.

Figure 41
Chain hoist with "Endless" Chains (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

"Endless" Chains

An ***"endless" hand chain*** turns the drive pulley. The drive pulley is connected to the lifting chain through a series of reduction gears that multiply the amount of force the operator exerts on the hand chain. To lower a load, you simply pull the hand chain in the opposite direction. Endless-chain hoists have the advantage of holding the load without requiring a separate brake.

"Come-Along"

Come-alongs (also called pullers) are similar to chain hoists but are operated by a ratchet lever rather than an endless chain. They are more convenient for horizontal pulls than chain hoists because they are compact, although they usually have a smaller lifting capacity than chain hoists. Similar to chain hoists, the rated capacity for come-alongs must be clearly marked and must never be exceeded.

Come-alongs are commonly used in repair shops to pull heavy parts into position before welding or bolting. Inspection procedures include checking the lifting medium (chain or wire rope). Safety requirements for wire rope, chain, and other attaching devices are equivalent.

Never substitute regular chain for the original lifting chain supplied with the come-along. Do not use any extensions on the handle to increase leverage.

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

Tirfor Jacks

Tirfor jacks (see Figure 42) are hand-operated lifting or pulling devices with an unlimited rope travel distance. They work by applying a direct pull on a wire rope that typically has a hook attached to one end and a plain end on the other (the plain end is fed through the Tirfor jack first). The pulling force is applied through two pairs of self-energizing smooth jaws that grip the rope in proportion to the load. The initial pressure that causes the jaws to grip the rope and starts the self-energizing action is provided by springs that exert a pressure of about 800 kPa (120 psi).

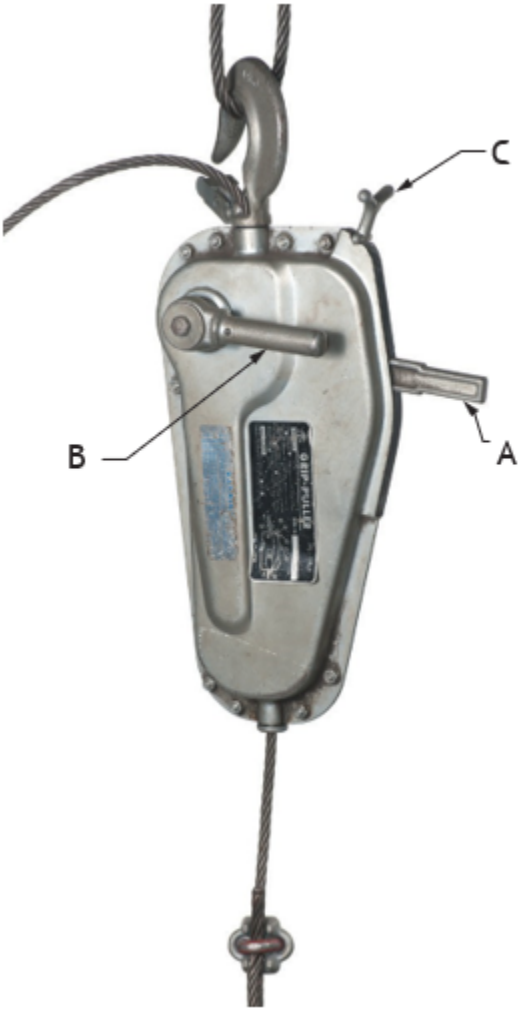

Figure 43 *Tirfor jacks (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Two levers (A and B) activate the jaws to move the rope forward or backward, depending on which lever is used. The release lever (C) must **never** be left in the released position. A removable pipe handle is used to operate the levers. The jack may be attached directly to the load or anchored near the ground.

Always position the jack so that you will not be harmed or injured if the load drops.

Tirfor jacks are available in three capacities: 750 kg (1600 lb.), 1600 kg (3500 lb.) and 3200 kg (7000 lb.). All Tirfor jacks models include overload protection consisting of a shear pin in the lifting-lever connection (Figure 42B), which breaks if the load weight exceeds the rated capacity, preventing further movement of the load.

Never replace the specific wire rope used with the Tirfor jack with another piece of wire rope unless the replacement rope meets the exact same specifications as the original.

Electric Hoists

Electric hoists are much faster and more productive than manual hoists, although they are often more expensive. They usually have a push-button control suspended from a chain or wire rope. Both manual and electric hoists may be stationary or movable. Movable types are used on overhead runways, gantry cranes, jib cranes, and overhead travelling cranes.

Figure 44 *Electric hoist on a runway* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Some hoists are manually pulled along the overhead runway or boom, while others are motor driven. Hoists are manufactured in many capacities.

Workplace regulations typically require all trolleys to be equipped with ***drop stops***, which are automatic brakes that prevent the load from falling.

Floor Hoists

A typical hydraulic floor hoist or floor crane is shown in Figure 44. The lifting reach can be adjusted by moving the boom in or out. However, as the boom extends, the lifting capacity decreases. The rated lifting capacity of these hoists is based on lifts with the boom fully extended. Floor hoists are available in various sizes and may be manually, hydraulically, or electrically powered.

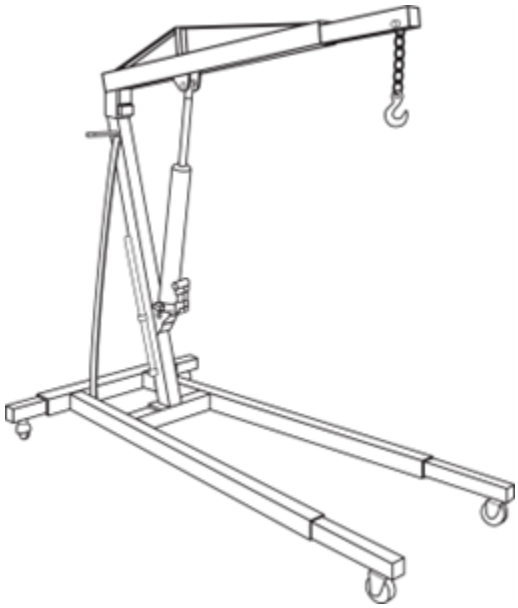

Figure 45 *Floor hoist (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Superstructures for Hoists

Hoists are generally suspended from an overhead support (a ***superstructure***) that may be stationary and provide for only vertical lifting or may allow the load to be moved from one area to another horizontally. These support structures must have a safe lifting capacity greater than the capacity of the hoist, and the safe capacity must be clearly marked.

All superstructures and supports must be certified by the engineer or manufacturer for lifting capacity.

Gantry Cranes

One of the most basic support structures that can also provide mobility is the ***gantry crane***. With this superstructure, the load can be lifted and the entire crane assembly and the load can be moved to another area.

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

Overhead Runways

Runways usually consist of *H*-type or *I*-type structural steel beams fastened to heavier cross beams on the ceiling or mounted on floor supports. The hoist is attached to rollers or trolleys that run along the bottom flange of the beam.

Runways are used extensively in shops to move materials. They often extend from outdoor loading, unloading, and storage areas right into the shop. Switches, loops, and drop arms can be installed to move materials to strategic locations.

Jib Crane

Another type of support structure is the ***jib crane***, which features a boom attached to a vertical member that rotates. Jib cranes may be wall-mounted or pedestal-mounted. Entire jib-crane assemblies can also be mounted on rails to move materials between areas of a shop.

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

Overhead Travelling Cranes

Overhead travelling cranes (also called bridge or gantry cranes) may be ***top-running*** or ***under-running***, depending on where the hoist assembly is mounted. Top-running cranes generally have greater load-carrying capacity. The trolleys on which the hoist assembly moves is mounted on top of ***bogeys (end-trucks)*** that move along parallel runways. Under-running travelling cranes are used for lighter loads, usually not more than 907 kg (2000 lb.). In these systems, the hoist-carrying bridge or beam is mounted on trolleys.

Figure 48 *Overhead travelling crane (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Mobile Lifting Equipment

Mobile lifting equipment used in the piping trades includes cranes, boom trucks, loaders, Tirfor jacks, and "*tuggers*."

Tuggers

Tugger is a broad term that refers to an electric or hydraulic drum ***winch***. Some electric winches can be bolted to a wall or floor and used with a snatch block (pulley block) to lift pipes into place in a mechanical room.

Mobile Hoists

Boom Trucks

Boom trucks are mobile hoisting units with three features:

- A hydraulic crane mounted on the truck chassis for lifting heavy loads.
- A flatbed for transporting equipment and materials.
- (Often) a personnel hoist or fibreglass basket that allows workers to reach elevated work areas.

Boom trucks are often equipped with outriggers for stability. Boom styles can vary from straight telescopic to articulating, and capacities generally range from 3 to 75 tons, with reaches of 12 to 21 metres.

Boom truck operators require proper training and certification.

Part 14: Cranes and Hoists (https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation/part-14-cranes-and-hoists) of the OHS Regulation (https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation/) requires annual inspections of boom trucks and requires that they not be used unless a professional engineer certifies that the structural, mechanical, and control components of the truck are safe for use.

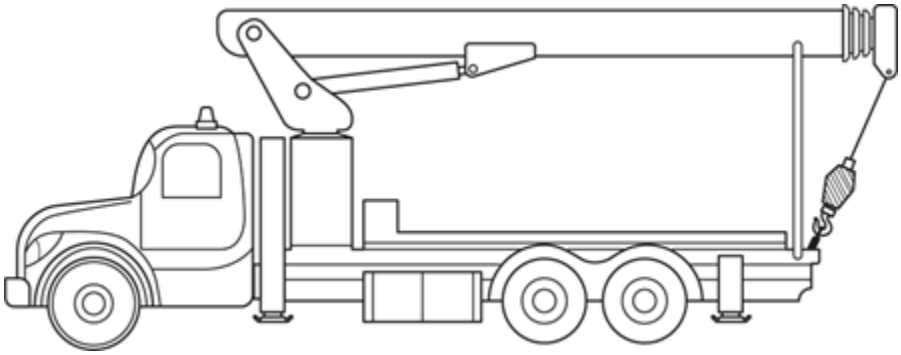

Figure 49 *Boom Truck (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure 50 *Boom truck in action (Artaxerxes/Wikimedia Commons) CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/deed.en)*

Forklifts

No person may operate a forklift without training. All training must typically be provided in accordance with the requirements of CSA Standard B335-94 (https://www.csagroup.org/store/product/2410931/), Industrial Lift Truck Training.

One of the most common types of materials-handling equipment is the motorized forklift, used for lifting and transporting materials that can be stacked or placed on pallets.

The main identifying features of the forklift are the two horizontal arms (or forks) that extend from the vertical mast (Figure 49). The mast can tilt forward between 10° and 25°.

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

The forklift's load-lifting capacity depends on the spacing of the forks, the height and tilt of the mast, and the floor or ground surface conditions. Lifting capacities range from 907.2 kg to 31 752 kg (2000 lb. to 70 000 lb.). Forklifts may be powered by electricity or internal combustion engines.

Manual forklifts (also called *pallet trucks* or *pallet jacks*) are hand propelled units used to lift and move palleted loads on smooth floors.

They cannot be used to stack loads one on top of the other, as their maximum lift height is only 150–200 mm (6–8 in.) above the floor. They have small steel wheels under the forks and require smooth surfaces to travel on when loaded.

The pallet jack shown here uses a hydraulic jack that is operated by pumping the handle to raise the forks. Travel is achieved by pushing or pulling. Loads can be lowered gently to the floor by using a control lever on the handle.

Figure 52 *Pallet jack (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Rollers

Rollers can be used to move heavy objects by hand. Commercially available rollers can support many tons and consist of a series of roller bearings that rotate around a central core. These rollers are often used by house movers and modular-building installers.

On construction sites, large heavy items such as full skids of pipe often need to be moved. These heavy loads can be moved using a jack and several pieces of steel pipe. The pipe should be approximately 50–75 mm (2–3 in.) in diameter, and the jack must be strong enough to safely lift one end of the load. A minimum of three pipes is required, and sometimes two jacks.

To Move the Load

1. Jack up one end of the load enough to place two of the pipes under the load.
2. Position the jack at the end of the load closest to the load's final location.
3. Place one pipe past the midpoint of the load and the second pipe near the jack.
4. Lower the load onto the pipes.
5. Push the load towards its final destination.
6. As the load moves, place the third pipe in front of the load and allow the load to roll onto it.
7. As the load rolls off the last pipe, move that pipe to the front and continue the process.

This method only works if the ground is firm enough to prevent the rollers from sinking and the surface is somewhat free of small debris.

Safety Considerations

- Never allow the rollers to protrude excessively from the edge of the load.
- Keep your hands and feet clear of the rollers and the load. Watch for pinch points.
- Stay clear of the load at all times.
- Practice with light loads before applying these procedures to heavy loads.

Self-Test B-4.2: Describe Hoisting, Lifting and Rigging Equipment

Complete Self-Test 4.2 and check your answers.

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2879#h5p-8 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2879#h5p-8)

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WorkSafeBC. (n.d.). *Occupational health and safety regulation: Part 15—Rigging*. https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation/part-15-rigging

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- **Figure 50** Boom truck Grove Street downtown Brattleboro VT April 2024 (https://commons.wikimedia.org/wiki/File:Boom_truck_Grove_Street_downtown_Brattleboro_VT_April_2024.jpg), by Artaxerxes on Wikimedia Commons is used under a CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/deed.en) license.

B-4.3 Describe Lifting and Hoisting Communication

Communication Signals for Crane and Hoist Operations

Whenever the operator of lifting or hoisting equipment does not have a direct ***line of sight*** to the load, or when radio communication is not possible, a competent ***signal person*** must be positioned where they have a clear view of both the load and the operator. The signal person must watch the load at all times and direct all movements of the load from this vantage point. Only one person should signal to the operator of hoisting or lifting equipment at any one time.

A **STOP** signal can be given by **any** worker. This is the only signal the operator will accept from anyone other than the signal person.

Communication must consist of previously agreed-upon hand signals or radio contact. The ANSI B30.5 standard requires signal persons to be trained and tested prior to performing crane signaling. Other forms of communication may include bell, light, or horn signals.

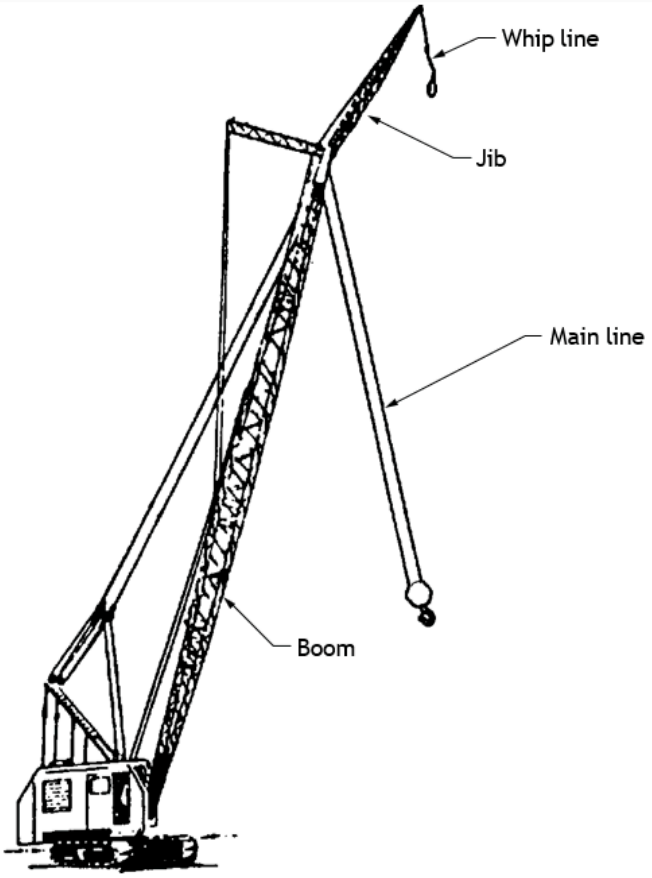

Figure 1 *Mobile crane with telescopic boom (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Audible Signals

Horn signals for traveling and mobile cranes:

One blast = STOP
Two blasts = FORWARD
Three blasts = REVERSE

Control of Platforms or Skips (Crane-Hoisted Containers):
One bell or light = STOP
Two bells or lights = RAISE LOAD
Three bells or lights = LOWER LOAD
Four bells or lights = ALL CLEAR

Hand Signals

The movement of cranes and loads is controlled using internationally recognized hand signals. These signals are used by all trades involved in lifting or hoisting operations.

If a signal is unclear or not understood, the crane operator must not respond.

"Raise the Load"

With your upper arm horizontal, forearm vertical, and your forefinger (index finger) pointing up, move your hand in small horizontal circles.

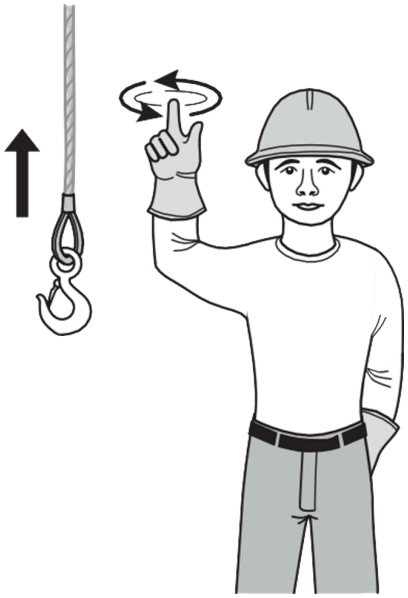

Figure 2 *Raise the load (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

"Lower the Load"

With your forearm extended downward and your index finger pointing down, move your hand in small horizontal circles.

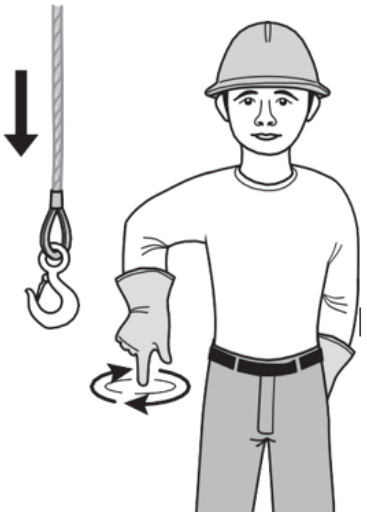

Figure 3 *Lower the load (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

"Stop"

If both your hands are free, extend both arms horizontally with your fingers outstretched. If only one hand is free, face your palm toward the operator with fingers extended and wave your hand side to side.

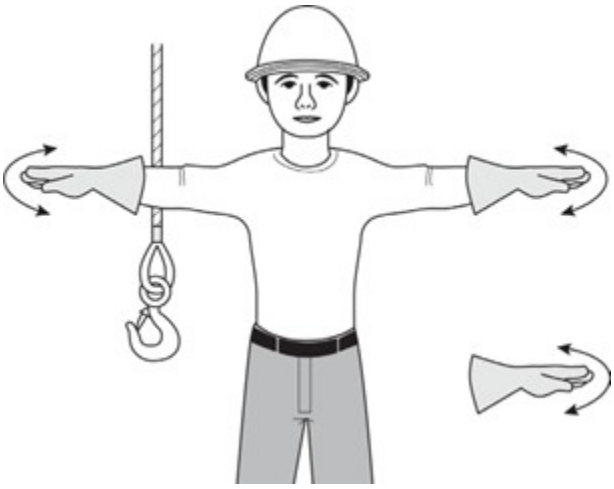

Figure 4 *Stop (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Boom Signals

To signal boom movement, extend your arm with fingers closed and use your thumb to indicate whether the boom should be raised or lowered. Remember that boom movement causes the load to move laterally—toward or away from the crane—not just vertically.

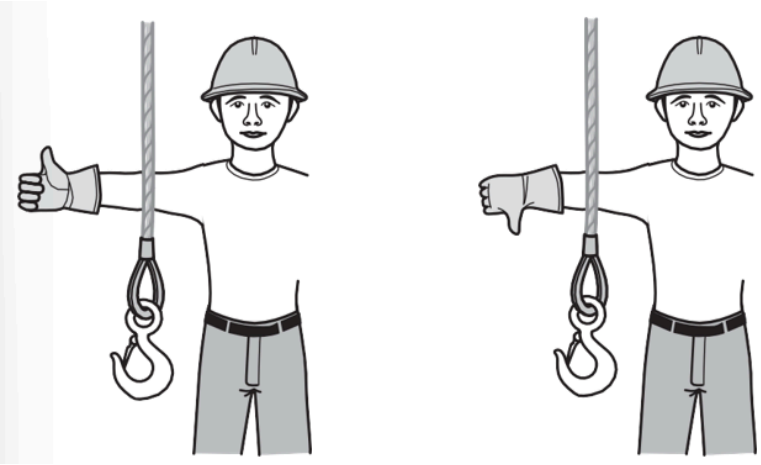

Figure 5 Raise boom and lower boom (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Cranes equipped with an extendible or telescopic boom can be signalled to extend (lengthen) or retract (shorten). This is done by holding both fists in front of the body and pointing the thumbs outward (extend) or inward (retract).

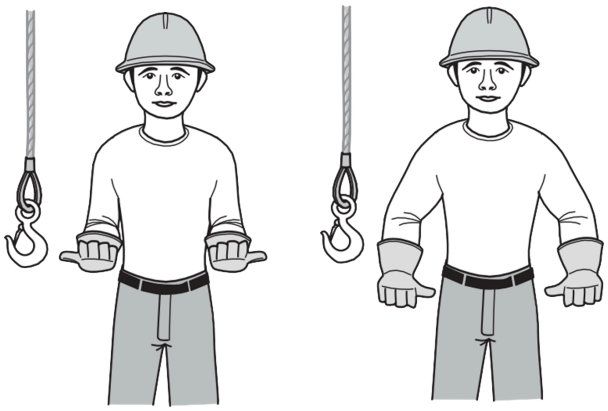

Figure 6 *Extend boom and retract boom (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Note: These signals may be performed with only one hand when necessary.

To signal the crane operator to swing the boom, extend one arm and point with your index finger to indicate the direction of the swing.

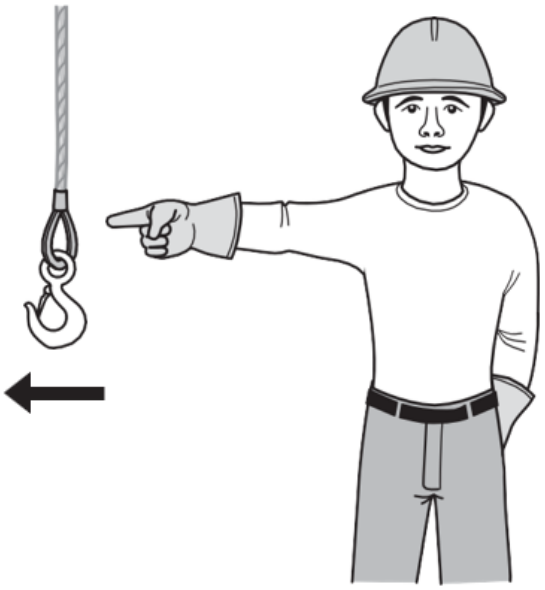

Figure 7 *Swing/travel (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Dual motions can be signaled to the crane operator when required. For example, signaling the operator to lower the boom while raising the load keeps the load at the same elevation, which is useful when avoiding an obstruction. This may be done with one or both hands. When you are using only one hand, your thumb indicates the direction of the boom, and flexing your fingers indicates the movement of the hook.

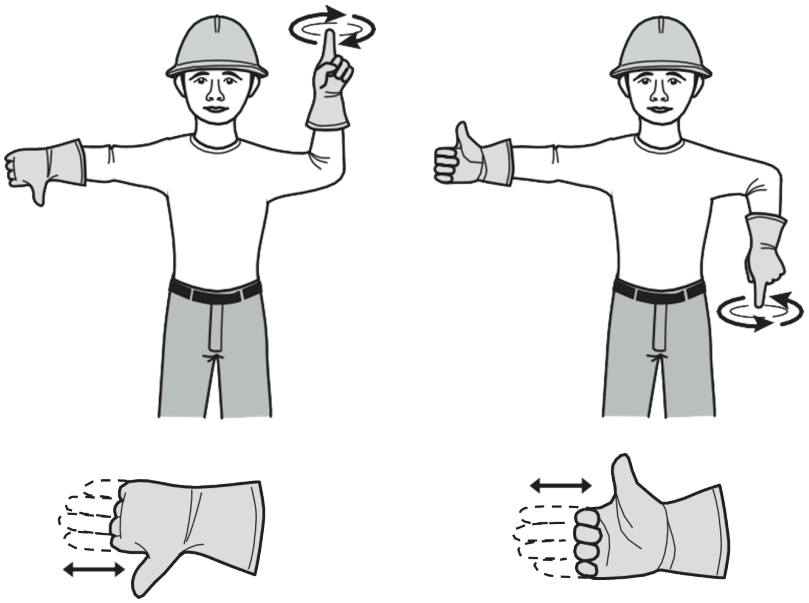

Figure 8 *Left: lower the boom/raise the load; right: raise the boom/lower the load (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Line Signals

Some cranes are equipped with a jib to extend the crane's reach for secondary loads or, occasionally, for construction personnel during installation work. From this jib, a ***whip line*** or ***auxiliary hoist*** is suspended from the jib, while the ***main line*** hangs from the boom.

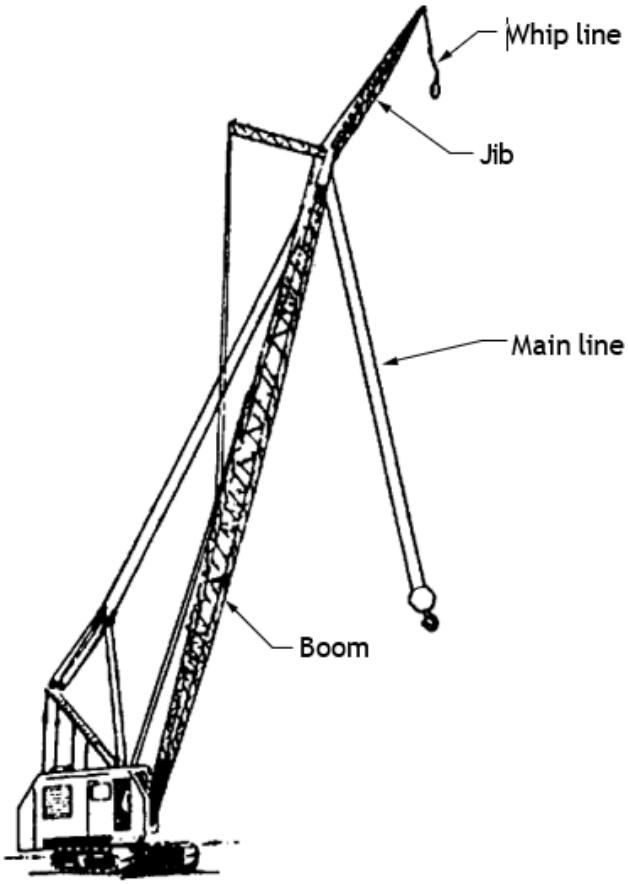

Figure 9 *Crane equipped with jib (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The following signals indicate to the crane operator which line to use.

1. **Main line:** Tap your fist to the top of your head. Then use standard hand signals to direct further movement.
2. **Whip line:** Tap your elbow with one hand (or point to your shoulder. Confirm this variation with the crane operator before the shift. Then use standard signals to direct further motion.

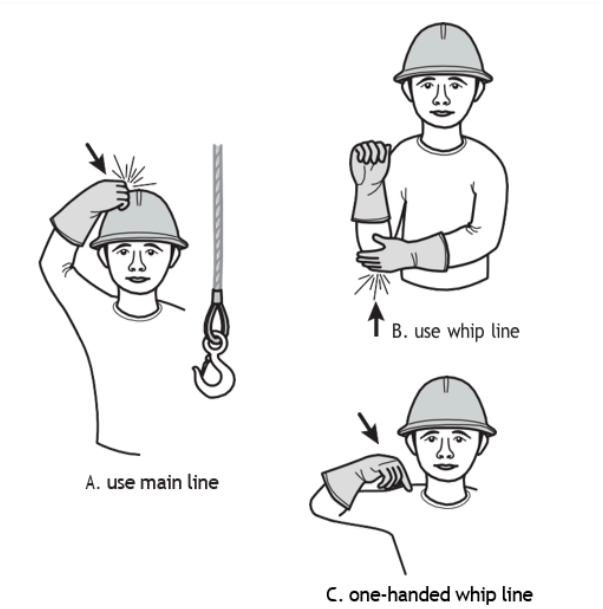

Figure 10 *A: use main line B: use whip line C: (alternate) use whip line (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

"Move Slowly"

When slow movement is required, hold the palm of your free hand motionless in front of the hand giving the signal for the main line or boom (see example below).

Figure 11 *Raise the load-slowly (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

"Dog Everything"

The ***dog everything*** signal is given by clasping both hands with thumbs and forefingers together in front of your body. At this signal, the crane operator must lock **all** crane functions until further instruction from the signal person.

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

Vertical Hoists

Construction material hoists are used on larger construction projects where the amount of material to be moved warrants the installation of a hoist.

Material hoists must be inspected by a registered professional engineer before the first lift. Light-duty hoists and shingle hoists used for roofing do not require engineering inspection as long as they are set up according to the manufacturer's specifications.

Workers must never ride a material hoist. Exceptions apply only in critical work environments (e.g., ironworkers or pipefitters accessing high installations) using engineered equipment under strict supervision.

Construction hoists must be inspected weekly unless the manufacturer specifies more frequent inspections.

References for Crane / Hoisting Hand Signals

Standard crane hand signals used in hoisting operations are defined in the WorkSafeBC *Occupational Health and Safety Regulation*. Similar signal systems are described in CSA and ANSI/ASME crane safety standards.

- WorkSafeBC – Occupational Health and Safety Regulation
  - Part 15—Rigging (https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation/part-15-rigging)
  - Part 14—Cranes and Hoists (https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation/part-14-cranes-and-hoists)
- CSA Group: B167: Overhead Cranes, Gantry Cranes, Monorails, Hoists, and Jib Cranes (https://www.csagroup.org/store/product/2410931/)
- OSHA: Standard Crane Hand Signals (https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926SubpartCCAppA)
- ANSI B30.5: Mobile and Locomotive Cranes (https://webstore.ansi.org/standards/asme/asmeb302025-2602058)

The video Crane Standard Hand Signals: The Complete Guide | Toolbox Talk (https://youtu.be/1pX2a8qVjE8) [10:18] by GotSafety (2024) provides a clear visual demonstration of commonly used signals in real-world contexts. Watching these movements in action can help reinforce the correct form and improve communication during lifting operations. Note: This video demonstrates widely used North American standard crane signals. Always follow site-specific procedures and applicable regulations, such as WorkSafeBC Occupational Health and Safety requirements, when performing lifting operations. Try practicing these signals as you watch the video.

Self-Test B-4.3: Describe Lifting and Hoisting Communication

Complete Self-Test 4.3 and check your answers.

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2883#h5p-11 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2883#h5p-11)

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B-4.4 Select Slings and Tie Knots, Bends, and Hitches

Natural and Synthetic Ropes

Fibre rope may be made from either natural or synthetic fibres. Natural fibres include manila and sisal. Synthetic fibres include nylon, polypropylene, and polyester. Each of these fibres has unique properties. Fibre ropes are not the same as fibre slings, which are specifically designed and manufactured for lifting. Fibre slings are designed and commercially fabricated for lifting purposes and have their safe working load indicated on a tag sewn to the sling.

Stranding

The individual fibres in ropes, whether natural or synthetic, are relatively weak. Fibre ropes become strong only when many hundreds of these fibres are woven or twisted into *strands*.

Braided Rope

Braided ropes are generally made from synthetic materials. A braided rope has no inherent twist to it making it easy to handle. This type of rope consists of several strands of braided yarns, one inside the other.

Twisted Rope

The traditional *fibre* rope consists of three strands twisted together. The strands twist in a clockwise direction. Each strand is made up of many smaller strands called *yarns*, and each yarn is made of even smaller strands called fibres. The yarns within the strands are twisted counterclockwise, while the fibres within the yarns are twisted in a clockwise direction. By alternating the twist direction at each layer, the rope remains stable under load because the fibres stay relatively straight.

A twisted synthetic rope is preferred for *lifelines* because it stretches slightly, helping to cushion a worker's fall.

Natural Fibre Ropes

Figure 1 *Three-strand twisted natural fibre rope (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Manila

Manila rope is available in six grades and is not as strong as synthetic rope. As grade and strength decrease, the colour darkens.

Table 1: Grades of Manila Rope

Grade	Description
Yacht rope	Considered the highest quality manila rope, yacht rope is pale yellow in colour. It is expensive and therefore used only on special jobs.
Bolt rope	This is a high grade, pale yellow rope. In strength, it falls between yacht rope and No. 1 grade.
No. 1 grade	No. 1 grade is light yellow and usually contains one or more coloured strands as identification. It is the lowest grade suitable for overhead lifting.
No. 2 grade	This type is slightly darker than No. 1 rope and does not have coloured identity strands. It loses strength more rapidly than No. 1 grade.
No. 3 grade	Considerably darker than either No. 1 or No. 2 grade, No. 3 loses strength very rapidly when in service.
Hardware store rope	This is the darkest and poorest grade of manila rope. Since it is constructed with a high percentage of short fibres, it has little strength, a short life, and a much rougher texture with many fibre ends sticking up from the surface.

Sisal

Sisal rope is white, coarse-textured, and rough to the touch. It is weaker than manila and should be used only when cost is more important than strength.

Natural fibre rope must **not** be used for hoisting with a powered hoist.

Synthetic Fibre Ropes

Figure 2 *Twisted nylon rope with braided sheath (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Nylon

Nylon is approximately $2\frac{1}{2}$ times stronger than manila. Nylon rope is usually pure white, soft, pliable, and smooth to the touch. It has an elastic quality and can stretch up to 40% of its length.

Nylon rope loses about 10% of its strength when wet but regains its original strength when dried. Nylon does not rot, is unaffected by mildew, and can withstand temperatures up to 150 °C (300 °F) without being damaged. It is adversely affected by acids and alkalis and can be damaged by them.

The highly elastic nature of nylon rope makes it capable of withstanding repeated *shock loads*. However, this same elasticity can be problematic if you are trying to lift loads in areas with restricted headroom.

Polyester

Polyester rope looks similar to nylon but is less elastic. It stretches only about 5% before breaking.

Polyester rope is 87% as strong as nylon. It is not as elastic as nylon and is capable of sustaining only 60% of nylon's shock load.

Polyester does not lose any strength when wet and, unlike nylon, is unaffected by acids or alkalis. For your own protection, however, you should wash polyester ropes and slings with cold water whenever they have been exposed to any chemicals.

Polypropylene

Polypropylene rope is available in a wide range of colours, but yellow is the most common. It is smooth, somewhat slippery, lightweight, and floats on water.

Polypropylene gradually softens as temperatures increase and loses up to 40% of its strength at boiling water temperature (100 °C or 212 °F). Higher temperatures will eventually cause polypropylene to melt. This rope also deteriorates rapidly when exposed to sunlight.

Polypropylene rope is about 60% as strong as nylon and is capable of absorbing only 40% of the shock load of nylon. Of all the rope types mentioned, polypropylene has the best electrical insulating properties against electrical shock, but it should be noted that only dry ropes should be used near sources of high voltage.

Working Load Limit (WLL)

The *working load limit (WLL)* is the maximum load that a rigging component may carry while meeting the safety factors set forth by workplace regulations.

Most regulations set minimum safety factors for rigging materials. The WLL is typically determined by dividing the *breaking strength* of the rigging component by the safety factor.

The minimum safety factor for rigging used to support workers is 10. For lifting materials, the safety factor varies depending upon the rigging component. For example, lifting materials with a sling made of nylon fibre rope requires a safety factor of 9, while for an alloy chain the factor is only 4.

Breaking Strength

Breaking strength is the minimum force required to break a rope, measured in Newtons (N) or pounds.

The strength of different ropes depends on the fibre being used, the diameter of the rope, and the type of stranding, that is used. For equal diameter and stranding, the strongest of the commonly used fibre rope is nylon. Polyester and polypropylene are weaker than nylon, but other conditions may make them a better choice.

For the exact breaking strength of a specific rope it is best to consult the manufacturer of the rope.

Use of Ropes

Fibre ropes are very useful in construction. They are easy to handle and, because they come in very long lengths, they can readily be adapted to many custom situations.

It is very important to use the correct knot, bend, or hitch when connecting ropes together or to material to be lifted. If the incorrect knot is tied, it may slip, causing the load to fall or jam, and may permanently damage the rope.

New fibre bulk ropes come packaged in a plastic wrapper. To remove new rope from its shipping coil, place the coil on its side, reach down inside and pull the rope up from inside the coil. Leave the outer wrapping intact.

Remember: Tying a knot reduces rope strength by approximately 50%.

Safe Use Guidelines

Ropes should not be overloaded. Ropes that have been subjected to loads beyond their working load limit should be taken out of service. For lifting materials, the maximum load should never exceed $\frac{1}{9}$ the of the rope's breaking strength.

Avoid exposing rope to direct sunlight for long periods of time. Excessive exposure causes fibres to break down due to ultraviolet rays.

Do not use frozen rope. If you must handle rope that is frozen, do so very carefully, as bending may break the strands. To prevent rope from freezing, dry it well before exposing it to cold weather.

Avoid making sharp bends in rope. Sharp bends, including those made by knots, will reduce the rope's strength by 50%. Always pad the sharp corners of a load before applying the rope.

When attaching a small-diameter object such as a hook or ring to a rope, use a ***thimble*** to protect the eye of the rope.

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

Care and Maintenance of Rope

The life of any type of fibre rope can be greatly extended if you follow the basic care and maintenance procedures listed below.

Whipping

Whipping is a wrapping applied at the end of a rope to prevent the rope strands from unravelling. Whenever a rope is cut to a new length, the ends of the rope should have whipping applied before the rope is put into service.

Whipping is more than just a tidy decoration. It prevents the strands of the rope from slipping in relation to each other. Such slipping would cause one strand to carry more or less than its fair share of the load.

To apply whipping to a rope, use a strong, non-slipping twine. If the twine tends to slip, pulling it over soft tar, beeswax or pine pitch will usually correct the problem.

Tape may be used as whipping if applied tightly. Whipping should be replaced when it shows signs of fraying or loosening.

How to Apply Whipping

1. Begin by holding one end of the twine (A) at the end of the rope. Then form a long loop along the rope.

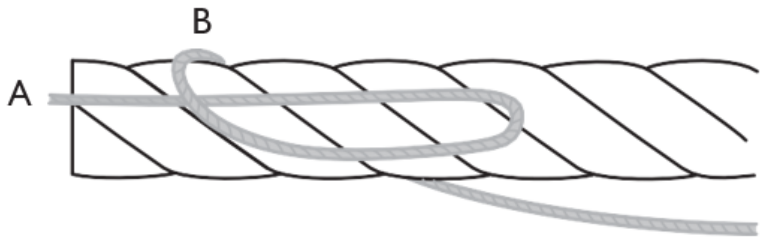


Figure 4 *Loop the twine (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

2. Hold the end of the twine (A) and the left end of the loop with your left hand and begin wrapping the other end of the twine (B) around the rope over the long loop.
3. Continue to apply wraps as close to each other and as tight as possible until you have covered a distance approximately $1\frac{1}{2}$ times the rope diameter.
4. Take the twine end (B) and pass it through the loop as shown here.

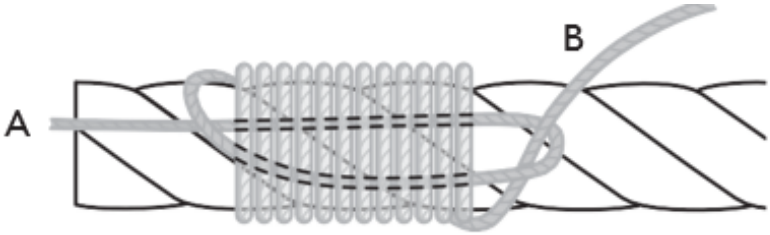


Figure 5 *Pass the end through (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

5. Pull on the twine end (A) until you feel that the two ends of the twine are approximately midway under the whipping.

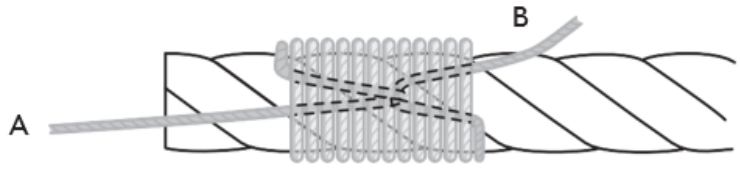


Figure 6 *Pull the end to the centre (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

6. Trim the end of the twine as close as possible to the whipping; then trim the end of the rope so that a portion approximately half the rope's diameter projects beyond the whipping.

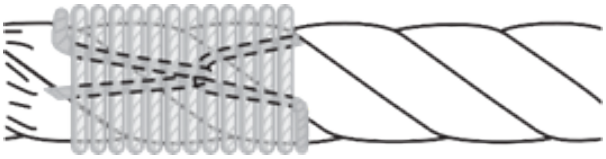


Figure 7 *Trim the ends (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Instead of using whipping on nylon, polyester or polypropylene ropes, you can melt the fibres together with a hot iron or flame. Roll the end of the melted rope between two flat surfaces (scraps of wood) while the rope cools; otherwise, the end may become larger than the rope's diameter. When the ends of the rope are larger than the rope diameter, they become difficult to untie.

When you are using the hot iron or flame to melt the rope fibres, be careful to avoid burning yourself.

Storage

Rope should be kept clean. Soil embedded in the fibres acts as an abrasive, wearing the rope down. Soiled rope should be washed in cool water, loosely coiled, and hung in a well-ventilated area to dry before storage. Apart from this cleaning, rope requires very little maintenance.

Be sure to coil rope when you are preparing it for storage. The coiled rope should then be hung on large diameter pegs in a cool, dry room with good air circulation to prevent mildew. Improper storage of fibre rope leads to rot, brittleness, crushed fibres, kinks, and many other defects. Any kinks or small loops should be carefully removed before the rope is put under tension and pulled taut.

With basic care and proper storage, natural fibre rope will provide many years of service. If left lying on the ground in a damp environment, the rope will become useless in a very short time.

A thorough, visual inspection should be done before performing every lifting task. When inspecting fibre ropes, look for:

- Broken strands
- Wear and abrasion
- Heat damage or melting
- Contamination with petroleum products, which can damage the rope
- Evidence of rot or damage from exposure to the elements
- Crushing, twisting, or kinking
- Loose, broken, or damaged thimbles

***Note*: Any damage will affect the lifting capacity of the rope.**

Tying Knots and Hitches

To use rope effectively, you must be able to select the correct knot, bend, or hitch for the task and tie it properly. Any knot, bend, or hitch must support the load imposed on it, be quick and easy to tie, and be easy to untie once the load has been removed.

Rope Work Terms

To better understand the following instructions on knot tying, you will need to identify the parts of a rope.

Figure 6 shows an overhand loop. A loop is the starting point for most knots. The portion of the rope that forms the loop is termed the "***bight***." The long portion of the rope is termed the "***standing part***." The end of the rope is called just that, the "***end***."

An overhand loop is formed by passing the end of the rope over or in front of the standing part of the rope. (Figure 10).

Figure 8 *Overhand loop (Camosun College/BCcampus)* CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

An underhand loop is formed by passing the end of the rope under or behind the standing part (Figure 11).

Figure 9 *Underhand loop (Camosun College/BCcampus) CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

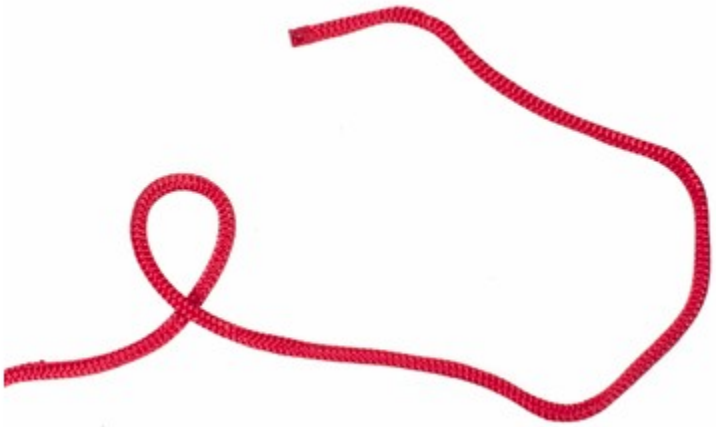
General Rules for Tying Knots, Bends, and Hitches

Bowline Knot

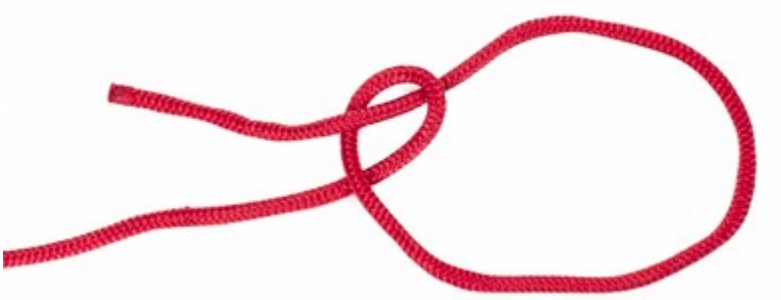
The ***bowline knot*** forms a non-slip loop at the end of a rope. It is strong, secure, and easy to untie—even after being loaded.

The bowline is used when a ***slip-proof loop*** is needed, such as when attaching a rope around a fixed object.

How to Tie a Bowline



Step 1: *Form a small loop by passing the end of the rope over the standing part. (Camosun College/BCcampus) CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*



Step 2: *Pass the end under the bight and pull it up through the loop. (Camosun College/BCcampus) CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Step 3: *Pass the end behind the standing part. (Camosun College/BCcampus) CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Step 4: *Insert the end back down through the loop (Camosun College/BCcampus) CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Step 5 *Tighten the knot by holding the end of the rope and the loop in one hand and the standing part in the other hand. Then pull until the knot is tight.* ***Figure 10 (Steps 1–5)*** *Tying a bowline knot (Camosun College/BCcampus). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

To untie the bowline, loosen the knot by pushing the loop that surrounds the standing part away from the knot. Once the knot is loosened, it is easily untied.

Bowline on a Bight

The ***bowline on a bight*** is a knot that creates two fixed-size loops in the middle (or bight) of a rope. Its advantages are that its loops do not slip and it is also reasonably easy to untie after being exposed to a strain. This knot can be used to provide a toe hold in the middle of a rope or to make an emergency ***Bosun's chair*** (a device used to suspend a person from a rope to perform high work).

How to Tie a Bowline on a Bight

Start by creating a bend in the middle of the rope to double it (the doubled end now acts as the rope's "end"). Form an overhand loop.

Step 2: *Pass the bent end through the backside of the loop, forming a second, larger loop.*

Step 3: *Spread open the bent end and pull over the larger loop.*

Step 4: *Continue to bring the bent end around until it encircles the doubled standing part.*

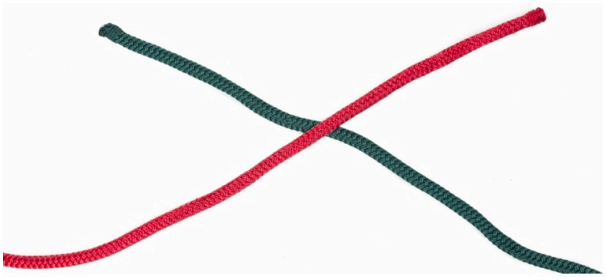
Step 5: *Tighten by pulling the double standing part and the bent end in opposing directions.*

Step 6: *Finished bowline on a bight*
Figure 11 (Steps 1-6) *Tying a bowline on a bight (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Reef or Square Knot

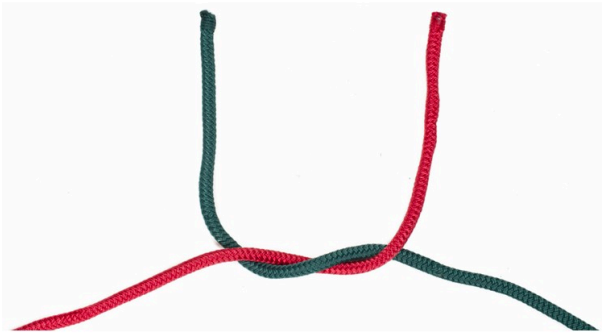
The ***reef knot*** *or square knot* is used to fasten together two ropes of equal diameter.

How to Tie a Reef Knot



Step 1

Cross the ends of the ropes and turn one rope around the other.



Step 2

Cross the ends again and turn one end around the other end, making sure the second turn is done in the opposite direction to the first.

Step 3

Tighten the knot.

Step 4

Figure 12 (Steps 1-4) *Tying a reef or square knot (Camosun College/BCcampus). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

You can remind yourself how the reef knot is tied by using the following verse:

Left over right and under

— then —

right over left and under

The finished reef knot should have both the standing part and the end of each rope on the same side of the bight formed by the other rope.

Sheet Bend

The ***sheet bend*** is used to attach two ropes of unequal diameter together.

How to Tie a Sheet Bend

1. To tie the sheet bend as shown, form a bight in the larger diameter rope.
2. Pass the end of the smaller diameter rope up under and through the bight; wrap it around the back of the bight's end and standing part of the larger rope.
3. Pass the end under the section of the smaller rope where it first came through the bight and continue with the small end until it lies across the top or face of the bight formed by the larger rope.
4. Hold both the standing part and the end of each rope in each hand and pull in opposite directions to tighten.

Step 1

To tie the sheet bend as shown, form a bight in the larger diameter rope.

Step 2

Pass the end of the smaller diameter rope up under and through the bight; wrap it around the back of the bight's end and standing part of the larger rope.

Step 3

Pass the end under the section of the smaller rope where it first came through the bight and continue with the small end until it lies across the top or face of the bight formed by the larger rope.

Step 4

Hold both the standing part and the end of each rope in each hand and pull in opposite directions to tighten.
Figure 13 *(Steps 1-4) Tying a sheet bend (Camosun College/BCcampus). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

For additional holding strength, pass the running end around and under the bight an second time to create a double sheet bend.

Figure 14 *Double sheet bend (Camosun College/BCcampus). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Round Turn with Two Half-Hitches

The *round turn and two half-hitches* is a hitch used to secure the end of a rope to a fixed object. The name refers to the components used to form the knot: A round turn wraps the rope around the object (completely encircling it), and the two half-hitches secure the end around the standing part.

How to Tie It

1. To make this round turn with two half-hitches, you must as mentioned wrap the rope completely around the object (a full round turn).
2. Pass the end of the rope around the standing part and pull the end between the object and the rope to form the

first half hitch.

Step 1

Step 2

3. Make a second loop around the standing part of the rope in the same direction as the first loop. (If one loop is clockwise and the other is counter-clockwise, the hitch will be difficult to untie.)
4. Finish by passing the end of the rope between the standing part and the two loops. As the standing part is pulled tight, the loop around the object will slip until the two half-hitches have jammed tightly to the object. They will not come untied if the pull on the standing part is relaxed.

Step 3

Step 4

Figure 15 *(Steps 1-4) Round turn and two half hitches (Camosun College/BCcampus). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Rolling Hitch

The ***rolling hitch*** is a knot used to attach a rope to a rod, pole, or other rope. A simple friction hitch, it is used for lengthwise pull along an object rather than at right angles. The rolling hitch is designed to resist lengthwise movement for only a single direction of pull.

Step 1

Step 2

Step 3

Step 4

Step 5

Figure 16 (Steps 1-5) *Tying a rolling hitch (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Clove Hitch

The ***clove hitch*** is used to secure a rope to a fixed object, such as a post.

How to Tie a Clove Hitch

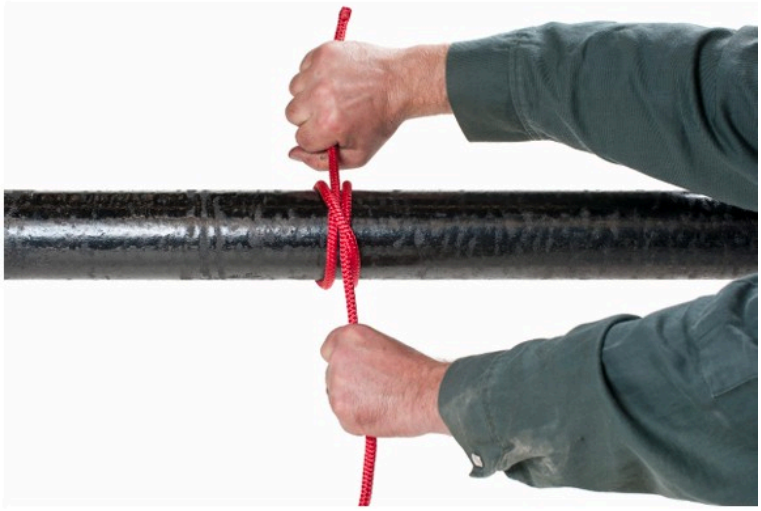
1. Wrap the rope around the object once, with the wrap passing to one side of the standing part.
2. Make a second wrap around the object, this time passing to the opposite side of the standing part.
3. Pass the end of the rope between the object and the second wrap.
4. Pull the two wraps together and tighten by pulling the standing part and the end in opposite directions.

Note: The clove hitch can be made even more secure by tying the end to the standing part with a single half-hitch.

Step 1

Step 2

Step 3



Step 4

Figure 17 *(Steps 1-4) A clove hitch tied in position (Camosun College/ BCcampus).* CC BY-NC-SA 4.0 *(https://creativecommons.org/licenses/ by-nc-sa/4.0/)*

Figure 18 *Clove hitch pre-tied to slip over end of pipe (Camosun College/ BCcampus). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/ 4.0/)*

Timber Hitch

The ***timber hitch*** is used to secure a rope to a plank, timber, post, or pipe when the object must be lifted in an upright position. The timber hitch is a series of modified half-hitches.

How to Tie a Timber Hitch

1. Wrap the rope around the object with an overhand loop and tie a single half-hitch around the object. (Steps 1 and 2)
2. Pass the free end of the rope between the object and rope two more times.
3. Pull the hitch tight by pulling the standing part of the rope at 90° to the object.
4. Using the standing part of the rope tie one or more half-hitches along the length of the pipe or object to make the pipe secure and allow it to be hoisted vertically.

Step 1

Wrap the rope around the object with a overhand loop.

Step 2

Tie a single half-hitch around the object.

Step 3

Pull the hitch tight by pulling the standing part of the rope at 90° to the object.

Step 4

Using the standing part of the rope tie one or more half-hitches along the length of the pipe or object.

Tie two half hitches to make the pipe secure and allow it to be hoisted vertically.
Figure 19 *(Steps 1-5) Tying a timber hitch (Camosun College/BCcampus).* *CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Trucker's Knot (or Trucker's Hitch)

The ***trucker's knot*** is a very useful knot for tying loads down. The knot forms a slip-resistant loop that acts like a pulley in a system. You can generate almost three times as much tension on a rope using the trucker's knot as you would if you just pulled on a straight rope.

You may find this video Truckers Hitch (https://media.bccampus.ca/media/Truckers%20Hitch/0_x4iyzc34) by Camosun College (2022) helpful.

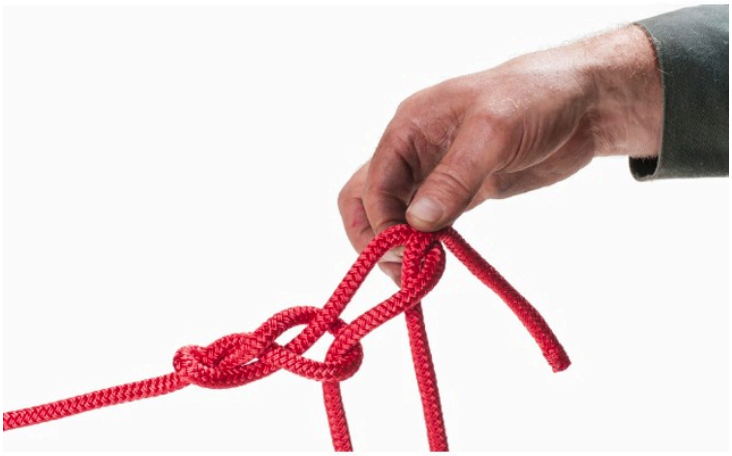
How to Tie a Trucker's Knot

1. Form a small loop in the rope and twist the loop formed by the bend three times.
2. Take a bend in the standing (dead) end and pass this new doubled bend through the loop formed by the three twists to form a second loop. This second loop becomes your "pulley" used to apply tension to the rope tying down your load.
3. Pass the dead end of the rope through a tie-down point or hook on the truck, then through the second loop formed by the trucker's knot.

4. Pull to apply tension, then secure with a double half-hitch.

Step 1

Step 2



Step 3

Step 4

Figure 20 *(Steps 1-4) Tying a trucker's knot (Camosun College/BCcampus).*
CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Figure Eight Knot

The simple *figure eight knot* is used to form a stopper on the end of a rope. This "*stopper*" is used to prevent the rope from running through a sheave or pulley or to stop the rope from slipping through another knot.

How to Tie a Figure Eight Stopper

1. Form a loop.
2. Pass the end around the standing part.
3. Bring the end back through the loop.
4. Tighten.

Step 1

Step 2

Step 3

Figure 21 *(Steps 1-4) Tying a figure eight knot or "stopper" (Camosun College/BCcampus).* CC BY-NC-SA 4.0 *(https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Figure Eight Loop

A figure eight knot can also be tied into a non-slip loop. This loop could be used to secure the end of a lifeline around a solid object.

Tying a Figure Eight Loop

1. Tie a regular figure eight but leave a long tail.
2. Wrap the tail around the object.
3. Take the end of the tail and retrace the path of the rope back through the figure eight.
4. Pull the knot snug.

Step 1

Step 2

Figure 21 *(Steps 1-4) Tying a non-slip loop (Camosun College/ BCcampus). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/ by-nc-sa/4.0/)*

Do not join ropes for overhead lifting! Use only single-piece ropes.

Video Resources

The following videos by Camosun College (2022) demonstrate important rope knots used in rigging operations.

- Knots and Hitches (https://media.bccampus.ca/media/Knots%20and%20Hitches/0_1zyju8c0) [10:03]– Demonstrates several common knots used to secure loads and rigging equipment.
- Trucker's Hitch (https://media.bccampus.ca/media/Truckers%20Hitch/0_x4iyzc34) [3:00]– Shows how to tie a trucker's hitch to create mechanical advantage when tightening rope.
- How to Whip the End of a Rope (https://media.bccampus.ca/media/ How%20to%20Whip%20the%20End%20of%20a%20Rope/0_rhafq2j5) [2:57] – Demonstrates how to apply whipping to prevent the end of a rope from fraying and to extend the rope's service life.

Self-Test B-4.4: Select Slings and Tie Knots, Bends and Hitches

Complete Self-Test 4.4 and check your answers.

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

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2887#h5p-12 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2887#h5p-12)

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Camosun College. (2022c). How to whip the end of a rope [Video]. BCcampus Media. https://media.bccampus.ca/media/How%20to%20Whip%20the%20End%20of%20a%20Rope/0_rhafq2j5

Media Attributions

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B-4.5 Use Hoisting, Lifting and Rigging Equipment

High-Voltage Line Clearance

Use extreme caution when working with a crane near high-voltage power lines. Although you may not be the operator of the crane, you may be rigging or handling the load that the crane lifts.

Keep your distance from power lines! Surrounding every live power line is an area referred to as the "***absolute limit of approach***." **DO NOT**, under any circumstance, move any crane boom, load line, or load into this area unless the power line has been *de-energized*. There are no exceptions.

This *limit of approach* varies according to local, provincial, and federal laws and the crane manufacturer's recommendations, but the generally accepted clearances are shown in Figure 1.

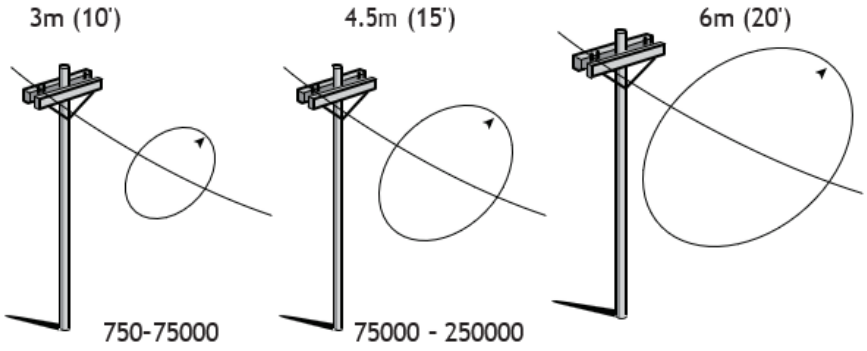


Figure 1 *Limits of approach to power lines, according to voltage (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Safety Precautions

- Whenever your work involves moving heavy loads, wear steel-toed safety boots.
- If there is any risk of your hands suffering cuts or abrasions, wear gloves.
- Be alert! Try to anticipate load movements.
- Plan ahead: have an escape route planned in the event something goes wrong.

Care of Slings and Wire Rope

Wire rope and fibre slings should be stored in a dry location off the ground. The strength of a nylon sling is reduced when it becomes wet.

Lubricate wire rope regularly with a light oil to prevent corrosion. You can brush the oil on or pass the wire rope through an oil bath. In either case, it is important to ensure complete penetration of the oil into the inner wires.

Wire Rope Safety

When working with wire rope slings, always wear gloves and eye protection. The following safety precautions should be followed when handling wire rope:

1. Use the correct rope for the job.
2. Inspect the wire rope regularly.
3. Never overload the rope.
4. Minimize shock loads by lifting or hoisting and stopping loads slowly.
5. Avoid sudden loading in cold weather.
6. Take special precautions and/or use a larger rope when:

- The exact load is unknown
- There is a possibility of shock loading
- The conditions are abnormal or severe, or
- There is a hazard to personnel

7. Protect rope from sharp corners or edges with padding (use ***softeners***).
8. Avoid dragging the rope from under loads or over obstacles.
9. Avoid dropping wire rope slings from heights.
10. Avoid rolling loads over the slings.
11. Store all unused ropes in a clean, dry place.
12. Prevent loops in slack lines from being pulled tight and forming ***kinks***. Once a kink has formed in a wire rope, the the damage is permanent. A weak spot will always remain even if the kink appears to have been straightened.
13. Never use wire rope that has been cut, badly kinked, or crushed. Obtain approval to destroy and discard any slings or hoisting equipment found to be unsafe.
14. Use metal ***thimbles*** in eye fittings at all times.

Damage to Wire Rope and Wire Rope Inspection

Individual wire breakage may be found in almost any rope. In most cases, broken wires do not require rope removal if they are at well-spaced intervals. Note the area and watch carefully for any further wire breaks. Clean up broken wires by bending the wire back and forth until the wire breaks off. This allows the broken end to remain inside the rope where it will do less harm. Cutting broken wires with pliers may leave jagged ends that can damage other wires.

A wire rope used for lifting must be permanently removed from service if there are six or more randomly distributed broken wires in one***rope lay***, or three or more broken wires in one strand in one rope lay.

A rope must also be permanently removed from service if there is more than one broken wire near an attached fitting. Breaks that occur near attached fittings are usually the result of fatigue stresses concentrated in these localized sections. Wire breaks of this type should be cause for replacement of the rope or renewal of the attachment to eliminate the locally fatigued area.

Once broken wires appear in a rope operating under normal conditions, many more will show up within a relatively short period. Attempting to use a rope beyond the allowable number of broken wires will create a hazard.

Worn and Abraded Wires

Each individual wire in a rope, when new, is a complete circle in cross-section. Wear due to friction on sheaves, rollers, drums, etc., eventually causes the outer wires to become flat on the outside, reducing the circle to a segment that gradually becomes smaller as the "flat" increases. These worn areas become void of lubrication and are characterized by their bright appearance. This is part of normal service deterioration and, in most installations where operating conditions are not particularly severe, relatively even abrasion will occur on the outer wires.

Peening

When wire rope strikes against a structural part of the machine or beats against a roller or itself, the wires and strands are flattened and distorted and become brittle. This continuous pounding is called "***peening***." Often, this can be avoided by placing protectors between the rope and the object it is striking.

Another common cause of peening is continuous working, under high loads, over a sheave or drum. Where peening action cannot be controlled, it is necessary to have more frequent inspections and to prepare for earlier rope replacement.

Scrubbing

Scrubbing refers to the displacement of wires and strands as a result of wire rope rubbing against itself or another object. This, in turn, causes wear and displacement of wires and strands along one side of the rope.

Fatigue Fractures

Wires that break with square ends and show little surface wear have usually failed as a result of fatigue. In almost all cases, these failures are related to bending stresses or vibration. ***Fatigue fractures*** in wire ropes are most often found near a fitting.

Corrosion

Corrosion, while difficult to evaluate, is a more serious cause of wear than abrasion. Usually it signifies a lack of lubrication. Corrosion will often occur internally before there is any visible external evidence on the rope surface. *Pitting* of wires is cause for immediate rope removal.

Usually a slight discolouration because of rusting merely indicates a need for lubrication. Severe rusting, on the other

hand, leads to premature fatigue failures in the wires, necessitating the rope's immediate removal from service. To retard corrosive deterioration, the rope should be kept well lubricated. In situations where extreme corrosive action can occur, it may be necessary to use *galvanized* wire rope.

Strands

Replace the rope if the strands are crushed, flattened, or jammed. These conditions usually occur when there are multiple layers on drums. Independent steel wire-cored ropes should be used to prevent crushing. Crushing can also occur if the hoist rope becomes slack and cross-coiled on the drum or trapped in the machinery. No further operations should be carried out until the rope has been paid out, examined for possible damage and correctly re-spooled.

If the rope displays ***high stranding or unlaying (unwinding)***, replace the rope or renew the end connection to reset the rope lay. In cases such as this, excessive wear and crushing take place and the other strands become overloaded.

Bird Caging, Kinks and Bulging

"***Bird caging***" is damage that can result from either a sudden stop, winding on too small a drum, or where the rope is being pulled through tight sheaves. This is cause for rope replacement unless the affected section can be removed.

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

Kinks are usually caused by faulty handling or***reeving*** (where the rope is passed through a hole and stressed). The strands become ***dog-legged*** and, where running on sheaves, are subject to excessive wear at the kink. Replace the rope or the affected section of the rope.

Bulging is indicative of core slippage or "*turns*" being put into or taken out of the rope. Replace the rope, particularly if it is of rotation-resistant construction.

If the rope has gaps, excessive clearance between strands, or core protrusion, replace the rope.

Heat Damage

After a fire or exposure to elevated temperatures, there may be metal discoloration, an apparent loss of internal lubrication or damage to fibre cores. Under these circumstances, the rope should be replaced.

Electric Arcs

Rope that has either been in contact with a live power line or been used as "*ground*" in an electric welding circuit will have wires that are fused, discoloured, and/or ***annealed***, and must be removed from service.

Hook Safety

Hooks, like all rigging hardware, must be inspected frequently. You must be alert for signs of wear, particularly in the saddle and the throat opening. Measure the throat's opening to make sure it is not widening (a sign that the hook has been overloaded and weakened). Check for cracks, corrosion, and distortion. If you discover evidence of wear, immediately discard the hook. Destroy the hook before throwing it away to prevent someone else from attempting to use it.

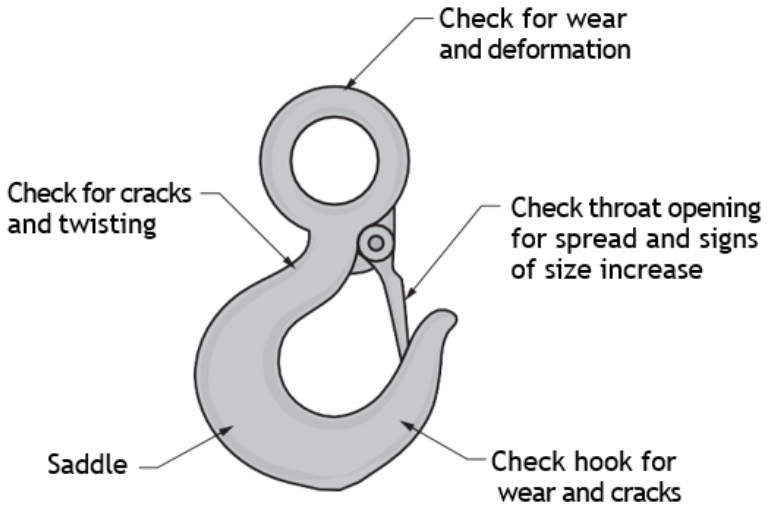


Figure 3 *Parts of a hook to check (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Safety of Other Hardware

The *Workers' Compensation OHS Regulation* requires that every piece of rigging hardware must be tagged with the working load limit (WLL).

Rings, Links and Swivels: Inspect rings, links and swivels regularly for wear, cracks and abrasion.

Eye Bolts and Ring Bolts: Inspect eye bolts and ring bolts regularly for wear, cracks and abrasion. The angle that the sling forms with the eye bolt affects the WLL of the eye bolt considerably. Always try to keep the pull of the sling as close to in-line with the shank of the eye bolt as possible. Use a spreader bar, if necessary, to reduce the angle at the eye bolt.

Turnbuckles: Inspect ***turnbuckles*** regularly for wear, cracks, abrasion and deformation.

Shackles: Inspect shackles regularly for wear, cracks and abrasion.

Synthetic Web Slings: Inspect web slings for worn eyes and worn fittings, cuts, holes, punches, tears, frayed material, broken stitching and burns caused by acid, caustics or heat. If a damaged sling is found, remove the sling from service immediately. Do not attempt to repair a damaged sling yourself.

Safe Rigging Practices

Whenever you are handling materials, remember that you are responsible for your own safety and for the safety of others. The best form of personal protection is to stay alert. Before you lift a load, check the rigging components to make sure that they meet the lifting requirements and that the rigging has been safely attached to the load. You must assure that your personal safety and the safety of other workers has not been compromised.

Each circumstance will require that different precautions be taken and the following information should be considered as the minimum safety requirements in any situation.

Personal Protection

Wear safety headgear at all times, but specifically if there is any risk of falling objects or injury to your head.

If the materials you are handling could injure your hands, wear gloves for protection. Gloves should have short cuffs. Gauntlet-type gloves are not safe because the cuffs tend to catch on projections and also serve to funnel dirt and small objects into the glove. If you are handling corrosive or irritating chemicals, wear rubber gloves to prevent skin contact.

When working with materials that are rough and abrasive, wear a protective apron to protect your clothing from becoming worn or ripped.

Your feet should be protected by CSA-approved safety footwear. Always wear safety glasses or safety goggles.

Clothing

The clothing you wear should protect you from dirt, scrapes and abrasions. Your clothing should be loose enough to allow free movement, yet not so loose that it poses a danger of being caught on or in any materials or equipment. All jewellery should be removed, and long or loose hair should be tied back and tucked under a hat or hair net.

Housekeeping

Job-site housekeeping habits can make material handling safe or dangerous. Keep all traffic areas clear to prevent tripping. Spills should be cleaned up immediately to prevent slipping and falling.

Safe Handling of Loads Supported By Cranes

When using slings to attach a load to a crane, ensure that the slings are secure and the load is balanced. Often, when the crane begins to lift the load, the load shifts to one side or the other. If the load shifts, make sure you will not be trapped. Be especially careful to avoid getting your fingers caught between the load and the slings.

If you must apply a sideways force to a suspended load, always push the load away from you. Loads that cannot be adequately controlled must have tag lines attached.

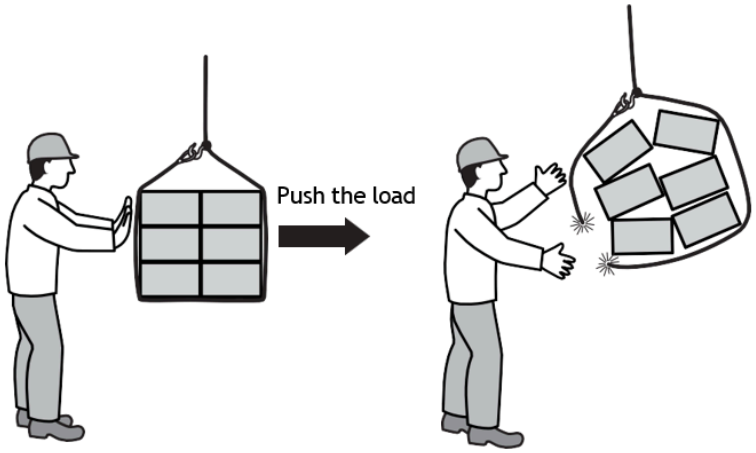


Figure 4 *Push a load* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Pulling a suspended load could result in back strain or, much worse, entrapment (as shown in Figure 5) should the load come loose.

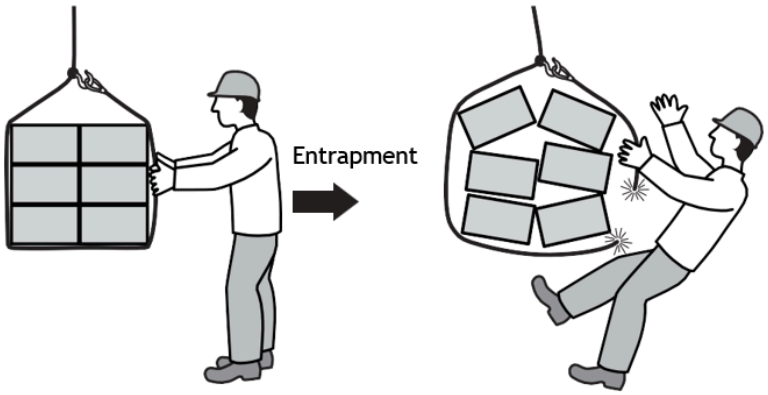


Figure 5 *Never pull a load* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Be familiar with the standard signals used in hoisting operations so that even if you are not directly involved, you can anticipate the movement of the load.

Never work under a suspended load. Have a plan of action, including an escape route to safety, in case a suspended load falls.

Tag Lines

Always use tag lines to control the load. Tag lines permit you to control the load from a safe distance. Should the load shift or drop, you will be out of danger.

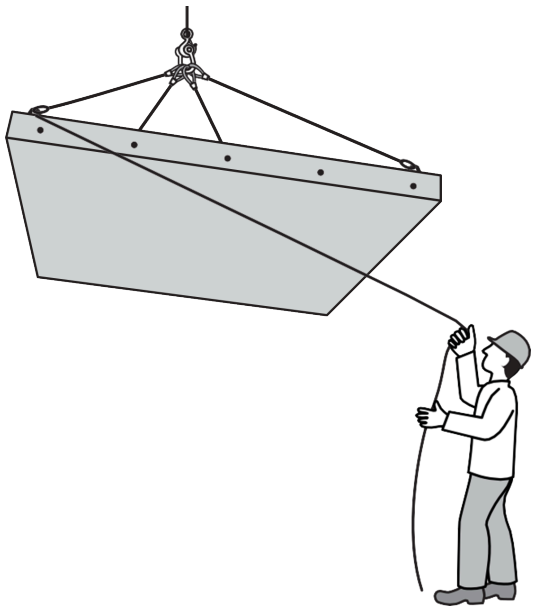


Figure 6 *Use tag lines (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

When working with large cranes moving objects near power lines, use a power-line spotter to avoid moving the crane or the load within the safety zone. Electric shock can kill!

Rope for Tag Lines

Every effort should be made to keep away from energized power lines. But if accidental contact is made, the tag line must not conduct the current to the worker guiding the load. Wire rope should not be used, and because nylon lines absorb water, they should not be used.

The preferred rope for a tag line is polypropylene rope. Polypropylene does not conduct electricity and is inexpensive.

Length of Rope

The length of the tag line should be long enough to allow a worker to control the load while it is near the ground or any other structure.

Two Tag Lines

Use two tag lines when the load needs to be maneuvered between or around objects or structures. Use a spreader bar when lifting long pipes with a crane. Use two tag lines, one at each end, to guide longer pipes into place.

Location of Attachment for Tag Lines

Locate tag lines near the end of a long load. Tie the tag line to the load using a bowline. The tag line should be attached to the load so that it will not become trapped when the load is landed.

Safety When Using a Tag Line

The tag line is used to allow the worker to guide the load and still stay out from under it.

Do not stand under the load at any time.

Wear gloves to protect your hands.

Do not double wrap the tag line around your hand or body to avoid entanglement. Keep the tag line clear of your feet.

***Note*: If there is a sudden movement of the load, do not attempt to hold the load with the tag line.**

Do not use the tag line to move the load into position. The tag line is used only for guiding the load. If the crane cannot reach the landing position with the load, the crane will have to move.

Unsafe Rigging Practices

1. Never wrap or choke the load with the hoisting line.
2. Avoid impact loading caused by sudden jerking when lifting or lowering. Lift the load gradually until the slack is eliminated.
3. Never ride the load that is being lifted.
4. Never allow the load to be carried over the heads of any personnel.
5. Never work under a suspended load.
6. Never leave the load suspended in the air when the hoist or crane is unattended.
7. Never make temporary repairs to a sling.
8. Never lift loads with one leg of a multi-leg sling until the unused legs are made secure.
9. Never lift a load with the point of a hook.

Use of Faulty Equipment

Examine all hardware, equipment, tackle, and slings before using it. DESTROY defective components so that discarded equipment may not be used by someone who is not aware of the hazards or defects.

Rigging Structural Shapes

Structural shapes are manufactured with several different configurations and require careful attention when rigging for lifting, turning, stacking, and blocking.

Loose bundles of round stock should be double wrapped with slings prior to lifting to secure those pieces on top of the load. When setting the load down, set it on blocking that has side-restraining chocks (Figure 7) to prevent the pieces from spreading.

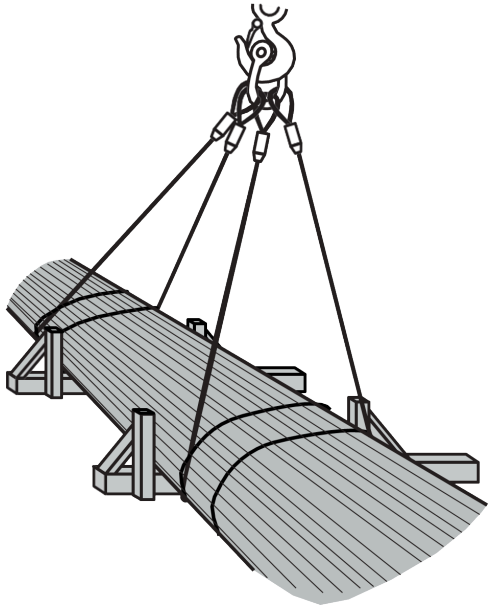


Figure 7 *Blocking for pipe (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

When rigging long loads, use slings with sufficient length that the dimension *L* is always greater than dimension *S*. This will ensure that your sling angles are always greater than 60° from horizontal.

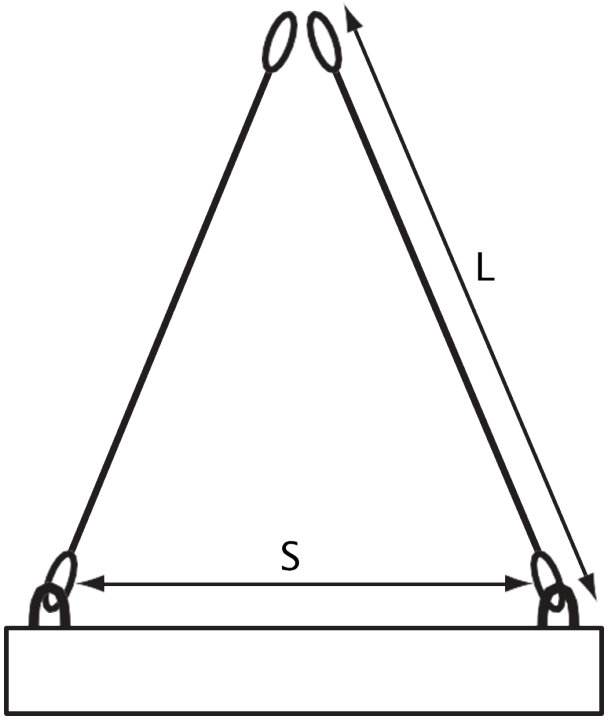


Figure 8 *Correct sling angle (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Never wrap the sling on the lifting hook to prevent movement. This weakens the sling considerably and may render it useless.

Figure 9 *Never wrap a hook (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

You can form a choker hitch from a looped rope, provided that the loop contains a metal thimble. Rope loops without thimbles can suffer severe abrasion by the cutting section of the line running through the eye.

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

If you are rigging a choker with the aid of a shackle, you must make sure the shackle pin bears on the eye of the sling. DO NOT allow the pin to bear on the running line. The movement of the running line could loosen the shackle pin, causing the load to drop.

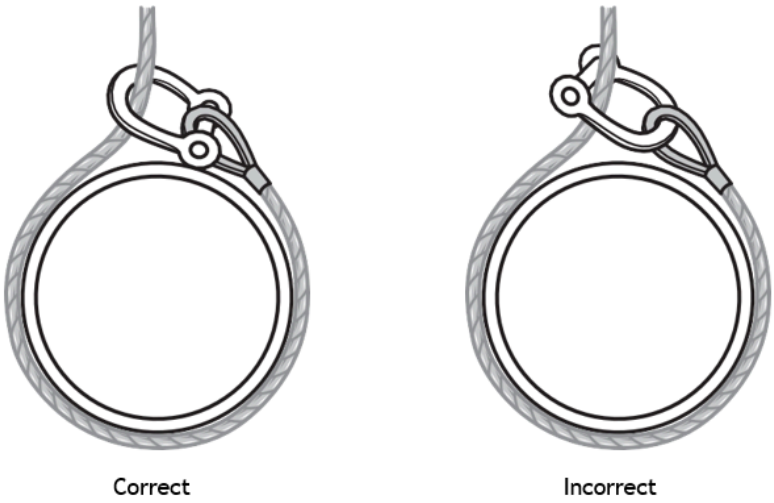


Figure 11 *Shackle use (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

When working with large cranes that are moving objects near power lines, use a power line spotter to avoid hitting the lines with the crane or the load. **Electric shock can kill!**

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

When connecting two or more ropes to the lifting hook, use a shackle to attach the ropes to the hook. The shackle should have the pin bearing on the hook.

Many structural shapes have sharp edges and corners that can damage slings. To prevent damaging the slings, always provide padding between the sling and the sharp corners of the load.

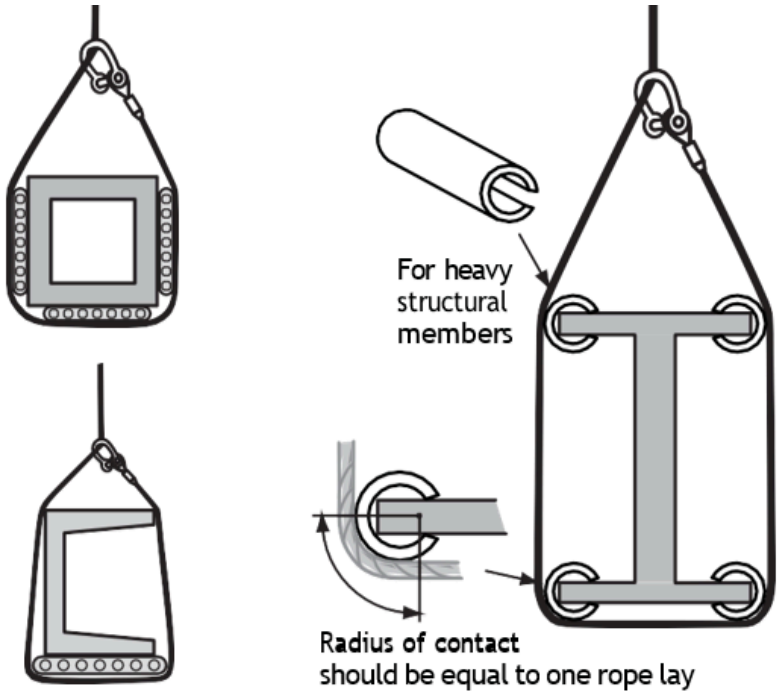


Figure 13 *Protective padding (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Turning Loads

When using a crane or hoist to turn heavy structural shapes, you must attach your rigging so that you have full control of the load at all times. Avoid violent or jerky movements because these could cause severe injury to bystanders.

By rigging a load as shown in Figure 14, start the roll by lifting the load. Then by gently lowering the load, continue the roll while maintaining full control.

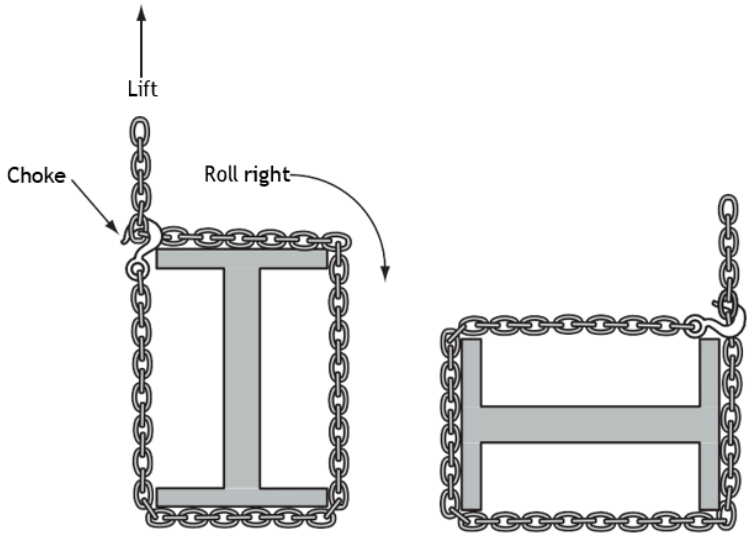


Figure 14 *A controlled turn (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

If you were to rig a structural shape, the load would flip violently regardless of how slow you made the lift. The load would then rock back and forth several times before it could be lowered.

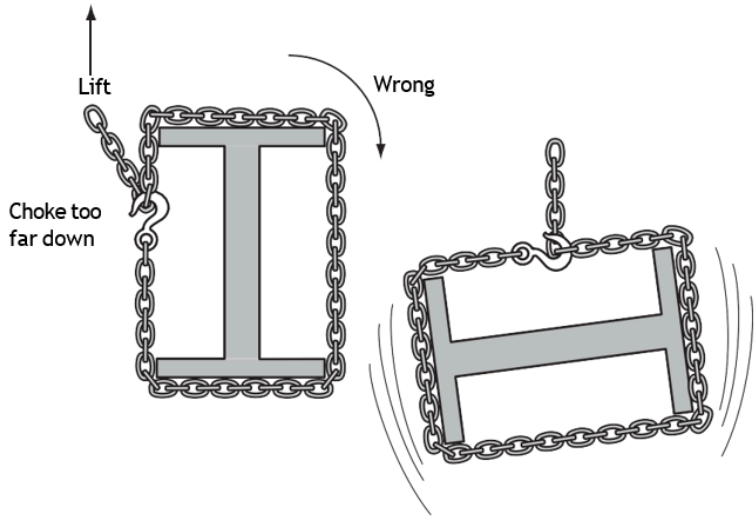


Figure 15 *Unsafe flip (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Correct Storage Practices

Store materials in such a manner that they are easily accessible and protected from harm. Piles or stacks of material must be securely stacked and pose no threat to people in their vicinity.

To allow cranes or forklifts access to materials, store the materials on ***dunnage*** (pieces of lumber for support) blocks or pallets.

Materials that can be damaged by bending or buckling should be stored on adequate supports to prevent such damage. If materials will be exposed to rain, store them at a slight slope to permit the rainwater to run off.

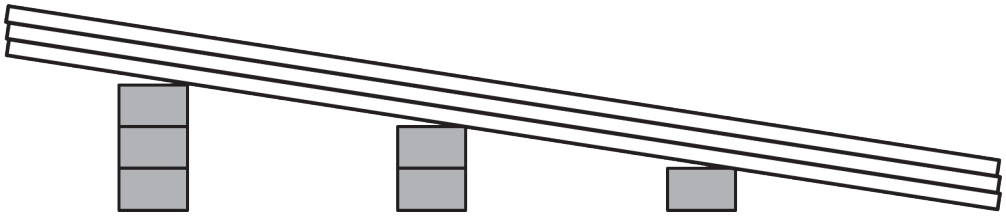


Figure 16 *Slope for water run-off* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Pipe should be piled with the bottom row of each stack well blocked, as illustrated in Figure 17. The blocking prevents the bottom row from being spread apart by the weight of the subsequent rows. Nail or screw blocking whenever possible. Narrow wedges may be sufficient for small stacks of small diameter pipe, but larger diameter pipe will roll right over them, so use blocking adequate for the situation. Continue to stack rows in a pyramid pattern for stability.

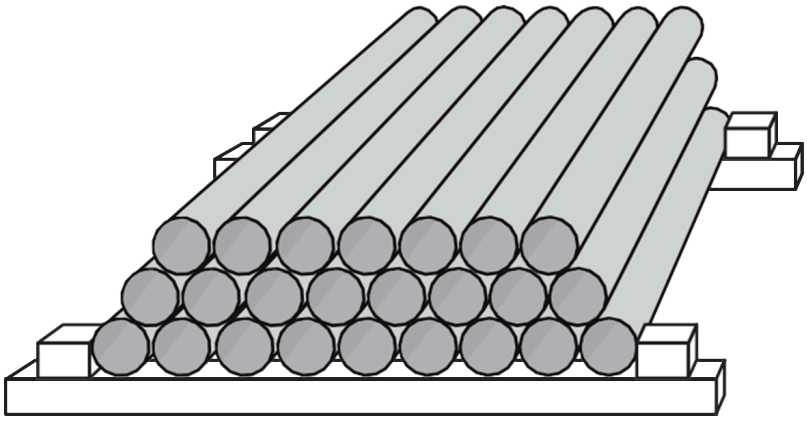
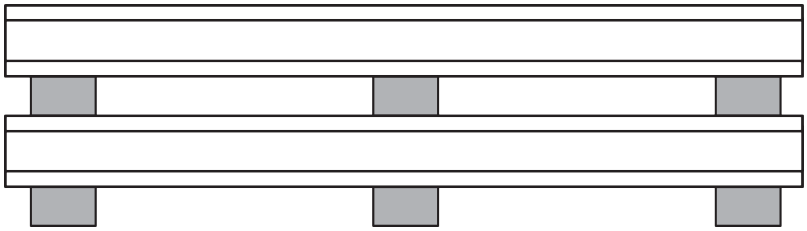


Figure 17 *Blocking stacks of pipe* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

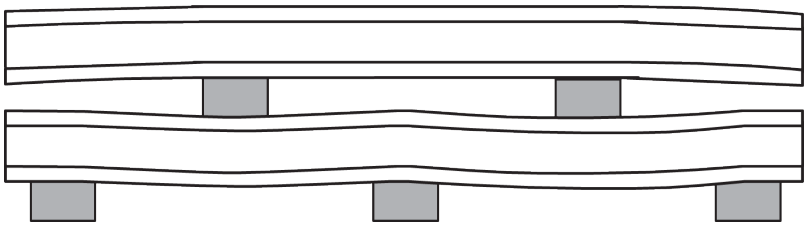
Loose materials should be banded together and stored in containers or bins.

Blocking and Stacking

When stacking structural shapes, you must provide blocking under the first row and cross-sticks between each successive row. The cross-sticks must be positioned directly above the previous row to prevent the materials from buckling and kinking.



Correct blocking



Incorrect blocking

Figure 18 *Correct and Incorrect Blocking* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Self-Test B-4.5: Use Hoisting, Lifting and Rigging Equipment

Complete Self-Test 4.5 and check your answers.

If you are using a printed copy, please find Self-Test A-4.5 and Answer Key in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2891#h5p-13 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2891#h5p-13)

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

- The competencies **Use hoisting, lifting and rigging equipment** and **Rig loads for cranes** (our sections B-4.5 and B-4.6) align with and are adapted from the *Piping Trades Apprenticeship Program: Use Tools and Equipment—Level 1 Harmonized* curriculum (Industry Training Authority, 2019). See: SkilledTradesBC. (2025). Plumber program outline (harmonized). https://skilledtradesbc.ca

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B-4.6 Rig Load for Cranes

Cranes are mechanical hoisting equipment designed to lift, move, and land a load deemed too heavy to move safely by hand. The potential of modern cranes is immense, with some having a capacity in the hundreds of tons. As a tradesperson, it is important to be familiar with the many different types of cranes and derricks, and to understand how to select the appropriate crane to perform a hoist safely and effectively.

If you are working with a crane, your responsibilities include the following:

- Use safe behavior around a crane.
- Be able to identify basic crane components and types.
- Ensure the crane site is safe and ready for use and that the landing spot or lay-down area is ready for the hoisted load.
- Ensure the load is stable.

Industry employs cranes to move everything from bundles of pipe to sections of buildings, from vehicles to personnel. Because of the potential for catastrophic consequences when a lift goes badly, crane operations and crane components are heavily controlled and regulated. OHS Regulations, Part 15: Rigging (https://www.worksafebc.com/en/law-policy/occupational-health-safety/searchable-ohs-regulation/ohs-regulation/part-15-rigging) describes minimum safety standards, referring to Canadian Standards Association (CSA), American National Standards Institute (ANSI), and American Society of Mechanical Engineers (ASME) standards for the design, inspection, maintenance, and repair of all cranes.

Describe Crane Procedures

Crane Component and Terms

Block: A collection of sheaves that provide a mechanical advantage in a lift. Blocks are often found at the hook.

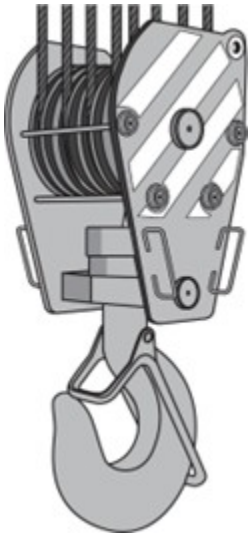

Figure 1 *Crane block and hook (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Boom: The primary arm of a crane. It acts as a lever and positions the block and hook directly above the load.

Boom cylinder: The hydraulic control of a boom.

Boom radius: Also referred to as the operating radius, this is the horizontal distance from the centre of rotation to the hook and is a function of boom angle and length. This concept is crucial to understanding safe crane capacity.

Counterweight: A supplementary ballast added to the weight of a crane to provide additional stability during a lift.

Figure 2 *Counterweights (Cjp24/Wikimedia Commons) CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/deed.en)*

Cribbing: Material used for dunnage or blocking under a load to allow for the attachment and removal of rigging.

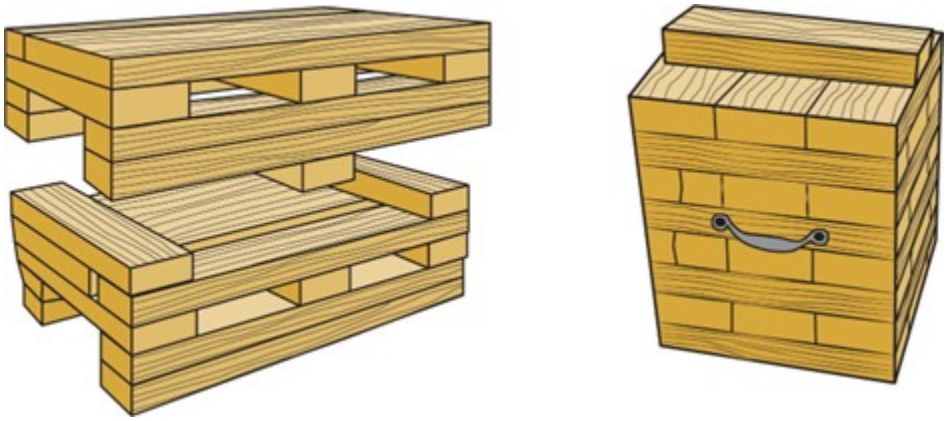

Figure 3 *Cribbing or support blocks (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Gantry: A fabricated structural, bridge-like crane operating on tracks or wheels at or near ground level.

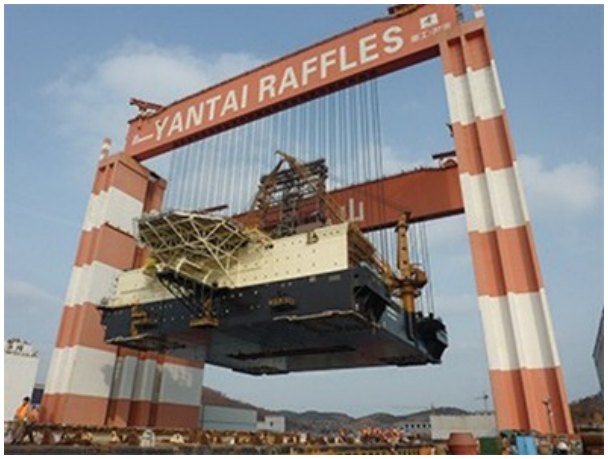

Figure 4 *Gantry crane (Haakman/Wikimedia Commons) CC BY 3.0 (https://creativecommons.org/licenses/by/3.0/deed.en).*

Headache ball: A crane hook, generally without a block.

Hoist line: The wire rope that controls the main block, jib block, or hook.

Jib: A secondary arm of a crane, used to extend the boom for specific lifts.

Lashing: An arrangement of wire rope and securing hardware such as U-bolt clips, used to secure two or more objects together. It is often used to temporarily secure a load, prior to a hoist.

Load chart: Manufacturer's documentation or literature that describes a crane's lift capacity under all possible operating configurations.

Outrigger: A support member that projects beyond the natural outline of a crane to provide additional support and to prevent toppling.

Figure 5 *Boom truck with outriggers (Philafrenzy/Wikimedia Commons) CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0/deed.en)*

Pendant: Also called a stay, a supporting line that maintains a constant distance between two points of attachment, such as a counterweight and a gantry or mast.

Sheave: A grooved wheel or pulley used to redirect force along a hoist line.

Side-loading: A dangerous condition in which a portion of a crane hoist acts horizontally, placing force on the boom other than the true vertical lift that the boom is designed for.

Swing: The hazard area associated with the swing radius of the crane's carrier and counterweights. This area should be flagged off during crane operation and considered a no-go zone.

Tagline: Guy wires used to control crane loads and prevent unwanted rotation or swinging, allowing ground workers to control the load from a safe distance.

Whipline (auxiliary hoist): A secondary hoist line from the main hoist, usually lighter and faster.

Crane Selection

There is an incredible variety of cranes, so crane selection must consider a number of factors, including:

- Weight, shape and size of the load. Important: include all slings, spreaders, other lifting equipment used, and hook block in load weight calculations. Consider anything below the boom tip as load.
- Lift parameters, including boom or operating radius and height
- Number of lifts required
- Required mobility of the crane
- Site and terrain conditions

Crane Identification

You will find crane identification and user information permanently attached to the crane. Clear identification of all detachable components such as the boom, jib, counterweight, etc., indicates that these components are connected to that particular crane. In addition, permanently affixed, easily located, and clearly written capacity rating charts, or load charts, are required. These describe safe capacity loads at permissible boom lengths and angles. For example, a crane may have a capacity of 110 tons, but this capacity decreases as the boom extends or moves closer to horizontal. This information is provided in the rated capacity literature.

Industry categorizes cranes by lift capacity (rated in tons), boom style, and mobility.

Boom Style

- Telescoping
- Lattice
- Fixed
- Articulating

Mobility

- Rough terrain
- Crawler
- Truck mount
- Carrier mount
- Tower, stationary
- Tower, rail mounted

Ensure the load is stable whenever you are lifting loads with a crane. Start the initial lift very slowly, watching the load for any signs of tilting or shifting. If the load tilts more than 5°, lower the load and rearrange the rigging.

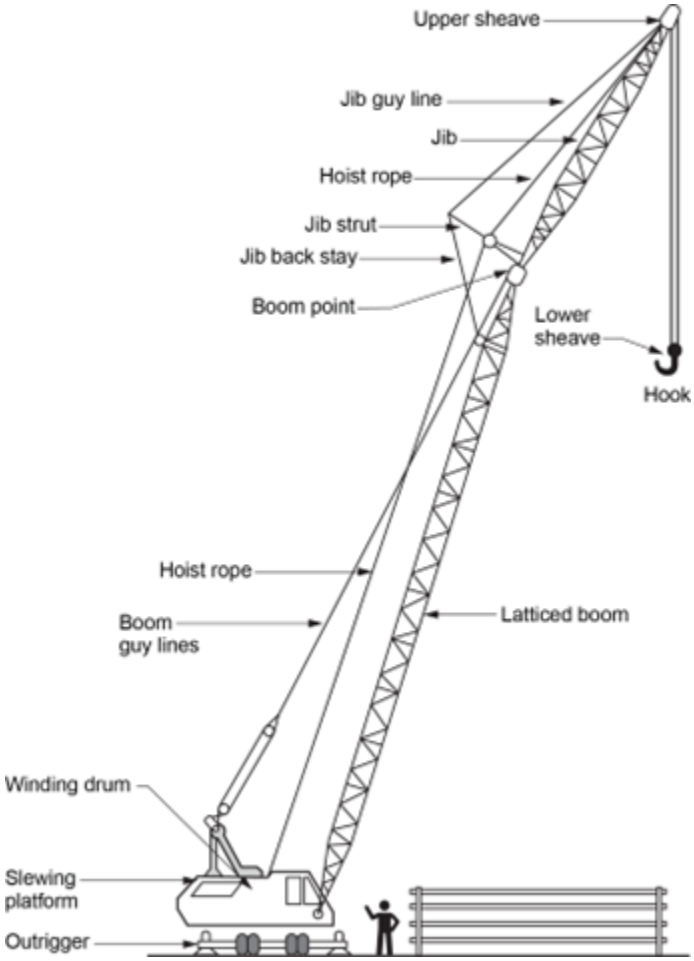

Figure 6 *Carrier mounted lattice boom crane (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

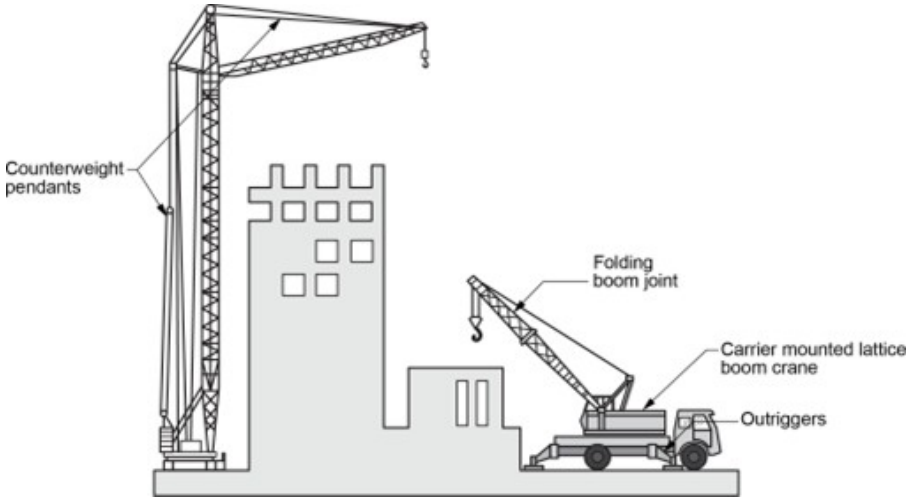

Figure 7 *Crawler crane with luffing boom (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

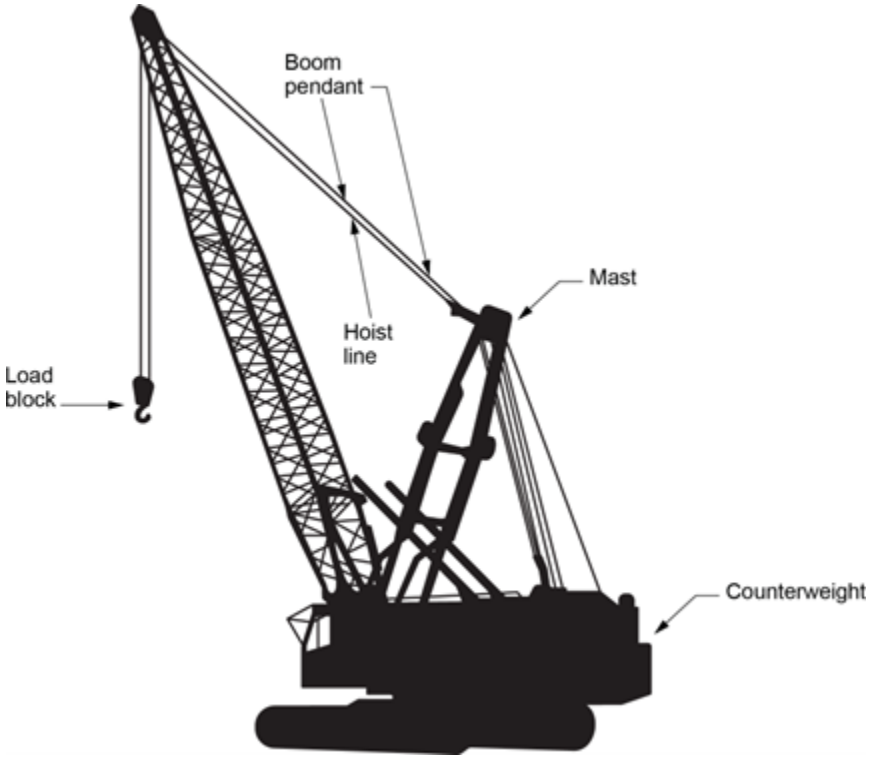

Figure 8 *Crawler mounted lattice boom* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

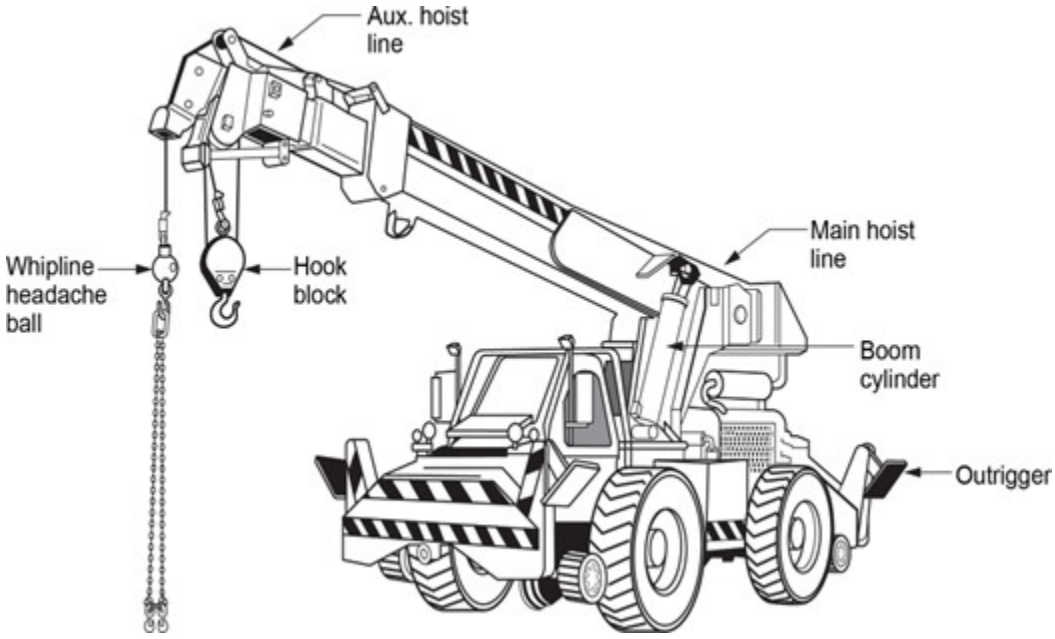

Figure 9 *Rough terrain crane with telescoping boom* (BC *Industry Training Authority*, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Load Chart

Load chart, shown below, informs the user of a crane's safe capacity in all permissible configurations of boom lengths and angles, base conditions, load radius, boom point elevation, and whether outriggers are used or not. The boom angle refers to the angle of the boom to the horizon. The load radius describes the measurement from the crane centreline to load centre at its most distant. The boom point elevation describes the distance from the ground to the centre of the outermost part of the boom. The tern outriggers describes equipment attached to the base of a crane designed to increase the base area and provide a great deal more stability, especially when the load is to the side of the crane.

Typically, as the boom lowers and approaches horizontal, and the centreline of the lift moves away from the centre of the crane, crane capacity diminishes. This is termed the *load radius*. When describing a 100-ton crane, this capacity rating describes the safe capacity with the boom near vertical or the minimum boom radius and the load directly to the rear of the crane with little to no swing.

Carrier Mounted Lattice Boom

Table 1: Load Charts for Two Different Types of Cranes

Boom length	Radius	Boom angle	Side pick- up, no outriggers	Rear pick- up with outriggers	Side pick- up with outriggers	Rear pick- up with outriggers
50 m	8 m	83°	32,226 kg	39,975 kg	99,135 kg	99,135 kg
50 m	15 m	75°	17,670 kg	18,656 kg	39,970 kg	47,261 kg
50 m	45 m	27°	1,875 kg	2,125 kg	7,305 kg	10,156 kg

Crawler Mounted Lattice Boom

Table 2: Load Charts for Two Different Types of Cranes

Boom Length	Radius	Boom Angle	Boom Point Elevation	Crawlers retracted	Crawlers Extended
21m	4.8 m	80°	23 m	177,968 kg	181,600 kg
21m	21m	19.5°	9.2 m	21,247 kg	23,880 kg

Note the extreme differences in load capacity as crane conditions change in the tables above. There may also be additional charts included to account for added counterweights.

Site Preparation

The crane operator, project engineer, or supervisor will select and oversee site preparation for a selected crane. Your involvement in this could involve any of the following tasks:

- Assess access roads in the area.
- Assess whether there is sufficient space to assemble the crane, if necessary.
- Level and compact the site.
- Identify and account for powerlines, and power down (de-energize them), if necessary
- Identify and make provisions for trenches, shoring, buried utilities, etc.
- Restrict public access and set up a perimeter using safety ribbon or barricades.
- Ensure proper clearances for the crane's swing radius.
- Provide outrigger mats and cribbing for soft ground conditions. Cribbing is material used for dunnage under a load to allow for the attachment and removal of rigging.
- Prepare a lay-down area for the load. This may include dunnage or other site preparation.

Certain conditions may require extra precautions, including avoiding the leading edge of a trench, underground sewer mains, and ground beside recently constructed buildings that may have uncompact backfill. If in doubt, consult a soil engineer.

Outriggers require mats that are at least three times larger in area than the floats and should be rigid and rated for the load. Never block the arm of an outrigger, only the float. Bearing mats can be made of wood or steel and offer more stability than native soil.

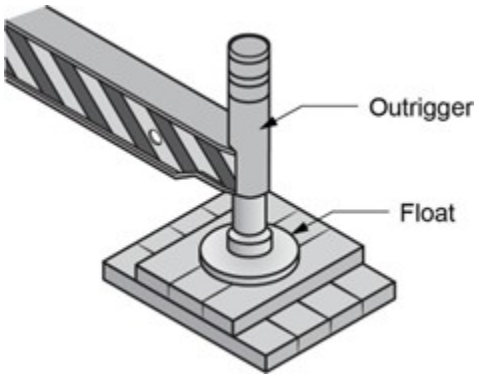

Figure 10 *Float and outrigger*

Once the crane is in place, perform a walk-around, paying particular attention to overhead hazards and crane support.

Crane Leveling

Cranes require a level base. Most safety standards require a grade of 1% or less, with some manufacturers requiring $\frac{1}{2}$

%. A 1% grade means a base with a length of 20 feet or 240 in. may only have an elevation change of $2\ \frac{3}{8}$ in. from one end to the other. This requirement prevents side-loading on the boom, a condition where force is applied to the boom at an angle, which the boom is not designed to withstand. The *IPT Crane and Rigging Training Manual* shows that a short-boom crane at the minimum hoist radius can lose 10% of its capacity for every 1% angle of side-load.

Level a crane with calibrated measuring tools, such as a *four-foot carpenter's level* or the *bird's-eye levels* found in the crane's cab.

After levelling the base, check the crane's level using the following method: raise the boom to its highest angle and hoist a small, compact load just off the ground. The hoist line should fall within the centreline of the boom. Do this for each of the four quadrants: front, side, and corners. If the hoist line is outside the boom, the crane is not level. This method is less accurate in windy conditions.

Secure Load for Rigging Attachment and Removal

Once the chosen crane is in place, a lift plan has been completed, and the crane site has been prepared, the worker can prepare for the lift. Preparation of a load before and after a hoist requires an understanding of proper material handling and a familiarity with hoisting and jacking equipment. Pipe trades workers need to learn the safety precautions required to prepare material and equipment prior to a lift, and to safely remove rigging equipment once the lift is complete.

Pre-Hoist Preparation

OHS Regulation 15.2 states: "*Rigging and slinging work must be done by or under the direct supervision of qualified workers familiar with the rigging to be used and with the code of signals authorized by the Board for controlling hoisting operations.*"

At this point, a trained and qualified individual should have established the weight of the load, confirmed the distance, height, and swing of the lift, and selected the appropriate tackle and hardware.

To prepare a load for hoisting, the load must be on dunnage or cribbing to allow for the application of slings or other approved hoisting equipment. If necessary, jack or pry the load and position cribbing beneath it. Distribute the weight evenly on the cribbing while leaving enough vertical clearance to apply the rigging equipment. This process creates a high risk of pinching injuries. **Remember: never place any part of your body under a load!**

At this point, if the load is not accessible to the crane hook, use appropriate equipment to move or position the load across the floor. Some options include:

- Roller jacks, steel dollies, air castors, or skates
- A forklift or pallet jack
- A chain fall, come-along, or chain hoists

Rig the load while it is supported by cribbing or dunnage. Always rig using the appropriate slings and equipment, and never wrap the hoist rope directly around the load.

Apply the rigging equipment with the centre of gravity (C of G) identified. The centre of gravity will always move directly under the hook when lifted, so anticipate load swing or shifting. Consider using a turnbuckle or come-along at the hook

to help centre and balance the load beneath the hook. Test the load by lifting it approximately one foot. If the load is more than 5° off level, lower the load and re-rig.

Attach taglines to adequately control swing and load rotation. Ensure that taglines are made of non-conductive material to reduce the risk of electric shock. Taglines should be long enough to allow workers to control the load from a safe distance. Use more than one tagline if necessary. Remove taglines after the lift is complete and the load is in its final position.

Post-Hoist Procedures

OHS Regs 15.3 states, "*Loads to be unhooked by a worker must be safely landed and supported before the rigging is detached.*"

This may mean lashing the load to a structural member or landing the load on prepared cribbing before releasing the hook.

Consider what will happen next. Is the load in the correct location, or will you need to rig it across the floor? Is the lay-down area sufficiently clear and ready? Is the load a piece of equipment that must be accurately placed on a pad? Be sure you are satisfied with the position of the load before removing the hook.

Self-Test B-4.6: Rig Load for Cranes

Complete Self-Test 4.6 and check your answers.

If you are using a printed copy, please find Self-Test A-4.6 and Answer Key in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2895#h5p-14 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2895#h5p-14)

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The competencies **Use hoisting, lifting and rigging equipment** and **Rig loads for cranes** (our sections B-4.5 and B-4.6, respectively) align with, and are adapted from, the Piping Trades Apprenticeship Program: Use Tools and Equipment—Level 1 Harmonized curriculum (Industry Training Authority, 2019). See: SkilledTradesBC. (2025). Plumber program outline (harmonized). https://skilledtradesbc.ca

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- **Figure 2** Potain tower crane2-Counterweight (https://commons.wikimedia.org/wiki/File:Potain_tower_crane2-Counterweight.jpg) [Counterweights] by Cjp24 on Wikimedia Commons is licensed under the a CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0/deed.en) license.
- **Figure 4** GTAISUN with SCARABEO (https://commons.wikimedia.org/wiki/File:TAISUN_with_SCARABEO_9.JPG) [Gantry crane], by Haakman on Wikimedia Commons is used under a CC BY 3.0 (https://creativecommons.org/licenses/by/3.0/deed.en) license.
- **Figure 5** Replacing an advertising poster in London using an articulated platform 01 (https://commons.wikimedia.org/wiki/File:Replacing_an_advertising_poster_in_London_using_an_articulated_platform_01.JPG) [Boom truck with outriggers] by Philafrenzy on Wikimedia Commons is licensed under CC SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0/deed.en)

Self-Test B-4.1: Describe the Principles of Lifting and Hoisting

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

1. State the formula for mechanical advantage of a lever.
2. Where should the slings attach to the load, in relation to the centre of gravity?
3. Where will the centre of gravity of a load be positioned after it is lifted off the ground?
4. Does the position of the centre of gravity depend upon how the load is rigged?
5. Which safety factor determines the working load limit of a rigging system designed as a crew lift?
    a. 1:1
    b. 5:1
    c. 10:1
    d. 15:1
6. Who decides whether a rigger is qualified or not?
    a. Worker
    b. Employer
    c. Foreman
    d. WorkSafeBC

Answer Key: Self-Test B-4.1 is on the next page.

Answer Key: Self-Test B-4.1

1. MA = length of effort arm/length of resistance arm.
2. The point of attachment must be above the centre of gravity, or the load may roll over.
3. Regardless of the rigging, the load will shift to put its center of gravity directly below the hook.
4. If rigged improperly, the shifting may cause the load to become unstable and result in an accident.
5. c. 10:1
6. b. Employer

Self-Test B-4.2: Describe Hoisting, Lifting and Rigging Equipment

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

1. Turnbuckles are used to adjust the length of slings so that loads can be lifted in what way?
    a. In a level position
    b. Higher
    c. Vertically
    d. From below
2. The screw threads at each end of a turnbuckle's sleeve must be designed in what fashion?
    a. Locking at one end and non-locking at the other
    b. Identical
    c. A larger diameter at one end than at the other
    d. Left-handed at one end and right-handed at the other
3. When several ropes are to be attached to a single hook, the connection to the hook must be made with a _____.
    a. Turnbuckle
    b. U-bolt
    c. Shackle
    d. Series of cable clips
4. The U-bolt part of a cable clip must be installed so it bears on which of the following?
    a. Thimble
    b. Live end of the rope
    c. Dead end of the rope
    d. Whipping
5. What does the number of cable clips required for a connection depend upon?
    a. Diameter of the rope
    b. Type of clip used
    c. Mass of the load
    d. Strength of the rope
6. Correctly installed cable clips will reduce the breaking strength of wire rope by what factor?
    a. 10%
    b. 20%
    c. 30%
    d. 40%
7. What is the safe working capacity of a jib or overhead travelling crane?
    a. Equal to that of the hoist assembly
    b. Not more than 10 Mpa (1450 psi) less than the hoist assembly
    c. Greater than that of the hoist assembly
    d. Displayed visibly on the device
8. The load-lifting capacity of motorized forklifts depends on the spacing of the forks, the floor or ground surface and _____.
    a. Height and tilt of the mast

b. Whether it is equipped with a torque converter
c. Size of the rear wheels
d. Steering capacity of the front wheels

9. How is the mechanical advantage of a hydraulic jack determined?

a. Length of the pump piston
b. Length of the lifting piston
c. Ratio of the pump piston's force to the lifting piston's force
d. Ratio of the pump piston's diameter to the lifting piston's diameter

10. To lower a load supported by a hydraulic jack, you must do which of the following?

a. Flip the lever downward
b. Set the pump to reverse
c. Lift the handle as high as possible
d. Open the valve

11. Which pulling device can use either chain or cable?

a. Chain fall
b. Block and tackle
c. Come-along
d. Gin pole

12. A Tirfor jack is a hoisting device that uses a _____

a. Nylon rope
b. Metal chain
c. Wire rope
d. Fibre rope

13. How are Tirfor jacks made to travel in the opposite direction?

a. Flipping the gear lever
b. Turning the handle in the opposite direction
c. Releasing the ratchet
d. Re-locating the pipe handle

Answer Key: Self-Test B-4.2 is on the next page.

Answer Key: Self-Test B-4.2

1. a. In a level position
2. d. Left-handed at one end and right-handed at the other
3. c. Shackle
4. c. Dead end of the rope
5. a. Diameter of the rope
6. b. 20%
7. d. Displayed on the device
8. a. Height and tilt of the mast
9. d. Ratio of the pump piston's diameter to the lifting piston's diameter
10. d. Open the valve
11. c. Come-along
12. c. Wire rope
13. d. Re-locating the pipe handle

Self-Test B-4.3: Describe Lifting and Hoisting Communication

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

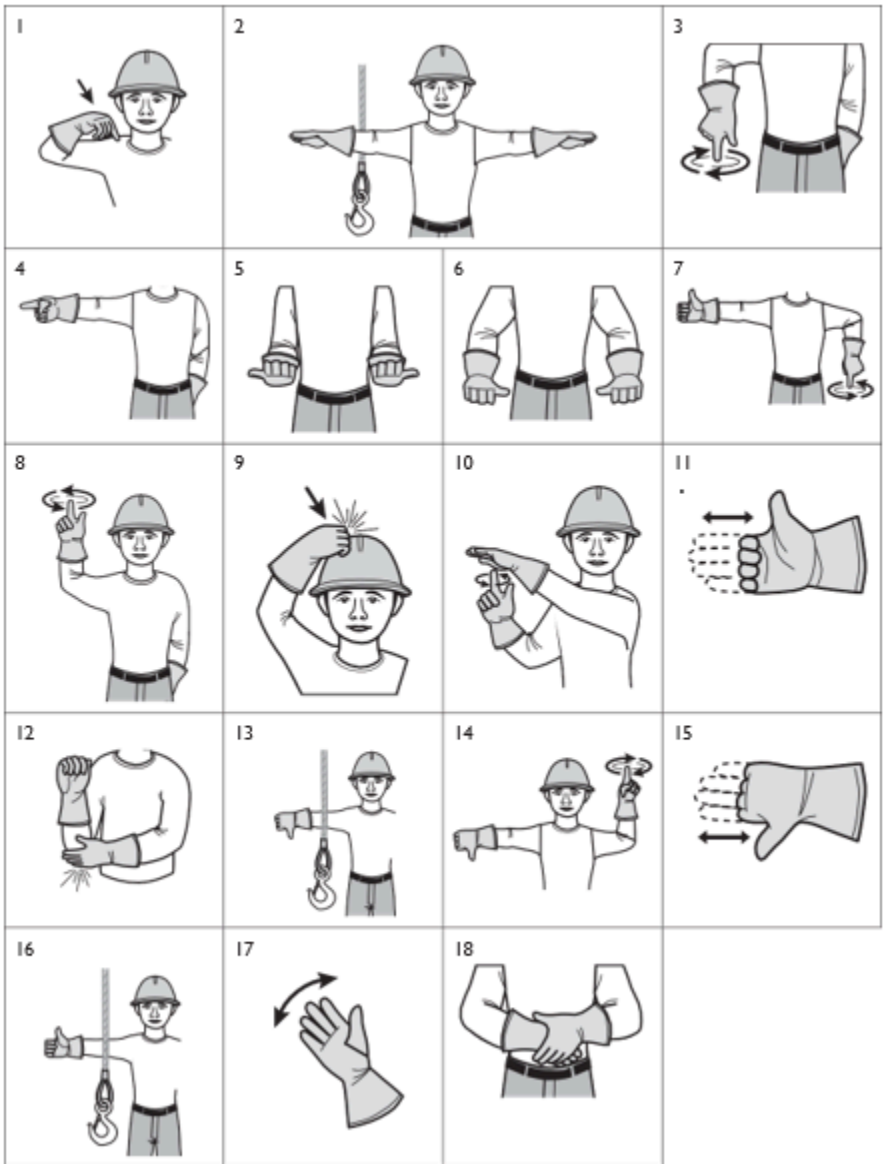

Figure 1 *Image for Question 1*

1. Using the illustrations above, fill in the corresponding number(s) on the next page for each of the hand signals listed below:

   _____A. “USE THE MAIN LINE”

   _____B. “STOP” (two signals)

   _____C. “RETRACT BOOM”

_____D. “LOWER THE LOAD”

_____E. “HOIST SLOWLY”

_____F. “LOWER THE BOOM AND RAISE THE LOAD” (two signals)

_____G. “EXTEND THE BOOM”

_____H. “USE WHIP LINE” (two signals)

_____I. “SWING THE BOOM”

_____J. “RAISE THE BOOM AND LOWER THE LOAD” (two signals)

_____K. “HOIST”

_____L. “LOWER THE BOOM”

_____M. “DOG EVERYTHING”

Answer Key: Self-Test B-4.3 is on the next page.

Answer Key: Self-Test B-4.3

a. 9
b. 2, 17
c. 6
d. 3
e. 10
f. 14, 15
g. 5
h. 1, 12
i. 4
j. 7, 11
k. 8
l. 13
m. 18

Self-Test B-4.4: Select Slings and Tie Knots, Bends and Hitches

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

1. What type of Manila rope has one or more coloured strands?
    a. Number 1 grade
    b. Yacht rope
    c. Hardware store rope
    d. Bolt rope

2. Which is the strongest of the ropes listed below?
    a. Polypropylene
    b. Sisal
    c. Polyester
    d. Manila

3. Which type of dry rope has the best electrical insulating properties?
    a. Manila
    b. Polypropylene
    c. Polyester
    d. Nylon

4. When loaded to the breaking point, nylon rope will stretch up to what percent of its original length?
    a. 10%
    b. 20%
    c. 30%
    d. 40%

5. The portion of the rope which forms the loop is called the _____.
    a. Middle
    b. Standing part
    c. Circle
    d. Bight

6. Which of the knots listed below forms a non-slip loop?
    a. Square knot
    b. Bowline
    c. Reef knot
    d. Timber hitch
7. The knot, hitch or bend illustrated in Figure 1 is a _____.

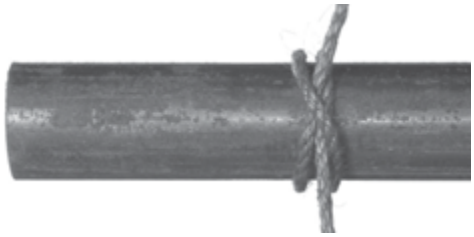

Figure 1 *Image for Question 7*

a. Carrick bend
b. Timber hitch
c. Clove hitch
d. Trucker's knot

8. Which knot multiplies the tension you apply to a rope?

a. Timber hitch
b. Bowline
c. Sheet bend
d. Trucker's knot

9. When joining a large diameter rope to a small diameter rope, what should be used?

a. Square knot
b. Carrick bend
c. Sheet bend
d. Half-hitch

10. When joining two ropes of the same diameter together, what should be used?

a. Double half hitch
b. Reef knot
c. Sheet bend
d. Timber hitch

Answer Key: Self-Test B-4.4 is on the next page.

Answer Key: Self-Test B-4.4

1. a. Number 1 grade
2. c. Polyester
3. b. Polypropylene
4. d. 40% its original length
5. d. Bight
6. b. Bowline
7. c. Clove hitch
8. d. Trucker's knot
9. c. Sheet bend
10. b. Reef knot

Self-Test B-4.5: Use Hoisting, Lifting and Rigging Equipment

Complete Self-Test B-4.5 and check your answers.

1. How should slings and wire rope be stored?
2. What should be done with a wire rope sling that has a kink in it?
3. What should be done if there is a possibility of shock loading when using a wire rope sling?
4. What should be done with a broken wire in a wire rope sling?
5. Is it safe to replace a lost pin in a shackle with a high-strength bolt? Explain.
6. If a danger of stepping on protruding nails exists, what type of footwear will protect you from injury?
    a. Steel-toed boots
    b. Cowboy boots
    c. Steel insoles
    d. Non-skid rubber soles
7. When a crane starts taking up the slack in the slings around a load, what should be avoided?
    a. Standing back from the load
    b. Getting your fingers pinched
    c. Checking the loads balance
    d. Planning an escape route
8. When moving a suspended load,_____.
    a. Pull the load towards yourself
    b. Stand under the load
    c. Guide and follow the load
    d. Stand on the load
9. How should loose materials be stored?
    a. Tied together
    b. Stacked on shelves
    c. In containers or bins
    d. According to length
10. When rigging loose bundles of pipe what should be used?
    a. Double-wrapped basket hitches
    b. Two-leg bridle hitch
    c. Four-leg bridle hitch
    d. Single choker hitch
11. Tag lines should be used to control loads because they allow control from _____.
    a. Directly under the load
    b. A safe distance
    c. Above the load
    d. Within the crane
12. What loads should padding be applied to?
    a. Excessive weight
    b. Slippery surfaces

c. Irregular surfaces
d. Sharp corners

Answer Key: Self-Test B-4.5 is on the next page.

Answer Key: Self-Test B-4.5

1. Wire rope and fibre slings should be stored in a dry location off the ground.
2. Destroy and discard a kinked wire rope sling.
3. Take special precautions and/or use a larger-sized rope.
4. The broken wire ends should be removed as soon as possible by bending the broken ends backward and forward by hand or with a pair of pliers.
5. No. The bolt is not designed to support the loads required.
6. c. Steel insoles
7. b. Getting your finger pinched
8. c. Guide and follow the load
9. c. In containers or bins
10. a. Double-wrapped basket hitches
11. b. A safe distance
12. d. Sharp corners

Self-Test B-4.6: Rig Load for Cranes

Complete Self-Test B-4.6 and check your answers.

1. Which term best describes supportive material intended to keep a load off the ground and allow for proper and safe application of slings?
    a. Blocks
    b. Cribbing
    c. Sheaves
    d. Counterweights

2. Which term best describes an auxiliary hoist line, which is typically lighter and faster than the main hoist?
    a. Tagline
    b. Pendant
    c. Forestay
    d. Whipline

3. Which term best describes the horizontal distance from the centreline of the hook to the centreline of crane rotation??
    a. Swing
    b. Whipline
    c. Hoist line
    d. Boom radius

4. Which terms best describes the dangerous condition of force applied to the boom at an angle from vertical?
    a. Side-loading
    b. Side-stressed
    c. Boom-torque
    d. Non-vertical lift

5. Which term best describes support members that project beyond the natural outline of the crane to prevent toppling?
    a. Side-loads
    b. Outriggers
    c. Gantry masts
    d. Headache ball

6. Where would a worker find a crane's capacity rating chart?
    a. In the main office
    b. With the foreman
    c. Affixed to the crane
    d. On the manufacturer's website

7. Which of the following terms best describe a bridge-like crane often found affixed to rails or on wheels?
    a. Gantry

b. Crawler
c. Boom truck
d. Telescoping

8. The load weight calculations does not include the rigging equipment such as spreader bars, slings, and block hooks as these are integrated within load calculations.
    a. True
    b. False

9. Which of the following term is not a boom style?
    a. Fixed
    b. Lattice
    c. Telescoping
    d. Rough terrain

10. Which phrase best describes how a crane's load capacity changes as the boom radius increases?
    a. Increases
    b. Decreases
    c. Is not affected
    d. Depends on side-loading

11. Which term best describes a supplementary weight added to the base of a crane?
    a. Ballast
    b. Gantry
    c. Load chart
    d. Counterweight

12. What size should outrigger pads be?
    a. Outriggers should never use pads
    b. Three times the area of the floats
    c. Size of the pads is not relevant
    d. Approximately the size of the floats

Answer Key: Self-Test B-4.6 is on the next page.

Answer Key: Self-Test B-4.6

1. b. Cribbing
2. d. Whipline
3. d. Boom radius
4. a. Side-loading
5. b. Outriggers
6. c. Affixed to the crane
7. a. Gantry
8. b. False
9. d. Rough terrain
10. b. Load capacity decreases
11. d. Counterweight
12. b. Three times the area of the floats

PART V

B-5 USE SOLDERING AND BRAZING AND OXY-FUEL CUTTING EQUIPMENT

Plumber Apprenticeship Program – Level 1

Propane torch soldering copper pipe (https://commons.wikimedia.org/wiki/File:Propane_torch_soldering_copper_pipe.jpg) (Kevin L Neff/Wikimedia Commons) CC BY 2.0 (https://creativecommons.org/licenses/by/2.0)

B-5 Use Soldering and Brazing Equipment and Oxy-Fuel Cutting Equipment Introduction

Hand tools are used in almost every trade, though many are designed for specific tasks within particular industries and trades. You may have already used some of these tools at work, at school, or at home. However, this may be your first opportunity to examine their design, function, and applications in greater detail. Understanding how tools are designed and why they are used in certain ways will help you work more safely, efficiently, and confidently in your trade.

Learning Objectives

After completing this section, you should be able to:

- Describe Oxy-Acetylene Equipment.
- Use Oxy-Acetylene Equipment.
- Describe Soldering and Brazing Equipment.
- Describe Cutting, Brazing and Soldering Techniques.
- Use Soldering and Brazing Equipment.
- Use Oxy-Fuel Equipment.

You will be required to reference publications and videos available online at WorkSafeBC. (https://www.worksafebc.com/en)

Terminology

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

- **acetylene:** A flammable fuel gas made of carbon and hydrogen that burns at a very high temperature

when mixed with oxygen. It is commonly used for welding, brazing, and cutting metal. (Section B-5.1)

- **backfire:** A small explosion that occurs when the flame burns back into the torch tip during cutting or welding, often making a popping sound. (Section B-5.1)
- **capillary action:** The way a liquid (like melted solder) is pulled into small spaces between two surfaces without being pushed. (Section B-5.2)
- **eutectic alloy:** A special type of metal mixture that melts and hardens at one exact temperature instead of over a range. (Section B-5.2)
- **flashback:** A dangerous condition where the flame travels backward through the torch and hoses toward the regulator, which can lead to fire or explosion. (Section B-5.1)
- **flashback arrestor:** A safety device installed in oxy-fuel equipment that stops flames from travelling backward through hoses or equipment during a flashback. (Section B-5.1)
- **flux:** A substance used in soldering or brazing to clean metal surfaces and help melted metal flow smoothly into a joint. (Section B-5.1)
- **kerf:** The cut or gap left in a material after it has been cut with a tool or torch. (Section B-5.1)
- **neutral flame:** A flame with the right mix of oxygen and fuel so it burns clean and does not damage the metal. (Section B-5.2)
- **oxidizing effect:** The ability of oxygen to make materials burn faster and hotter by increasing the rate of combustion. (Section B-5.1)
- **oxidizing flame:** A flame with too much oxygen that can cause metal to burn or become brittle. (Section B-5.2)
- **oxy-acetylene:** A system that uses a mixture of oxygen and acetylene gas to produce a high-temperature flame for cutting, welding, or heating metal. (Section B-5.3)
- **plastic (pasty) range:** The temperature range where a metal is partly solid and partly liquid, making it soft and easy to shape. (Section B-5.2)
- **purging:** The process of clearing gas from hoses or equipment to remove air or mixed gases before lighting a torch. (Section B-5.3)
- **regulator:** A device that controls the pressure of gas flowing from a cylinder to ensure safe and consistent operation. (Section B-5.3)
- **reverse flow check valve (RFCV):** A device that prevents gases from flowing backward into hoses or cylinders, helping to reduce the risk of fire or explosion. (Section B-5.3)
- **slag:** The leftover melted material that forms during cutting or welding and may stick to the metal or fall away. (Section B-5.1)
- **striker:** A tool used to safely ignite a welding torch by producing a spark. (Section B-5.3)

B-5.1 Describe Oxy-Acetylene Equipment

Fuel Gases

Fuel gases are extensively used in the pipe trades for cutting, welding, brazing, and soldering metals, so it is important that you know the properties of these gases. It is also important that you learn how to handle, store and transport the various components of a welding outfit safely and correctly.

Oxy-Fuel Gases

The process of gas cutting, brazing, or soldering requires two gases and a source of ignition:

- Oxygen
- A fuel gas such as acetylene, MAPP, natural gas, propane

Figure 1 *The combustion triangle (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Oxygen

Oxygen is the element in our atmosphere that supports ***combustion*** (the process of burning). Second only to nitrogen in its volume, oxygen is the other major component of the air we breathe. It is a colourless, odourless, tasteless gas at ordinary temperatures. By itself, it is slightly heavier than air. One of the hazards of oxygen is that it accelerates combustion rapidly and raises the combustion temperature of fuel gases, which can cause hazards if the oxygen

content is above standard atmospheric percentage (20.8%). Oxygen must be considered potentially dangerous because it combines readily, and in some cases explosively, with many substances.

Under normal conditions, the heavy nitrogen content in air tends to retard combustion and reduce the flame temperature. Combustion with pure oxygen is much faster than combustion in air (which is a mixture of gases), and this increases the flame temperature. In general, materials that burn in air burn much more rapidly in pure oxygen. It is also true that some materials that are not considered combustible in air will burn readily in oxygen-enriched atmospheres. The acceleration of combustion is called the ***oxidizing effect***. Under WHMIS (https://www.canada.ca/en/health-canada/services/environmental-workplace-health/occupational-health-safety/workplace-hazardous-materials-information-system.html) provisions, oxygen must be appropriately labelled, stored, and handled using specific safe work procedures.

Rubber and Oxygen

Rubber will burn in air. The flame is dull red, smoky, and gives off a heavy odour. When rubber burns in oxygen, it burns rapidly, with a white flame, high flame temperature, almost no smoke, and little odour.

The hoses of an ***oxyacetylene*** outfit are made from rubber and cotton and you must exercise caution to keep them from being burned, cut, or ruptured. If either hose on the equipment catches fire while under pressure, the fire cannot be extinguished using a fire extinguisher alone. This is because oxygen is being fed to the flames from inside the hose. A fire extinguisher works on the principle of excluding oxygen from the air and thereby smothering the flame; it can only be used after you stop the flow of oxygen and ***acetylene***. You must turn off the supply of oxygen and fuel gas before attempting to put out the fire using a smothering-type extinguisher. The fire will continue to burn as long as fuel and oxygen is supplied to it from the hoses because the rupture in the hose acts as a torch opening.

Oil or Grease and Oxygen

At normal temperatures, oil or grease is not considered to be highly flammable, but if either one is brought into contact with pure oxygen under slight pressure, a violent explosion can occur.

Keep oxygen equipment away from oil, grease, oil-based cleaning fluids, and gasoline. Never use oil to lubricate regulators or any part of the torch.

Oxygen + Oil = Potential Explosion

Steel and Oxygen

Although steel is not normally considered to be combustible, when it is heated to a red heat and brought into contact with oxygen (as it is during the cutting process), it burns quite rapidly and reduces the reacted metal to iron oxides. An oxyacetylene cutting attachment allows this burning process to be controlled while cutting steel plate. Steel will also combine with oxygen and moisture, causing the steel to oxidize slowly (rust).

Oxygen must always be considered a potential danger because it speeds up the combustion of known flammable materials and combines readily, and often explosively, with materials not generally considered combustible.

Acetylene

Acetylene is a compound formed by uniting two atoms of carbon (C_2) with two atoms of hydrogen (H_2) to form a molecule of acetylene (C_2H_2). Like oxygen, acetylene gas is colourless, but it has a pungent, garlic-like odour. Only 1% of acetylene present in the air is quite noticeable to the average person's sense of smell, making it easy to detect. Acetylene can form combustible mixtures in almost any concentration. It has ***explosive limits*** (allowable concentrations that will support combustion) between 2.5% and 81%, giving it one of the widest available ranges of flammability for any fuel gas.

Acetylene gas generates high heat when burned. When it is proportionately mixed with oxygen, as it is in the oxyacetylene gas welding process, the resulting flame can reach 3300°C (6000°F). This is the highest flame temperature derived from the combustion of any two gases, making the combination of oxygen and acetylene useful for gas welding, metal cutting, and brazing.

Acetylene gas is flammable and highly explosive.

It is important to treat all mixtures of oxygen and acetylene as potentially explosive. Acetylene can quite easily be detected. The moment you smell it, extinguish all open flames immediately and ventilate the room even before turning on a light switch. Then test for leaks in the lines by brushing soapy water on suspected joints or areas. Watch for bubbles. Never test for leaks near an open flame.

Acetylene is an unstable compound. The term "unstable" means that the material is likely to break down (decompose) or undergo a physical change without much provocation or cause. The point at which this happens is said to be its ***critical point***.

The critical point of free acetylene is 28 psi (193 kPa) at a temperature of 70 °F (21 °C), which is the calibration temperature for most acetylene gauges. If this pressure is reached, acetylene breaks down into carbon and hydrogen, and an explosion results. If the temperature is increased, the pressure at which acetylene becomes critical is lowered. To allow for any temperature fluctuations in the work area, acetylene should not be stored or used at pressures over 15 psi (103 kPa).

When acetylene is put in a gas cylinder, the cylinder is packed with a porous filler such as asbestos, charcoal, or balsa wood and then filled with liquid ***acetone*** into which the acetylene is dissolved. This keeps the acetylene from reaching its critical point by not allowing it to be free. Acetylene can then be stored in cylinders at pressures of about 250 psi (1.7 MPa).

Never use copper or red brass for fittings, tubing, etc. with acetylene systems. Acetylene gas reacts with copper to form ***acetylide***, a residue that is even more unstable than acetylene. The slightest shock may cause an explosion and fire. Use only fittings of yellow brass, iron, or steel with acetylene.

Other Fuel Gases

For economic reasons, fuel gases other than acetylene are used for preheating in flame cutting. Three of the more common gases are:

- MAPP gas™ (methylacetylene-propadiene)
- Natural gas (primarily methane)
- Propane gas

These gases are used for flame cutting operations, and in some cases, preferred over acetylene. While acetylene and oxygen produce the highest flame temperature, which permits fast starts when cutting, this combination tends to leave ***slag*** at the bottom of the cut. The other fuel gases, although having lower flame temperatures and therefore slower starts, will produce cleaner cuts with little or no slag clinging to the bottom of the cut.

MAPP Gas

MAPP gas is a trademarked name belonging to Dow Chemical, for a fuel gas based on a stabilized mixture of methyl acetylene and propadiene. The name comes from the original chemical composition: *methylacetylene-propadiene propane*.

MAPP gas is shipped in low-pressure cylinders in liquid form, so it must be used in an upright position. Although it provides less heat than acetylene, it is safer to use and may be safely compressed.

One MAPP cylinder is roughly equal to five acetylene cylinders in terms of equivalent cutting and welding capacity. The flame temperature, 2900°C (5300°F), is lower than acetylene, but the gas is stable and relatively inexpensive when compared to the cost of acetylene.

Natural Gas

Natural gas is preferred in areas where it can be piped in, eliminating the handling of fuel gas cylinders. It is not shipped in a liquid form. The main constituent of natural gas is methane. The flame temperature reaches 1980°C (3600°F), lower than acetylene or MAPP gas. Natural gas requires two volumes of oxygen to one volume of fuel to burn completely. Because of its lower flame temperatures and reduced heating efficiency, either longer preheating or slower cutting speeds are required.

Natural gas is inexpensive compared to acetylene.

Propane Gas

Propane gas is supplied in liquid form in low-pressure cylinders for easy, safe handling. It is widely used because of its

ability to produce clean cuts at a relatively low cost. Propane has a high heat value, but requires 4 $\frac{1}{2}$ volumes of oxygen to one volume of fuel to produce a neutral flame. The flame temperature is 1980°C (3600°F).

Specially designed cutting tips and, in some cases, mixing chambers are necessary with the liquid fuels (MAPP and propane) as the amount of oxygen required for burning it is considerably higher than for acetylene. Of the four fuel gases mentioned, acetylene and propane are the two most common. Table 1 illustrates the key characteristics of these two gases.

Table 1: Key Characteristics of Acetylene and Propane

Acetylene	**Propane**
Hydrocarbon C_2H_2	Hydrocarbon C_3H_8
Burning rate through tip is 100 m/s (300 ft./s) using approximately a 1:1 mixture with oxygen.	Burning rate through tip is 18 m/s (60 ft./s) using approximately a 1:4 mixture with oxygen.
Flame temperature approximately 3000°C (6000°F).	Flame temperature is approximately 2540°C (4600°F).
Principal uses are flame cutting, heating, fusion welding, braze welding and hard- facing.	Principal uses are flame cutting and heating.
Advantages are high flame temperature, reduced preheat time and the capacity to perform a wide variety of tasks. Disadvantage is high cost.	Advantage is low cost. Disadvantage is restricted use due to lower flame temperature.

Gas Cylinders

Oxygen cylinders are forged in one piece from high-grade steel plugs for strength. At the slightest sign of damage, the cylinders are withdrawn from service. Cylinders are not generally sold, but remain the property of the supplier, and are loaned out for a certain period of time. Only full cylinders of gas are distributed. The returned cylinders are drained of any remaining gas in case it is contaminated, and then refilled. Cylinders must be labelled according to WHMIS regulations (https://www.canada.ca/en/health-canada/services/environmental-workplace-health/occupational-health-safety/workplace-hazardous-materials-information-system.html) and the Workers' Compensation Board regulations (https://www.worksafebc.com/en/law-policy/workers-compensation-law/workers-compensation-act-regulations).

Oxygen cylinders are made in various sizes, ranging from 0.5 m^3 to 7 m^3 (20 ft^3 to 244 ft^3) capacity (this may vary slightly with each manufacturer). The oxygen is compressed to 2200 psi (15 MPa) at 21 °C (70 °F). Figure 2 shows a 7 m^3 (244 ft^3) cylinder.

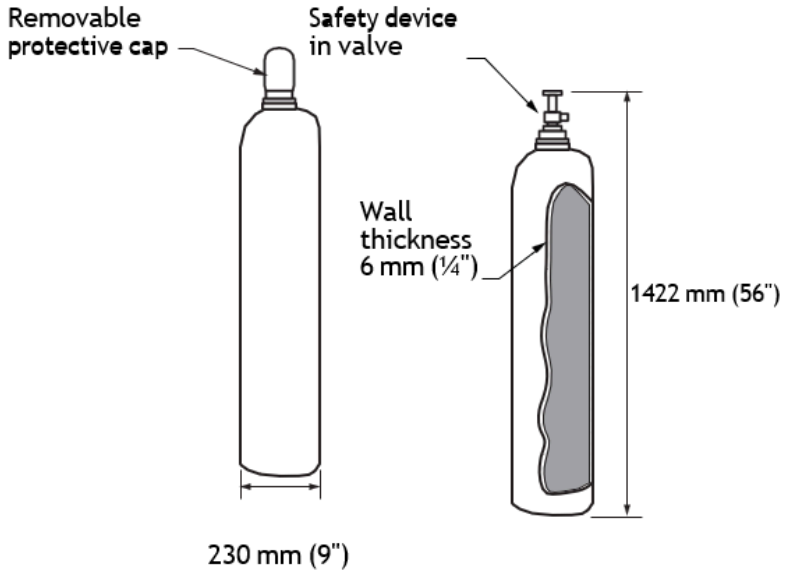

Figure 2 *Oxygen cylinder (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The cylinder valve is protected by a screw-on protective cap. The cylinders and protective caps are usually black, although green and other colours are used occasionally. The caps have right-hand threads (like all oxygen fittings) and come in various sizes to match the cylinders.

Table 2 provides an indication of how temperature change significantly alters the pressure of a full oxygen cylinder:

Table 2: Oxygen Pressure–Temperature Comparison

Temperature		Pressure (approximate)	
Celsius	**Fahrenheit**	**MPa**	**PSI**
49	120	17.3	2500
38	100	16.4	2380
27	80	15.5	2246
21	70	15.2	2200
16	60	14.8	2140
10	50	14.3	2080
4	40	13.9	2020
–1	30	13.5	1960
–7	20	13.1	1900
–12	10	12.7	1840
–18	0	12.3	1780
–23	–10	11.9	1720
–29	–20	11.5	1660

It is important to monitor the amount of oxygen in the cylinder. When the flame is no longer consistent and the working pressure cannot be maintained, remove the cylinder from service. This will prevent poor welds and decrease the possibility of fire or explosion.

Oxygen Cylinder Valves

The ***oxygen cylinder valve*** is designed to operate at high pressures. The double-seal construction prevents leakage of oxygen around the stem when the valve is completely opened. When the valve handle is turned clockwise (closing it), pressure is forced down on seal #1, which shuts off the oxygen supply to the regulator. When the valve is turned counter-clockwise (opening it), pressure is released from seal #1, allowing oxygen to flow into the regulator. The part above seal #1 then threads upward, forcing pressure onto seal #2. This cuts off any oxygen travelling up and around the stem. The outlet fitting for the regulator has a standard external thread to which all standard oxygen pressure regulators may be attached.

Before attaching the regulator, the valve should be "cracked" (briefly opened and re-closed) to remove any dirt that may be lodged in the passage to the regulator.

Never attempt to repair a damaged valve. Tag the cylinder to indicate the fault, move it to an open area, and immediately notify the supplier.

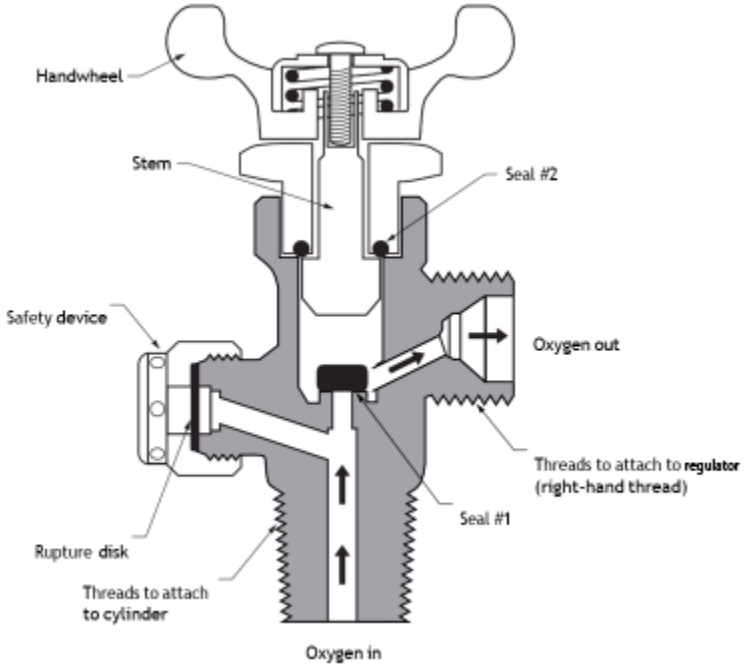

Figure 3 *Oxygen cylinder valve (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Cylinder Safety Devices

The safety device for the oxygen cylinder is located in the valve. It consists of a pressure or rupture disc, which will burst and release cylinder oxygen into the air when excessive pressure build-up occurs, such as from an increase in temperature.

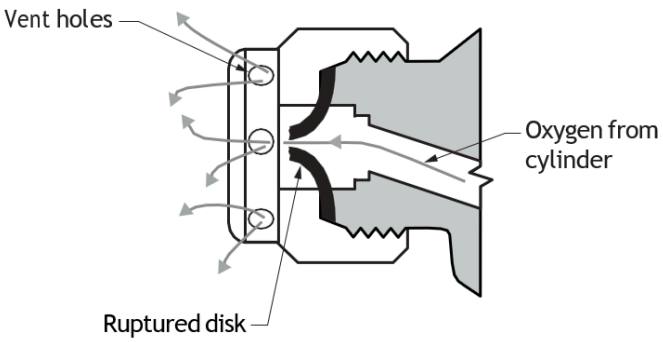

Figure 4 *Safety device on oxygen cylinder (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Acetylene Cylinders

The instability and explosiveness of acetylene requires that the gas be handled with extreme caution at all times, and special considerations are made in construction of the acetylene cylinder.

The acetylene cylinder is a strong, welded-steel container completely filled with a porous material called ***agamassan*** (a porous material such as asbestos, charcoal or diatomaceous earth). This filler material is saturated with acetone, a straw-coloured, stable liquid that is flammable, volatile and strong smelling. Acetone has the ability to absorb acetylene gas and is used in the cylinders to make them safe at high pressures by stabilizing the acetylene. One volume of acetone will absorb 20 volumes of acetylene gas at atmospheric pressure. This ratio increases as pressure is increased.

Because the acetone is in liquid form, acetylene cylinders must be used in an upright position. Otherwise, the acetone may flow into and contaminate the regulator, hose, torch, and flame.

Free acetylene gas is dangerous when stored at pressures above 15 psi (103 kPa), but when porous material and acetone are used, the manufacturer is able to charge the cylinders to an average pressure of approximately 250 psi (1.7 MPa) to 350 psi (2.4 MPa).

It is important to monitor the amount of acetylene in a cylinder. When the flame is inconsistent and the working pressure cannot be maintained, remove the cylinder from service (to prevent acetone from being drawn off into the lines).

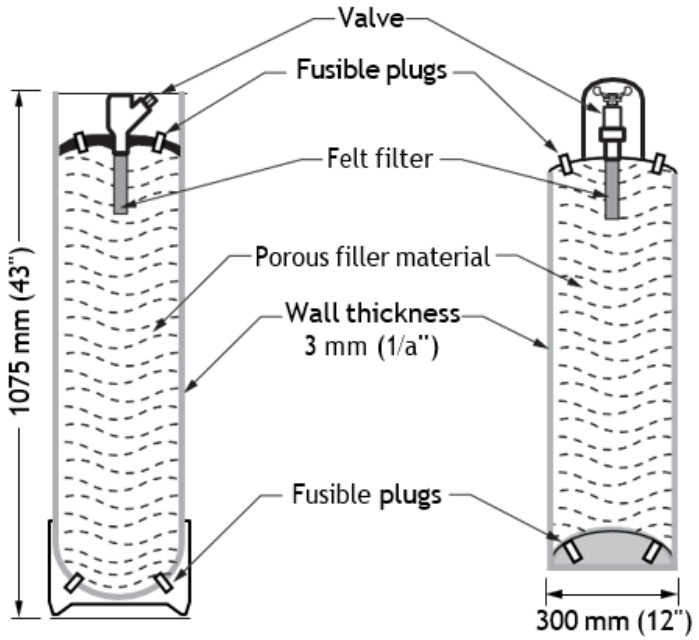

Figure 5 *Two types of acetylene cylinders (BC Industry Training Authority, 2019).*
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Acetylene Cylinder Valves

Unlike the special double-seal design of the high-pressure oxygen cylinder valve, the acetylene cylinder valve has a simple construction to accommodate the relatively low pressure. The valve is opened with a removable wrench or hand wheel. It should be slowly opened $\frac{1}{4}$ to $\frac{1}{2}$ turn. Leave the handle in place in case it must be shut off quickly. When the handle is turned counter-clock-wise (opening it), pressure is released from the seal, allowing acetylene to flow to the regulator.

Figure 6 *Acetylene cylinder wrench* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Cylinder Safety Devices

The safety device for the acetylene cylinder consists of fusible (heat-activated) plugs threaded into the top and bottom of the cylinder. Excessive heat causes these alloy plugs to melt, which in turn releases the cylinder contents to avoid an unsafe pressure rise. The average range of melting temperatures for these plugs is 104 °C to 115 °C (220 °F to 240 °F).

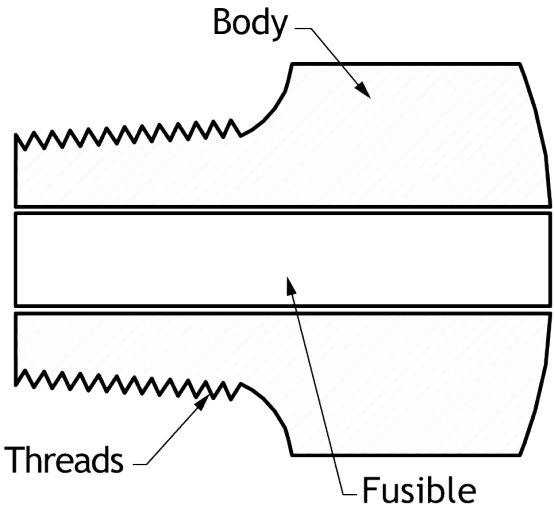

Figure 7 *Safety plug on acetylene valve* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Liquid Fuel Cylinders

Fuels such as propane and MAPP gas are liquids when stored in cylinders. When the cylinders are shipped full, there is still a space above the liquid for gas (vapour) to occupy. Gas escapes when the cylinder valve is opened, reducing the pressure on top of the liquid. This allows the liquid to "*boil off*" (evaporate) more gas.

Since the cylinder contains a liquid, it must be operated in an upright (valve up) position to allow only the vapour to be withdrawn. These liquid fuel cylinders contain a greater yield of gas than an acetylene cylinder.

There are also cylinders designed to operate in a horizontal position, such as those used for RVs and forklifts. When intended for this purpose, they are marked as such and must be correctly positioned to function properly.

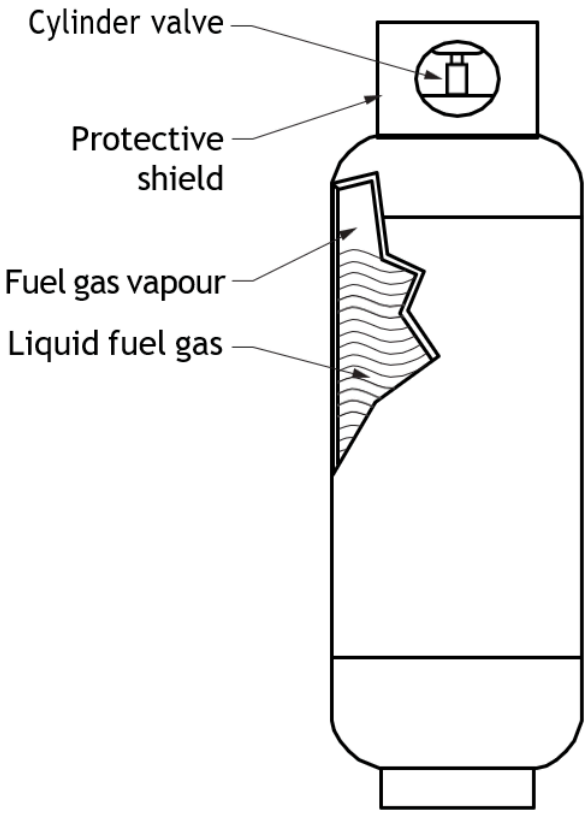

Figure 8 *Liquid fuel cylinder (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The flammable and explosive properties of the gases used in gas cutting, brazing and soldering make safety procedures essential at all times.

Storage

When storing cylinders outdoors, provision should be made for suitable cover from the weather. Full cylinders should be stored separately from empty cylinders; each type of gas should also have its separate storage location.

Cylinders should be stored where they will not be knocked over or damaged by falling objects, passing vehicles, or people. They should not come in contact with salt, corrosive chemicals or fumes. Cylinders (full or empty) should always be secured to a stationary object such as a wall to keep them from falling over.

- Cylinders should not be stored near radiators, stoves, or any other source of heat.
- All storage rooms should be well-ventilated.
- All cylinders should be used and stored in an upright position.
- Once a cylinder is empty, it is to be stored in the appropriate location and marked "MT."

Manifold Systems

In special circumstances, large volumes of acetylene gas may be required to perform a particular job and a single cylinder may not provide enough acetylene at the rate required. When the ***maximum rate of removal (the draw limit)*** is exceeded, liquid acetone will be drawn from the cylinder. To prevent exceeding the draw limit, a series of acetylene cylinders are connected with a ***manifold***. Manifolds are specially designed to connect a number of cylinders together so that the draw limit is increased. The manifold line is filled with stainless steel rod, steel shot, or silica sand to prevent the acetylene from reaching the critical point. The pressure is the same in the manifold as in the cylinders. These systems should be connected and used only by experienced and authorized persons.

Handling

Cylinders must always be handled very carefully. Never drop cylinders or allow them to bump together—they could tip over and explode. When cylinders are being transported, they must be fastened securely.

When your work is finished, close cylinder valves and put protective valve caps on before moving or storing the cylinders. Special cylinder carts should be used for moving cylinders.

Cylinders should be used in the order received from the supplier; when empty, their valves should be closed and the cylinders marked "MT."

Keep cylinders away from electrical wires. Keep oxygen and acetylene cylinders as far away as possible from any area where sparks or flames from welding or cutting work could come in contact with them. Never weld directly over cylinders. If a cylinder valve is clogged with ice or snow, never use a flame or boiling water to loosen it. Use warm water.

To prevent a serious explosive reaction, keep oily and greasy substances away from oxygen cylinders, valves, hoses, fittings, and attachments. Never use oil or grease to lubricate regulators, torches, cylinder valves, or other oxy-fuel gas equipment.

Leaky acetylene cylinders should not be used. When leaks are present, the cylinder should be moved to an area where

good ventilation exists. Warning signs should be displayed to caution people that smoking or using other sources of ignition are not allowed in the area.

The fusible safety plugs on acetylene cylinders should not be tampered with.

Never use a sling, choker, or hook when moving or hoisting cylinders with a crane, derrick, or other lifting equipment. A suitable cradle or box that has been certified and rigged by qualified personnel is the only acceptable method.

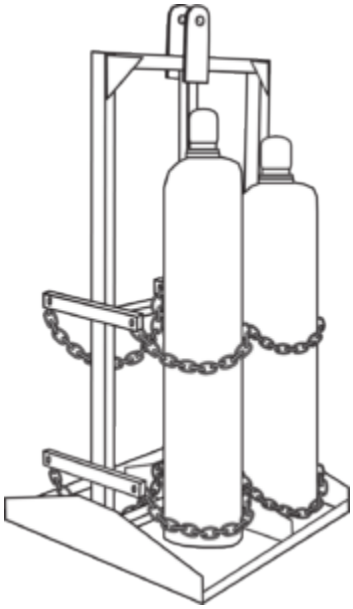

Figure 9 *Oxy-acetylene cart with lifting eye (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Regulators

Oxygen and fuel gases are stored in cylinders at higher pressures than what is required to perform a cutting, brazing, or welding task safely and efficiently. Because of this difference between the stored pressure in the cylinders and the working pressure required to perform welding or cutting operations, it is necessary to install a device on the cylinder that regulates or allows only the amount of pressure needed for a safe and effective operation.

A regulator must not be used for any type of service other than for which it was designed. Repairs to faulty regulators should only be performed by qualified service personnel.

When cylinders of gas come from the supplier, they do not have regulators attached. You must provide the right regulator for the type of fuel gas inside the cylinder.

Most regulators have two calibrated gauges attached. Also included are the permanently attached hex nuts on the regulator cylinder connections. When connected to a cylinder, the gauge with the higher numerical calibrations indicates the pressure inside the cylinder. It is positioned on the same side as the cylinder connection. The gauge with the lower numerical calibrations indicates the working pressure you select. It is on the same side as the hose connection.

Select a safe working pressure by turning the pressure adjusting screw on the regulator. Turning it clockwise increases the working pressure. Turning it counter-clockwise reduces the working pressure.

The oxygen regulator is always equipped with right-hand thread connections, and the acetylene regulator is always equipped with left-hand thread connections. This prevents installing the wrong regulators.

Oxygen Regulators

You can clearly identify an oxygen regulator by the following features:

- Right-hand thread connections
- Cylinder pressure gauge is calibrated from 0–4000 psi (most gauges are available in imperial calibrations only)
- Working pressure gauge is usually calibrated from 0–200 psi, but for heavy welding and cutting, it may read 400 or even 1000 psi
- The word “oxygen” should be printed on the regulator body and on one or both gauges

Figure 10 *Typical oxygen regulator (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

***Note*: Tag and remove any regulator that is found to be defective or damaged.**

Acetylene Regulators

You can clearly identify the acetylene regulator by the following features:

- Left-hand thread connections (and grooved nuts)
- Cylinder pressure gauge is calibrated from 0–400 psi

- Working pressure gauge is calibrated from 0–30 psi
- Working pressure gauge has a red warning line from 15–30 psi
- The word “acetylene” should be printed on the regulator body and on one or both gauges

***Acetylene working pressure must be kept below 15 psi (103 kPa) to prevent the unstable gas from exploding.**

Figure 11 *Typical acetylene regulator (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

All regulators are precision mechanisms. They should be treated with care and never dropped or misused. When they are removed, they should be stored in a box or suitable container to prevent damage. They should be cleaned with a dry, clean rag.

- If regulators are defective or damaged, they should be tagged and removed for service.
- Never use oil, grease, cleaning fluids, gasoline or other petroleum-based chemicals.

Oxy-Fuel Hoses and Fittings

Hoses that carry acetylene and oxygen are specifically designed for oxy-fuel applications. The hose consists of two or three layers of rubber, with a layer of strong fabric between each rubber layer for reinforcement.

The outside layer of rubber may be plain or ribbed.

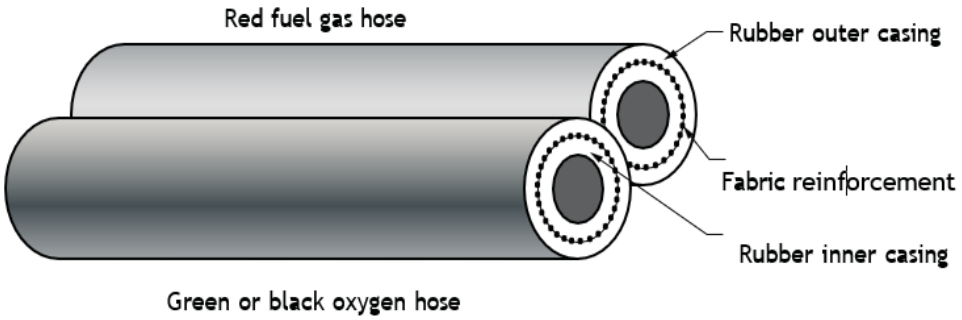

Figure 12 *Double oxy-fuel hose: Colour-coded and attached together (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Most hose used for oxy-fuel application consists of two hoses that have outside layers of rubber fastened together to eliminate entanglements. Since single hose is more prone to kinking and wear, it usually has two layers of reinforcement to make it tougher.

To avoid serious explosions or fires, only use hose in good condition. Faulty or damaged hose should be repaired or replaced immediately with approved products.

Coil, tie, and store hose to avoid kinking. Never expose hose to oil, grease, cleaning solvents, gasoline, paint or contaminants of any kind, and keep hose away from direct sunlight.

Fittings

The same strict manufacturing and handling requirements that apply to oxy-fuel hose also apply to the fittings.

All fittings and connectors used in the hook-up of hose to the regulators and torch body are made of a brass alloy. This prevents sparks if the fittings should accidentally bang against another metal or material. Also, brass alloy fittings will not corrode or produce any dangerous by-products if oxy- fuel gases come in contact with them.

Hose fittings are also right-hand threaded for oxygen, and left-hand threaded for acetylene to prevent switching the hose and possibly causing an explosion. A distinct groove is cut around the outside of the hex nuts on acetylene fittings.

Damaged or faulty oxy-fuel fittings must be replaced immediately. Use only approved fittings.

Oxy-Fuel Torch Assembly and Reverse-Flow Check Valves

The torch assembly is the first point at which mixing of the oxy-fuel gases takes place. It is also the point at which the flow of gases can be adjusted for specific tasks.

Although torch assemblies vary in design, they all have similar characteristics. At one end, the torch handle has gas inlets where the oxygen and fuel gas hoses are attached. At the other end, the mixing barrel has a threaded outlet for the torch attachment. Separate valves control the amount of oxygen and fuel entering the torch handle.

Oxyacetylene flame is used to cut and fuse (weld) metal pieces, but each operation requires a different type of torch assembly. You must select and install the correct attachment to meet a specific job requirement.

Below is a combination torch. The cutting attachment and the welding tip shown can both be interchanged on a single torch handle. When used for cutting purposes, the oxygen valve on the torch handle is opened all the way, and the required amount of oxygen at the torch tip is adjusted by operating the preheat oxygen valve on the cutting attachment.

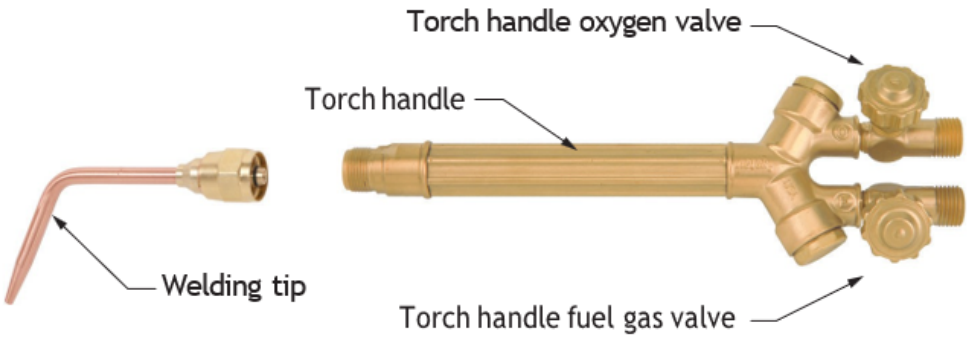

Figure 13 *Combination torch handle (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

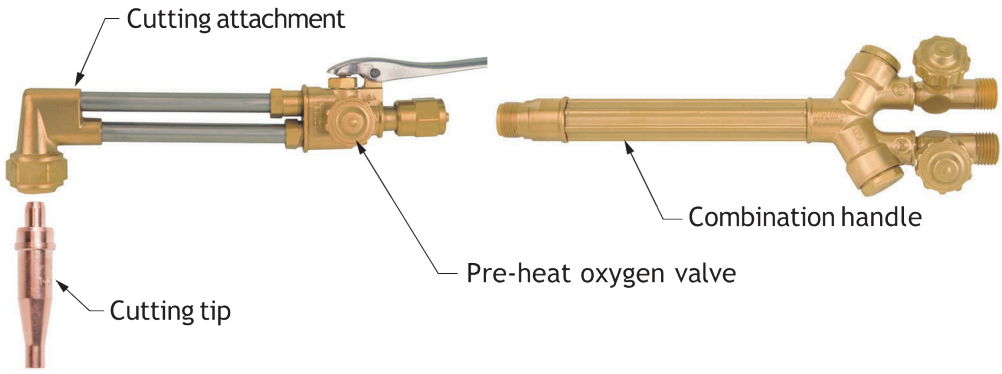

Figure 14 *Cutting torch (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Both the oxygen and acetylene valves on the torch handle are used to adjust the amount of gas flow during welding or brazing processes.

When you purchase a combination torch assembly, it includes a cutting attachment, a torch handle and various sizes of

cutting and welding tips. These components are specific to the manufacturer and cannot be used with other brands of torch assemblies.

When brazing with oxyacetylene, a combination torch may be fitted with a multi-port "***rosebud***" tip that is sometimes also used for preheating carbon steel pipe in fabrication work.

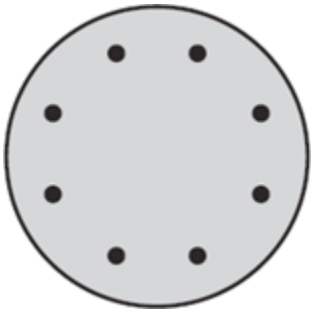

Figure 15 *Rosebud tip (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Torch Line Explosions

When acetylene and oxygen or acetylene and air mix, they form a highly explosive mixture. If this mixture ignites prior to exiting the torch head, it will cause a ***backfire*** or flashback explosion. This is a dangerous and uncontrolled explosion inside the torch equipment that can result in serious injury.

Backfire

During the welding or cutting process, the torch flame may burn back into the welding or cutting tip and make a "popping" sound. This is called a ***backfire*** and is usually the result of the gases pre-igniting inside the tip. The causes of backfire are:

- The obstruction of gas flow at the tip (carbon deposits, hot metal particles)
- A hot tip, from overuse or being too close to the work
- Working pressures too low
- A faulty connection between the torch handle and the welding or cutting attachment

Flashback

A ***flashback*** occurs when the backfire goes beyond the tip and through the hose to the regulator. The torch handle

becomes hot, black smoke and sparks appear from the tip, a squealing or hissing noise is heard, and the fire may eventually burn through the hose. The result of a flashback, aside from fire damage, is a possible explosion.

The causes of a flashback are:

- Incorrect adjustment of torch valves
- Grossly unequal oxygen and acetylene working pressures
- A clogged tip along with excessive oxygen pressure
- Failure to purge the lines before igniting the torch

To help prevent backfire and flashback, make sure the valves on the torch and regulators are functioning properly. The tip should have a clear, undamaged orifice, and ***reverse flow check valves* (RFCV)** should be used to prevent reverse flow in the lines.

A backfire causes the flame outside the tip of the torch to go out and re-ignite instantaneously. If the trouble does not clear up immediately, carefully inspect the equipment, purge the lines, and light the torch.

In the case of a flashback, you must stop the flame IMMEDIATELY before an explosion happens. Assume the worst and shut down the torch valves and cylinder valves as soon as possible. A flashback indicates that something is wrong with the setup. Before you light the torch, check all equipment to see if it is damaged, purge each line separately, and check and adjust working pressures. If a flashback occurs again, remove the equipment from service and have it examined by qualified personnel.

The safe and efficient performance of the torch handle, cutting attachment, and welding tip is dependent on careful use and handling. They are precision tools that can easily be damaged from misuse. Never use a welding torch in place of a hammer or prying tool. When the handle and attachments are removed, they should be placed in a box and stored in a clean, dry area not exposed to oil, grease, solvents, or gasoline.

Reverse Flow Check Valves

The best way to prevent flashbacks and explosions is to keep the gases separated. You should regularly inspect the valves on the torch and cylinders, as well as the gauges on the regulators. Inspection cannot prevent gases flowing in reverse inside the torch or hose. A device called a reverse flow check valve or RFCV (Figure 16) is designed for this purpose (OH&SR Section 12.120 (https://www.bclaws.gov.bc.ca/civix/document/id/loo68/loo68/13_296_97-12#section12.120)). These check valves are compact and are installed between the torch and the hose, or between the hose and the regulators. A stainless steel compression spring holds the valve closed. When the operator opens the regulator and torch valves, the RFCV opens to permit normal gas flow, then snaps shut if the flow reverses.

Different check valves are used for oxygen and fuel gas and sometimes a check valve is built into a cutting attachment. It is important to note that all check valves are marked with an arrow to indicate the direction of gas flow.

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

The WCB recommends that RFCVs be installed on both ends of the hose for safety. Since a torch is subjected to occasional banging or dropping, the RFCVs at that end of the hose may become faulty. Even with RFCVs at both ends of the hose, always check the operation of the valves at regular intervals.

A reverse flow check valve requires much more pressure to close the valve than to keep it open. A reverse flow check valve requires much more pressure to close the valve than to keep it open. For instance, 1.7 kPa (0.25 psi) pressure may open the valve to allow full flow of gases, but 4.3 kPa (1.6 psi) is needed to close the valve. This prevents the usual fluctuations in working pressure from repeatedly closing the valve. An increase in pressure occurs when heat is applied (as in a flashback), and the valve will close.

Reverse flow can be caused by:

- Using plugged or obstructed cutting, welding or brazing tips
- Bleeding the lines by turning off cylinder valves while torch valves are still open
- No pressure from either the oxygen or acetylene cylinders while the torch is in use (empty cylinders)

Flashback Arrestors

Flashback arrestors typically use a combination of methods to stop a flashback. They work just as effectively in any orientation, need very little maintenance, and are often small and light enough to be installed between the torch and hoses. They include:

- A flame trap to cool the flame front. They are designed to allow free flow of gas through them but they take the heat out of the flame front to get it below the ignition temperature of the burning gas mixture. The most common types are:
    - ***Sintered*** metal or ceramic
    - Layers of mesh
    - Ceramic beads
- **Temperature-triggered valves to stop the gas flow completely.** Because it relies on extracting heat from the flashback to stop it continuing, most arrestors have a temperature- controlled valve that will cut off the gas flow when the unit reaches around 90 °C (195 °F), until either the unit cools (if the unit is automatic) or a reset button is pressed (if the unit is manual).

Self-Test B-5.1: Describe Oxy-Acetylene Equipment

Complete Self-Test 5.1 and check your answers.

If you are using a printed copy, please find Self-Test A-5.1 and Answer Key in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2973#h5p-15 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2973#h5p-15)

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- Plumber: Competency B-5 Use Soldering and Brazing Equipment
- Plumber: Competency B-6 Use Oxy-Fuel Cutting Equipment
- Sprinkler Fitter: Competency B-4 Use Soldering and Brazing Equipment
- Steamfitter: Competency B-6 Use Soldering and Brazing Equipment
- Steamfitter: Competency B-7 Use Oxy-Fuel Equipment

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B-5.2 Describe Cutting, Brazing, and Soldering Techniques

The Oxyacetylene Cutting Process

When metal is heated to a red-hot temperature by the preheat flame, it combines easily with oxygen and forms oxides. The jet of oxygen from the central orifice causes the metal to burn and disintegrate rapidly, leaving a ***kerf*** (cut path). The rate of cutting depends on the oxygen pressure, the size of the tip, and the thickness of the metal.

Figure 1 *Oxygen valve controls oxygen to cutting lever and preheat valve (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Since the pressurized oxygen continues to flow as a narrow, penetrating stream some distance from the tip, it allows you to accurately control the cut simply by aiming the torch in the direction where you want the cut. The burnt metal (slag) is either blown away as red-hot particles or it may adhere to the underside of the cut surface. You will immediately notice the difference in appearance between the base plate metal and slag.

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

With the variety of oxyacetylene cutting torches available, sheet metal as thin as 0.8 mm ($\frac{1}{32}$ in.) and plate steel as thick as 600 mm (24 in.) can be accurately cut. The majority of cutting is done on plate ranging from 2 to 50 mm ($\frac{1}{8}$ in. to 2 in.) thick.

Not all metals can be successfully cut by this process. Metals that contain iron, such as low carbon steel and wrought iron, can be cut without difficulty. Metals that contain no iron (*non-ferrous alloys*), such as aluminum, copper or brass, cannot be cut with the oxyacetylene process.

Setting Pressures

1. Make sure the cylinder valves are open and the regulator pressure-adjusting screws are turned out all the way before setting working pressures.
2. Select and install the appropriate cutting tip. The tip may already be installed, but make a note of the cutting tip size. Remember, the thickness of the metal to be cut has a direct bearing on tip size, and tip size has a direct bearing on working pressure. Refer to the manufacturer's chart for correct settings.
3. Before setting working pressures, make sure the preheat oxygen valve on the cutting attachment is closed. Then open the oxygen valve on the torch handle all the way.
4. Open the acetylene torch valve no more than $\frac{1}{2}$ turn, and then turn in the pressure adjusting screw on the acetylene regulator until the gauge reads the selected working pressure. After adjusting, close the acetylene torch valve.
5. Open the preheat oxygen valve $\frac{1}{2}$ turn, then turn in the pressure adjusting screw on the oxygen regulator until

the gauge reads the selected working pressures. After adjusting, close the preheat oxygen valve.

Lighting and Adjusting the Flame

1. Equip yourself with appropriate personal protective equipment (PPE), including coveralls, heavy leather gloves, boots, shaded safety goggles, and a welding cap. Be careful where you point a lit torch and where you let slag deposit once you begin to cut.
2. Before lighting the torch, ensure that there is adequate ventilation, particularly if the metal to be cut is coated with primer or other treatment.
3. To light the torch, open the acetylene valve on the torch handle no more than $\frac{1}{2}$ turn and ignite the gas at the tip using a striker. The flame will be long and yellow. Adjust the valve until most of the smoke clears from the flame. Never attempt to light a flame with any other form of ignition other than a striker (e.g., matches or lighters).
4. Slowly open the pre-heat oxygen valve. You will immediately notice the flames change in colour from yellow to blue.
5. Adjust the preheat oxygen valve to a ***neutral flame***. The torch is now adjusted and ready to use for cutting.

Extinguishing the Flame

1. To extinguish the flame, first close the acetylene torch valve. The flame will go out but oxygen gas will continue to flow from the tip.
2. Close the preheat oxygen valve on the cutting attachment to temporarily stop the flow of oxygen. The torch can be left for a short time (10 minutes or less) in this state. Whenever work is stopped for a longer period, bleed the system completely.

Torch Position and Motion

If the plate is 13 mm ($\frac{1}{2}$ in.) thick or greater (Figure 3a), the cutting tip should be held vertically to the plate at a 90° angle. For plate 6 to 13 mm ($\frac{1}{4}$ in.) to $\frac{1}{2}$ in.) thick (Figure 3b), the cutting tip should be angled 60° to 70° back in the direction opposite the cut. This allows an increase in the cutting speed and helps prevent a buildup of slag underneath the plate. For plate less than 6 mm ($\frac{1}{4}$ in.) thick (Figure 3c), angle the tip 15° to 20°.

a. b. c.

Figure 3 *Angle of torch depends on thickness of metal (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Before lighting the torch, practise the cutting motion to become familiar with the required body and hand positions. Note the placement of the hoses. They should not lie where sparks or slag from the cutting operation could land on and burn them. Keep them well out of the way, preferably behind you, and away from sharp edges or heat sources. Do not use your body or arms to support them. Take any twist out of the hose.

With goggles and gloves on, hold the torch in your right hand*, with your thumb on the cutting lever. Rest the outside edge of your left hand about 150 mm (6 in.) from the line to be cut and support the torch with your thumb and index finger.

(Note that the positions suggested here are for right-handed operators.)*

Ensure that you are not positioned directly above the plume of the cutting torch. Placing your head to one side of the cutting line will reduce the amount of exposure to the metal fumes being produced and will allow you to better see the tip of the torch. Ensure that the ventilation takeout fitting is positioned opposite the material from you so as not to draw the fumes toward your breathing zone.

Figure 4 *One hand guides the torch, the other acts as a pivot (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Guide the torch with your right hand, and support it with your left. With the left hand acting as a pivot, swing the torch from one side of the plate to the other. The torch should always be moved away from you, rather than toward you. You will notice that the cutting tip moves in a wide arc. To make a straight cut, you must perfect the technique of sliding your left hand and the torch in such a way that the cutting nozzle stays on a straight line. On a dry run (without the torch lit), hold the torch so that the tip is pointing straight down, midway between the two ends of the cut line.

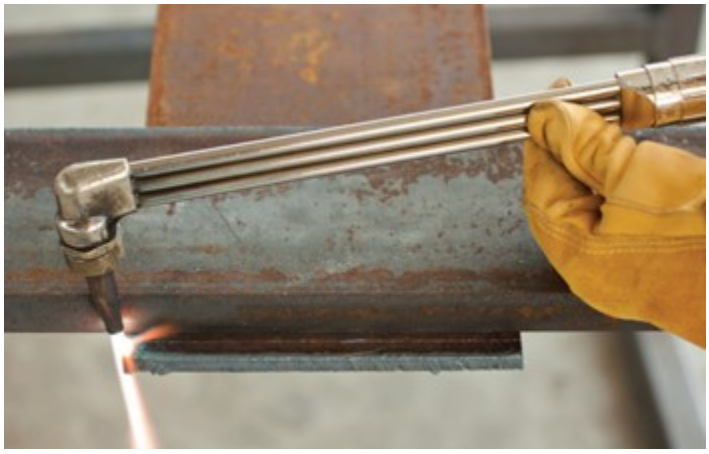

Figure 5 Technique for starting a straight cut (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)

Roll your left hand forward and to your right, to bring the tip directly over the starting point of the cut.

Steadily roll your left hand, from right to left and use your right to guide the tip along the cut line. Continue to roll and guide the torch until you reach the end of the line (Figure 6). The tip should remain approximately 10 mm ($\frac{3}{8}$ in.) above the surface of the plate at all times.

This roll may seem a little awkward and unnatural at first, but with practice, it will become easy. It is important to be comfortable and have full control of the torch. The same motion is used when making very long cuts, but it may be necessary to stop cutting and reposition yourself several times. Keep in mind that the angle of the tip should change according to the thickness of the metal.

Starting Methods

Several methods can be used to start a cut at the edge of a work piece. The most common is to place the tip halfway over the edge of the plate, steadily holding the ends of the preheat flames about 3 mm ($\frac{1}{8}$ in.) above the plate surface. When the edge reaches a cherry-red colour, slowly depress the cutting oxygen lever to start the cutting process.

Figure 6 *One method of starting the cut (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Another method is to put the entire tip over the edge of the material to be cut, then move it back and forth a short distance along the line of the cut until the material is cherry red in colour. Move the tip back from the edge, depress the cutting lever, and then slowly move toward the material to begin the cut. This method has the advantage of producing sharper corners at the beginning of the cut and reducing slag buildup on the underside.

Once the cut has been started (the cut is all the way through), move the torch along the line of cut with a smooth, steady motion. Maintain a constant tip-to-work distance as closely as possible. Move the torch at a speed which produces a light ripping sound and a smooth spark stream.

Cutting Results

Examine the surface on the edge of a cut plate to determine the quality of the cut and the performance of the torch. The following examples show possible cutting results as they appear on the plate edge. Use these as a reference when cutting plate.

Correctly Made Cut

On a good cut, drag lines (lines created by the cutting action on metal) are vertical and not too pronounced. The top edge should be square, and any slag is easily removed. The bottom edge should be sharp.

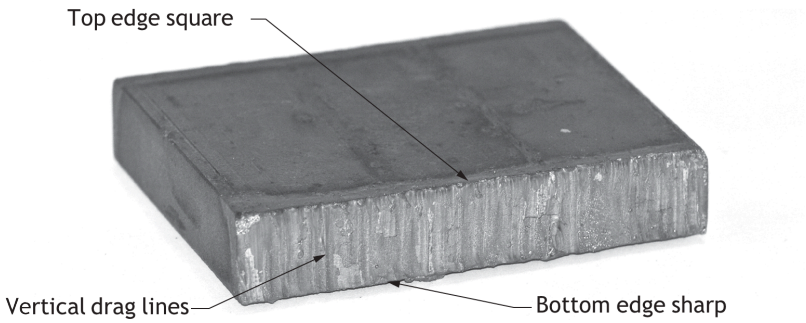

Figure 7 *Correctly made cut (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Cutting Speed Too Slow

On a cut made too slowly, the drag line will be irregular, the bottom edge will be uneven, and the top edge will be rounded. Too much cutting oxygen for the cutting speed is the cause, possibly from an oversized tip, incorrect pressure setting, or poor technique.

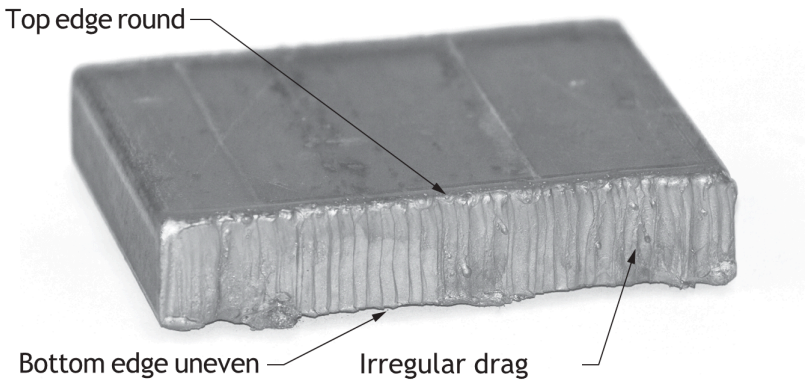

Figure 8 *Cutting speed too slow (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Cutting Speed Too Fast

On a cut made too quickly, the drag lines are curved, slag adheres to the bottom edge, the top edge is sharp, and the cut face is smooth. When not enough heating is used to complete the cut, slag will collect.

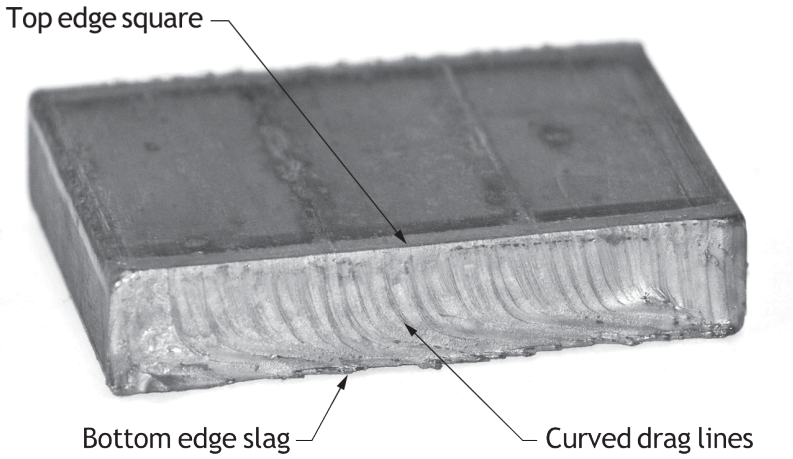

Figure 9 *Cutting speed too fast (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Dirty Tip Used

On a cut made with a dirty tip, drag lines are irregular, the cut face is rough, ***slag*** is excessive and control is poor while cutting. These problems are caused by dirt or slag in the tip deflecting the oxygen jet and reducing cutting efficiency.

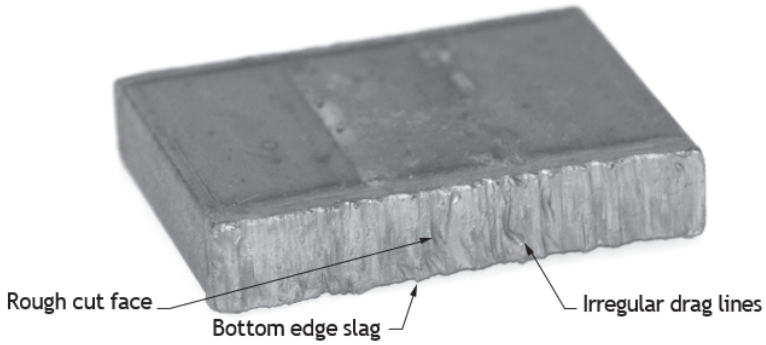

Figure 10 *Dirty tip used (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Factors that are important in achieving a quality cut are:

- Working pressure settings
- Amount of preheat flames
- Angle of torch tip relative to metal
- Tip size
- Speed of cutting torch across metal
- Control of torch by operator

After making a few cuts, see your instructor for an evaluation of the cuts. The instructor may suggest adjusting the torch

or the pressures, or perhaps altering your grip or the motion of the torch. Your instructor can provide helpful hints to aid you in achieving quality results.

Precautions with Containers

A common task is the potentially dangerous cutting and welding of tanks and containers. Combustible gases and solid residues make containers potential bombs unless they are carefully prepared before cutting or welding. Work involving flame or sparks should never be done on barrels, drums, tanks or other containers until they have been thoroughly cleaned to ensure that no flammable solids, liquids, or vapours remain and the container has been verified safe.

Fuel must combine with oxygen and have a form of ignition for a fire or explosion to occur. Most liquids and solids do not explode until they have been heated and vaporized into gases. Even a gasoline tank that contains no liquid gasoline can have enough vapour present to cause an explosion if ignited.

The importance of using correct procedures and precautionary measures to ensure that fires or explosions do not occur cannot be over-emphasized. The various methods used for cleaning containers, such as steaming, boiling or purging, should be done only by qualified individuals using specialized equipment.

If you are asked to cut or weld a container that you suspect may have contained a combustible substance, do not assume that the proper procedures for preparing the container have been completed. Do not proceed to cut or weld unless you are absolutely sure all necessary precautions have been taken.

Note: Do not attempt to weld or cut, smoke near, or bring a light into any tank or enclosure that contained gasoline or any other flammable material unless the space has been thoroughly purged and inspected.

Precautions with Oxyacetylene Equipment

When using oxy-acetylene equipment it is important to observe the following safety precautions:

- Never use cutting or welding torches where sparks or an open flame of any kind would be a hazard. If possible, take the workpiece to a location where there is no possibility of setting fires. If the workpiece cannot be moved, remove any flammable material, including matches from your pocket. When necessary, use sheet metal guards or flame-resistant curtains to contain sparks.
- Butane lighters are potentially explosive and should never be in your possession when welding or cutting.
- Keep sleeves and collars buttoned at all times. Avoid pants with cuffs and shirts with rolled- up sleeves or open pockets into which sparks may fly. Avoid greasy or oily clothing.
- Be sure to keep a clear space between the cylinders and the work. This is important in case the regulators need to be reached quickly.
- Always test an outfit for leaks before use.
- Never cut or weld any material on concrete, as concrete may explode when heated.

Soldering and Brazing

The basic principles behind soldering and brazing are adhesion, cohesion, state change, and ***capillary action***. Properly cleaning the tube and fittings and applying ***flux*** prepares the copper for the filler *alloy* to adhere to the surface of the copper. As the alloy is heated, it changes state from a solid to a liquid. The flux wets the alloy and reduces its surface tension, allowing it to flow readily into the joint. Capillary action draws this free-flowing liquid alloy into the annular space between tube and fitting. The filler alloy, once cooled, has strong cohesive properties to create a physical bond able to withstand the pressure of the system and resist physical damage.

Copper tube and fittings may be joined in a number of ways, depending on the purpose of the system. Soldering and brazing with capillary fittings are the methods used most.

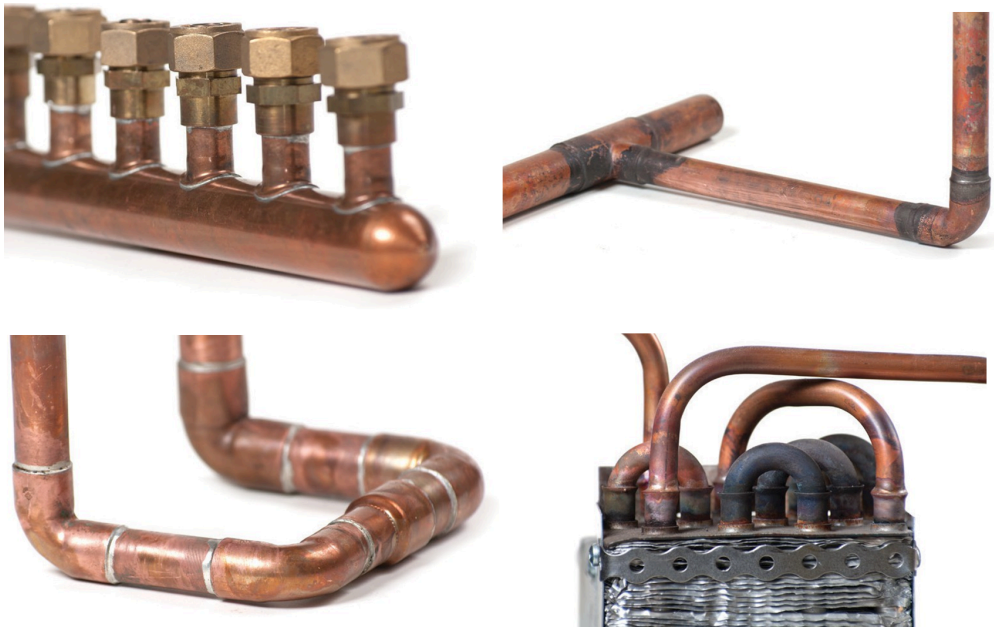

Figure 11 *Soldered and brazed fittings* (*BC Industry Training Authority*, 2019). *CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The American Welding Society (AWS) defines soldering as a joining process that takes place below 449 °C (840 °F) and brazing as a similar process that occurs above 449 °C (840 °F) but below the melting point of the base metals. In actual practice for copper systems, most soldering is done at temperatures from about 177 °C (350 °F) to 288 °C (550 °F), while most brazing is done at temperatures ranging from 593 °C (1100 °F) to 816 °C (1500 °F).

Potable water systems are often soldered as are hydronic heating and compressed air. Medical gas systems, fuel gas systems, and refrigeration systems are all brazed. As well, potable water underground must be brazed.

Definitions

alloy: A homogeneous metal composed of two or more elements.

capillary action: When liquid solder is drawn into the *annular space* between the inside fitting wall and the tubing's

outside wall because there is a stronger attraction (*adhesion*) between the copper and the liquid solder molecules than between the solder molecules themselves (*cohesion*).

solidus: The temperature at which 100% of the alloy is in a solid, crystalline form.

liquidus: The temperature at which 100% of the alloy is in a fluid, non-crystalline form.

plastic range: Also called the *pasty* range, the plastic range is the temperature range between the solidus and liquidus of an alloy; some portion of the alloy is solid, but the majority is liquid. This is due to the alloy's components solidifying at different temperatures.

eutectic alloy: Alloys are eutectic when the solidus and liquidus points are the same. The opposite of having a plastic melting range, eutectic alloys solidify at a single, sharp temperature.

Abbreviations

S*n*—tin
Pb—lead
A*g*—silver
N*i*—nickel
Cu—copper
S*b*—antimony
C*d*—cadmium
Z*n*—zinc

Soldering and Brazing Uses

- Potable water systems—residential, commercial and industrial
- Refrigeration tubing (silver brazing only)
- Fire sprinkler systems
- Extracted tee joints
- Drainage, waste and venting systems
- Medical gas systems (silver brazing only)

Solder Filler Metals

Soft soldering filler metals are a group of filler metals with melting temperatures below 800OF.

They are available in $\frac{3}{64}$ in., $\frac{1}{16}$ in., $\frac{3}{32}$ in. and $\frac{1}{8}$ in. diameter, 1 lb. spools. Other diameters and spool sizes are available from manufacturers on request.

50/50, 40/60, 60/40 Tin/Lead

With some exceptions, the tin/lead (i.e., **60/40** = 60% tin and 40% lead) solders can be used to solder copper and most copper alloys, lead, nickel alloys and steel.

Tin-lead solders are not recommended in high stress or vibration joints in the cooling industry due to lack of sufficient elongation properties. It is illegal to use lead alloys in connection with potable water systems. (Refer to lead-free solder information). 40/60, 60/40, and 50/50 solders are also available with rosin or acid cores.

95/5 Tin/Antimony

The 95/5 tin/antimony lead-free solder is useful for applications where moderately elevated temperature is a factor. With a higher electrical conductivity and high fluidity, 95/5 is recommended for lead-free installation of small-diameter, tight-fitting connections. The 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 lead-based solders with over 0.2% lead in potable water systems. This non-toxic solder alloy typically exceeds the physical advantages of lead-tin solders. Lead-free solders may contain all of or parts 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 will normally exceed the pressure point at which copper tubing will burst.

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

Brazing Filler Metals (Hard Solders)

Brazing alloys have two general categories:

1. **BAg** containing primarily copper and varying amounts of silver with some other minor elements.
2. **BCuP** comprised mostly of copper, with added phosphorus to act as a flux. Some BCuP alloys may contain small amounts of silver for added strength.

Copper tube and solder-type pressure fittings are accurately made for each other, and the tolerances permitted for each assure the capillary space will be within the limits necessary for a joint of satisfactory strength, regardless of whether you are soldering or brazing.

Brazing Copper Silver Alloys (BAg)

[B = Brazing/Ag = Silver] Used for high-temperature applications, loose tolerance situations and for dissimilar metals. Many contain cadmium (a highly toxic element) so treat these alloys with caution and wear proper Personal Protective Equipment. BAg is not used as commonly in the pipe trades as BCuP.

Brazing Copper Phosphorous Alloys (BCuP)

[B = Brazing/Cu = Copper/P = Phosphorus] Copper/phosphorous and copper/silver/phosphorous alloys are used to braze copper to copper and copper to brass. The phosphorus content in these alloys makes them ***self-fluxing*** on copper. When brazing brass or copper to brass, a brazing flux must be applied. BCuP alloys are not recommended for brazing steel or other ferrous metals.

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

Fluxes

Soldering fluxes are classified as corrosive, intermediate, or non-corrosive. The choice may depend on the metals being joined and the melting range of the alloy. Fluxes can be either petroleum based or water based.

Although brazed joints may not always require the application of a flux, soft solder joints will always require a flux to be applied to the metal surfaces prior to heating, primarily to remove any minor surface impurities. As the material is heated, fluxes prevent the formation of oxides, which may contaminate the joint. They also assist the flow of alloy into the capillary spaces of the cup and tube.

Different fluxes perform these duties in various ways and at different temperatures.

Soft Solder Flux (Petroleum Based)

Petroleum-based paste fluxes are basically made up of organic chlorides, zinc, bromides, fluorides and ammonium chlorides mixed in a petroleum-grease base. Because of their corrosive properties, it is necessary to properly limit the amount of flux entering the joint and to thoroughly clean the exterior after soldering to avoid further oxidation and visible discolouration.

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

Soft Solder Flux (Water Based)

Water-based fluxes are a newer development in fluxes in response to a need for materials that have less environmental impact. Many of these new fluxes are more sensitive to being heated within the temperature ranges in which petroleum-based fluxes are used. Care must be taken to avoiding charring the flux, as it has less tolerance to overheating than petroleum flux.

The active temperature range for these soft solder fluxes is between 200°F (93°C) and 600°F (315°C).

Composition:

- Chlorides

Precautions

- Fumes and gases can be hazardous to your health. Burns eyes and skin on contact.
- Can be fatal if swallowed.
- Before use, read and understand the manufacturer's instructions, the Material Safety Data Sheet (MSDS), and your employer's safety practices.
- Keep your head out of fumes.
- Use enough ventilation, exhaust at the flame, or both, to keep fumes and gases from your breathing zone and the general area.
- Avoid contact of flux with eyes and skin. Wear safety glasses and gloves.
- Do not take internally.

First Aid

- If contact with eyes, flush immediately with water for 15 minutes.
- If swallowed, induce vomiting.
- Never give anything by mouth to an unconscious person. Call a physician.

Brazing Flux

White brazing paste flux is an effective and efficient flux for use in silver brazing most ferrous and non-ferrous metals except aluminum, magnesium and titanium. Recommended filler metals for use with white brazing flux include those of BAg and BCuP classification.

The shelf life of these types of fluxes is approximately 1 year from the time of manufacture.

The active temperature range for brazing flux is between 566°C to 871°C (1050° to 1600°F).

Composition:

- Water
- Boric acid
- Potassium fluorides

Precautions

- Contains fluorides.
- Fumes and gases can be hazardous to your health. Burns eyes and skin on contact.
- Can be fatal if swallowed.
- Before use, read and understand the manufacturer's instructions, Material Safety Data Sheet (MSDS), and your employer's safety practices.
- Keep your head out of fumes.
- Use enough ventilation, exhaust at the flame, or both to keep fumes and gases from your breathing zone and the general area.
- Avoid contact of flux with eyes and skin.
- Do not take internally.
- Keep children away when using.

First Aid

- If contact with eyes, flush immediately with water for 15 minutes.
- If swallowed, induce vomiting.
- Never give anything by mouth to an unconscious person. Call a physician.

Soldering and Brazing Using Air-Acetylene

Size B Acetylene Tank Specifics

- Holds 40 cubic feet of pure acetylene gas (the smaller tank, size "MC" holds 10 cubic feet). Note: These capacities represent the volume of fuel available at standard atmospheric pressure (14.73 psia) and temperature (70°F). The B

tanks' true internal volume is actually 0.61 ft^3.

- Tank is normally supplied with a protective plastic cap or shield over the outlet to prevent the entry of debris before the regulator and hose are connected.
- Tank has *fusible* (liquefiable), temperature-sensitive plugs, which release excessive pressures when activated.
- Requires no oxygen cylinder; the oxygen required to support combustion is supplied from the air surrounding the torch tip.
- Produces a flame with temperature of about 4000°F—hotter than gases such as Butane, Propane and Natural Gas.
- Tank is packed with a porous material called *agamassan* (a porous material such as asbestos, charcoal or diatomaceous earth) that is saturated with acetone (acetone has the ability to dissolve many times its own volume of acetylene), so that there is no free unstable gas in the tank. It is therefore gas dissolved in liquid—but when pressure is released in the cylinder, the acetylene boils off.
- The pressure inside a fully charged tank at 70°F is approximately 250 psi. At higher temperatures the pressure will be also be higher; at lower temperatures, it will be lower, but these pressure variations have no effect on the quantity of gas in the tank. However, the amount of pressure change caused by a change in temperature varies according to the amount of acetylene in the tank.
- The newer versions of the tank have a regular wheel handle shut-off valve at the top. Older versions only have a square valve stem that needs a valve key to open and close the valve. Or the square hole in a tubing cutter reamer can be used.
- Never use pliers to open the tank valve; the valve stem will be damaged.
- Use the tank in the upright position.
- If acetone appears from the tip (purple, hazy flame), it is typically due to the tank having been laid on its side. Allow the bottle to sit upright for 24 hours before attempting to re-light. Contact the supplier if problems persist.

Figure 15 *B-tank outfit complete with regulator, handle, hose and torch (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

B and MC Tank Equipment

- Tips come in a variety of sizes. Tips are selected based on the required amount of heat for the job. A larger tip provides more heat than a smaller tip. For most brazing jobs, acetylene-air or B tanks will suffice. Always refer to the manufacturer's literature for correct tip size selection.
- The tank hose is typically $\frac{3}{16}$ in. in diameter and is available in 6, 12 and 25 ft lengths.
- Torch handle has a control valve for on/off command.
- The pressure regulator is equipped with a pressure regulating adjustment that allows a variable delivery pressure of up to 13 psi.
- A gauge displays the gas content (volume) at all times.
- A gauge to display working pressure (delivery pressure) is sometimes present, or can be added.
- A metal filter, located in the inlet of the regulator, prevents dirt or foreign particles from entering the regulator from the tank.

Setting Up the B Tank

1. Secure the tank.
2. Have fire protection equipment ready, including fire shields to protect nearby surfaces.
3. Remove the protective shield on the tank outlet, and open the tank valve briefly to clear any debris that may be lodged in the tank outlet.
4. Install the regulator, hoses, handle and tip. Excessive force must not be used on connecting nuts. Care must be taken not to damage the pressure regulator.
5. Make sure that the pressure regulator connecting nut and all hose and handle coupling nuts are secure. Do not allow the hose to come in contact with flame, sharp objects, oil or grease.
6. Open tank valve on half turn and test connections with soap and water to make sure there are no leaks.
7. Select the right size tip.
8. Turn the control all the way on at the pressure regulator.
9. Open the needle valve on the torch handle slightly and light it with a flint lighter.
10. Adjust flame to the required amount at the tank regulator with the torch handle control valve fully open.
11. If the flame should blow out, re-light the torch and adjust the regulator accordingly (clockwise for more flow).
12. If you smell acetylene gas at any time, check for leaks immediately.

Soldering and Brazing Procedures

The following instructions and techniques will aid in producing quality, leak-free soldered or brazed joints when connecting copper tube and fittings.

The procedures for soft soldering are similar to those for brazing. Above all, cleanliness is most important to avoid joint contamination and possible failures. Fluxes used for either process must be compatible with the temperatures involved, and flux may not be required under some circumstances (for example, copper-to-copper joints using BCuP alloy).

1. **Safety Precautions**

Always observe the following safety procedures when using soldering and brazing equipment:

- Wear eye protection and hand protection.
- Work in a well-ventilated area when possible.
- If the joints to be sweated (soldered) are near combustible materials, such as a wall or floor of a building, use a shield such as a fireproof board between the joints and the combustible material. Use care to avoid causing a fire with the torch.
- Always have a charged and appropriate fire extinguisher on hand. Have a hot-work permit, if required.
- Avoid contact with molten solder.

2. **Measurement**
   Measure and mark the tube with a pencil or marker. Remember to allow for the length of tube that fits into the fitting cup. Dry-fitting the tube and fittings before soldering will ensure that the fittings are square and the runs straight.
3. **Cutting**
   The tube is best prepared when cut with a rotary tubing cutter. Care must be taken that the tube is not deformed while being cut. If you are installing soft temper tube (annealed tube), you must be especially careful to not deform the tube end by applying too much pressure when cutting. Regardless of the method, the cut must be square to the run of the tube so that the tube will seat properly in the fitting cup.

4. **Reaming**
   Ream all cut tube ends to the full inside diameter of the tube to remove the small burrs created by cutting. If the 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 surface for better water flow. Also remove any burrs on the outside of the tube end created by the cutting to ensure proper entrance of the tube into the fitting cup. Tools that can be used to ream the tube end include the reaming blade on some tubing cutters, half-round or round files, a pocketknife or a suitable de-burring tool.
5. **Cleaning**
   The removal of all oxides and surface oils from the tube end and fitting cup is crucial to encourage proper flow of solder metal into the joint. Failure to remove them can interfere with capillary action and may lessen the strength of the joint. There are two methods of cleaning:

- **Mechanical cleaning** of surfaces can be accomplished by filing, brushing or scouring. Scouring the tubing and larger fittings with a product like *sand cloth* is the most common way to mechanically clean copper, brass and other soft metals. Smaller fittings, typically 1 in. and under, are often cleaned internally by a stainless steel *fitting brush*. Never use steel wool as it often contains contaminants.
- **Chemical cleaning** uses solvents or alkali substances for the removal of oils or grease. Carbon tetrachloride, trichloroethylene or methyl chloroform may be used. Chemically *pickling* uses an acid-bath for the removal of rust, scale and oxides from pipe and fittings. Acids such as hydrochloric, nitric and sulphuric acids are sometimes used. ***Note*: Strong chemical cleaning is highly corrosive to copper and brass and must be neutralized to protect the piping system. It is not the common method and is prohibited for use by modern plumbing codes.**

  Lightly clean the tube end and fitting socket using open-mesh sand cloth or emery cloth for a distance slightly more than the depth of the fitting cup. The capillary space (annular space) between the tube and fitting is approximately 0.004 in. Solder metal is drawn into this gap by capillary action. This spacing is critical for the solder metal to flow into the gap and form a strong joint. Copper is a relatively soft metal. If too much material is removed from the tube end or fitting cup, a loose fit may result in a poor joint

5. **Inert Gas Purge**
   Some systems, such as medical gas and refrigeration systems, require the brazing process to be conducted under an oxygen-purged condition. This is accomplished by pumping an inert gas such as nitrogen or argon through the piping during the brazing process, purging any oxygen and thereby eliminating the potential for oxidation. This condition occurs when materials are heated with oxygen available and oxides are created. These impurities, such as copper oxide, collecting on the surface of the tube, both inside and out. If this flaky by-product is permitted to be created inside the system, it could then damage components or in the case of medical gas, result in a life-threatening contamination.
6. **Applying Flux**
   Use a flux that will dissolve and remove traces of oxide (which is usually blackish or greenish in colour) from the cleaned surfaces. This will protect the cleaned surfaces from re-oxidation during heating and promote wetting of the surfaces for the solder metal. It is important to use fluxes that conform to the ASTM B 813 standard so that any flux residue left inside the system will flush out with water. Apply a thin, even coat of flux with a brush to both the tube and fitting immediately after cleaning.

   ***Note*: Do not apply the flux with your fingers.**

   Chemicals in the flux can be harmful if they come into contact with the eyes, mouth or open cuts. Careless workmanship can cause problems long after the system has been installed. If excessive amounts of flux are used, the flux residue can cause corrosion. In extreme cases, such flux corrosion could perforate the wall of the tube, the fitting or both.
7. **Assembly and Support**
   Insert the tube end into the fitting cup, making sure the tube is seated against the base of the fitting cup. A slight twisting motion ensures even coverage by the flux. Remove excess flux from the exterior of the joint with a cotton rag. Align, square and support the tube and fitting assembly to ensure 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 can lead to solder metal cracking under conditions of stress or vibration. The joint is now ready for soldering. Joints prepared and ready for soldering must be completed as soon as possible (preferably the same day) and should not be left unfinished overnight.
8. **Heating**
   Begin heating with the flame perpendicular to the tube. The copper tube conducts the initial heat into the fitting cup for even distribution of heat in the joint area. The extent of this preheating depends on the size of the joint. Preheating of the assembly should include the entire circumference of the tube in order to bring it up to a suitable temperature. Next, move the flame onto the fitting cup. Sweep the flame alternately between the fitting cup and the tube a distance equal to the depth of the fitting cup. Practice and experience will indicate the amount of heat and time needed. Observe the reaction of the flux as the heat is applied. The reaction of the flux will give some indication of the temperature when you arrive at the temperature to apply the filler metal. Soft solder fluxes look and react differently than silver brazing flux. Petroleum-based fluxes will show smoke, indicating that the joint is near a temperature that is adequate to attempt to introduce filler alloy. Be careful not to overheat the flux at this point. Touch the solder to the joint where the tube meets the hub of the fitting. If the solder does not melt, remove it and continue heating. Do not attempt to melt the solder with the torch flame. The alloy must be introduced to the joint by the heat of the fitting and tube itself. Avoid overheating the joint or directing the flame into the face of the fitting cup. Overheating could burn the flux, which will destroy its effectiveness. Also, the solder will not properly enter the joint. When the solder melts, apply heat to the base of the cup to aid capillary action in drawing the molten solder into the cup toward the heat source. Once the entire joint is heated to the point where the solder alloy flows smoothly, remove the flame from the joint in stages in order to maintain the desired amount of heat without continuing to increase the joint's temperature. Cap the entire circumference of the joint to make certain that no voids exist. Control of temperature can be a key to filling trouble spots. You may need to cool and

re-clean an area that is difficult to fill.

9. **Cooling and Post-Cleaning**
   Allow the completed joint to cool naturally to below its ***plastic (pasty) range***, as shock-cooling with water may stress the joint. As soon as the joint is cool, to be sure to clean off remaining flux residue with a damp rag. When soft soldering, excess solder may be visible outside the joint. Part of your duty as a tradesperson requires that you take great pride in your ability and the appearance of your work. While the joint is still molten, use the end of the solder metal to sweep the excess solder off, or carefully wipe the joint with a clean, dry rag. However, be careful not to bump or disturb the joint while the solder filler metal is still molten. Moving the joint before the solder has cooled to below its pasty range can cause internal stresses that weaken the joint. These added stresses may show up some time down the road as hairline cracks that will cause the joint to "weep."

Self-Test B-5.2: Describe Cutting, Brazing and Soldering Techniques

Complete Self-Test 5.2 and check your answers.

If you are using a printed copy, please find Self-Test A-5.2 and Answer Key in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2977#h5p-16 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2977#h5p-16)

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B-5.3 Use Oxy-Acetylene Equipment

You must understand the correct procedures and safety precautions to use when assembling, testing, lighting, adjusting, shutting down, and disassembling a portable ***oxy-acetylene*** outfit.

Always follow general fire safety procedures. Work in a well-ventilated area. Have a charged and appropriate extinguisher nearby and a ***hot-work permit***, if required. Remove all combustible materials from work area.

Assembly, Light-Up, Shutdown, and Disassembly of a Portable Oxy-Acetylene Setup

To avoid accidents, you must follow an organized procedure for assembling an oxy-acetylene unit.

1. Secure the cylinders in an upright position. A safety chain is commonly used to secure cylinders to a portable cart so they do not tip over or get jarred (Figure 1). The cylinder cart is designed to roll easily when tilted back on the wheels, yet be stable and secure when stationary.

Figure 1 *Portable oxy-acetylene setup (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

2. Remove the caps covering the cylinder valves once the cylinders are secured. The caps match the size and colour

of the cylinders. Oxygen cylinder caps will typically be red or green, and ***acetylene*** caps are typically black. Cylinder caps should always be in place when transporting or storing cylinders.

3. Before attaching the regulators, "crack" the valves by opening them slightly, then quickly closing them. This clears any dust or foreign particles from the valve outlets. Stand to the side of the valve outlets and make sure they are not pointed toward you or another person. Any particles inside the valves will be ejected with tremendous force.
4. Match the regulator connections to the cylinder valve connections. Start turning the nut by hand (it should turn easily), then tighten it with an appropriate cylinder wrench. Do not force the nut to start. If it is cross-threaded, it will not turn easily, and the threads will be damaged. Never over- tighten fittings. Remember, oxygen fittings have right-hand threads. Note that the oxygen cylinder valve is externally threaded on the regulator connection, while the acetylene valve is internally threaded.

Never lubricate fittings. Oil or grease combined with pressurized oxygen will ignite and cause an explosion. Machined fittings need no lubrication.

5. Turn the pressure-adjusting screws out (counter-clockwise) on both regulators. This closes off the regulators so that working pressure gauges are not permanently damaged when high-pressure cylinder gases are allowed to flow through the valves.
6. Install reverse flow check valves (RFCVs) or flashback arrestors to regulator connections and tighten them. Make sure to use RFCVs with correct arrow markings for the direction of gas flow. RFCVs have left-hand or right-hand threads to match with corresponding connections.
7. Connect the hoses to the correct RFCV or flashback arrestors. The oxygen hose must be connected to the right-hand threaded RFCV or flashback arrestor, and the acetylene hose to the left-hand threaded RFCV or flashback arrestor. Avoid over-tightening the fittings.
8. Turn the oxygen cylinder valve wheel counter-clockwise very slowly to prevent damaging the regulator. Watch the cylinder gauge. When maximum pressure is reached (the gauge needle will stop), turn the valve all the way open until it stops.
9. Turn the acetylene cylinder valve wheel or wrench counter-clockwise very slowly, watching the cylinder gauge at the same time. When the pressure reaches maximum pressure (when the gauge needle stops moving), turn the valve $\frac{1}{4}$ to $\frac{1}{2}$ turn more (this may vary slightly) to maintain that pressure. The small amount of turning provides for a quick closure of the valve should an emergency situation occur. If a cylinder wrench is used on the acetylene cylinder valve, leave it on the valve. Note that when adjusting the cylinder valves, working pressure gauges remain at zero. ***Note*: Always stand to the side of regulator and gauge faces in case the regulator fails.**
10. Attach the RFCVs to the torch handle (remember to match the arrows to the direction of the gas flow). Connect the hose to the RFCVs. Most workplace regulations advise using RFCVs at both the torch handle and regulator hose connections.

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

Since RFCVs are sensitive and may become plugged, it is recommended that they be tested once a week.

11. Place the welding tip on the torch handle and hand-tighten the nut. Never use a wrench or pliers to tighten the connection, as this can damage seals inside the tip.
12. Adjust the acetylene to the correct working pressure first. Open the acetylene torch valve no more than one turn. Turn the acetylene pressure-adjusting screw clockwise for higher pressure until the working pressure gauge reads 3 psi. This setting may vary, as different tip sizes and torch designs require different pressures. Refer to the manufacturer's specifications for correct settings. Next, close the torch valve gently, to prevent damage to the torch valve seat.
13. Follow the same procedure to adjust the oxygen to the correct working pressure. The working pressure gauge should read 5 psi (again, this may vary).

The torch is ready to use, except there is always the possibility that one or more of the oxygen or acetylene fittings may be leaking.

Testing For Leaks

Step 12 in the previous procedure has left the cylinder valves open, the working pressure gauge is set at 5 psi for oxygen and 3 psi for acetylene and the torch valves are closed. The system is considered to be pressurized from the cylinders to the torch valves and will remain so, if there are no leaks.

Before you start to use the torch, you should always check the line for leaks, whether the equipment is being assembled for the first time or the setup is used repeatedly. The line should also be tested after any new cylinders or parts have been installed.

Larger leaks can be quickly detected by closing the cylinder valves after correctly setting the working pressures. If a cylinder gauge shows a pressure drop, there is a leak. Smaller leaks may be detected the same way, but it will take longer for the pressure drop to show on the gauge.

To quickly determine if a small leak is present, increase working pressures to 10 psi after opening the cylinder valves. After adjusting the working pressure, close both cylinder valves again and watch the cylinder pressure gauges for pressure drop. Make sure the torch valves are closed.

If a gauge indicates a leak, use the following methods to pinpoint it:

1. Listen, smell and touch around connections, hoses and fittings for a leak.
2. If the leak cannot be found by those methods, apply a soapsud solution to possible leak areas. Bubbles will appear where there is a leak.

Figure 3 *Apply a soapy solution to locate leaks (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Note: Never use oil or flame near equipment when looking for leaks.

3. Repair the leak, if possible, then test the system again. When cylinder pressure readings remain constant, the system is okay. Be sure to adjust back to recommended working pressures after testing is done.

The equipment is ready for adjusting and lighting the torch.

Light-Up

Equip yourself with shaded safety goggles, heavy leather gloves, coveralls, boots and a welding cap.

1. Take a few minutes to familiarize yourself with the feel of the torch and striker while wearing gloves. Practise using the striker, holding it about 25 mm (1 in.) from the end of the welding tip.

Figure 4 *Correct striker position (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

2. As a safety precaution, always purge the torch and hose before igniting the flame, especially if the equipment was shut down. Flammable or explosive gas mixtures may have collected inside the torch and hose. Open each torch valve (one at a time) for 5 to 10 seconds, and then close them.

3. Open the acetylene torch valve no more than a $\frac{1}{2}$ turn, and light the gas coming out of the tip with a striker.

4. Set the striker aside and adjust the acetylene valve until the flame becomes turbulent and stops giving off black smoke (Figure 5). Another method is to slowly adjust the valve until there is a gap between the tip and the flame. The flame should be yellow-orange.

Note: Never use matches, a lit torch or burning paper to light a torch—use only a striker. Never place butane lighters near hot work.

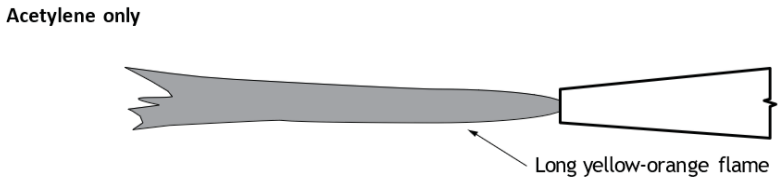

Figure 5 *– Acetylene only flame (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

5. Gradually open the oxygen torch valve and adjust it to a neutral flame. As oxygen is fed into the flame, the colour changes from yellow-orange to blue and a small, light green inner cone starts to form.

The inner cone is a fuzzy, irregular shape. As more oxygen is added, the cone becomes white, rounder and smoother. This is a neutral flame, in which acetylene and oxygen mix in the right proportion to release only heat and harmless gases. If the inner cone is pointed and the flame hisses, too much oxygen has been added. This is an oxidizing flame in which the metal being heated will burn or oxidize. A carburizing flame has too much acetylene and results in adding carbon to the metal. The flame is blue with a dark-blue, feathered inner cone. Each type of flame is used for specific applications, so it is very important to know how to produce all three flames.

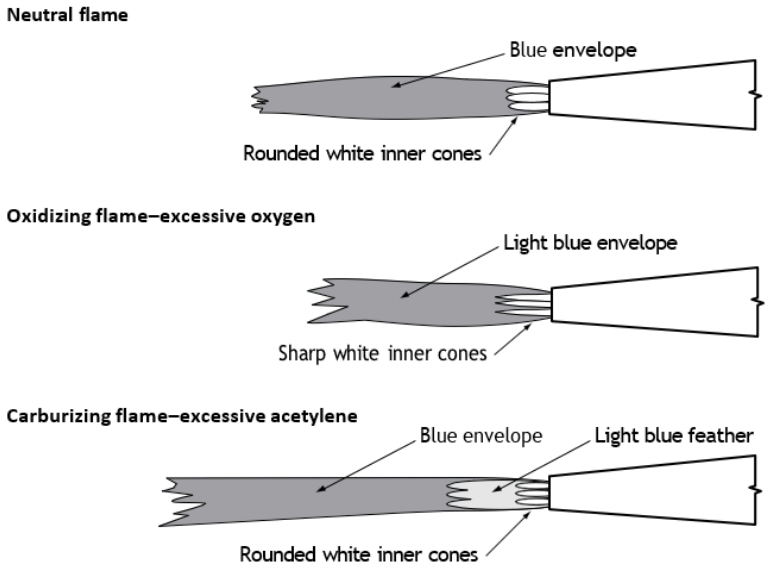

Figure 6 *Types of flame (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

A ***neutral flame*** is the ideal flame for fusion welding and preheating steel for cutting. Temperatures range from 3075°C (5600°F) to 3237°C (5900°F) at the hottest part of the flame (the tip of the inner cone). With a neutral flame, melted steel flows easily, and the welds are clean.

A ***carburizing flame*** is used for welding white metal (i.e., aluminum) and for brazing and other applications where oxidizing the metal would cause poor welds or where lower flame temperature is required.

An ***oxidizing flame*** produces a slightly higher flame temperature than a neutral flame and is used to braze with bronze rod. If used on steel, it will burn and cause foaming and sparking of the metal.

Shutting Down

It is very important to know how to correctly shut down an oxy-acetylene outfit once the welding is completed or when you leave the work area for more than ten minutes. A mistake could result in injury to yourself and others, so follow the shutdown procedure exactly as described.

1. Close the acetylene torch valve. The flame will immediately extinguish, and only the oxygen gas will flow from the tip.
2. Close the oxygen torch valve. Gas is no longer leaving the welding tip, but the system is still pressurized. In this state, the torch can be left for a short period of time (10 minutes or less). When work is stopped for a longer period, such as during lunch or overnight, the pressurized oxygen and acetylene must be bled from the torch, hose and regulators.
3. Bleeding the lines refers to the releasing of the gas pressure still in the system. To bleed lines, tightly close the acetylene cylinder valve first, then the oxygen cylinder valve.
4. Open the acetylene torch valve. The pressure readings on both acetylene gauges will drop to “0” and you will hear what is left of the acetylene gas in the line being released from the welding tip. Never bleed the acetylene near hot metal, sparks or open flames.

5. Turn the acetylene-pressure-adjusting screw all the way out (counter-clockwise) to close the regulator.
6. Close the acetylene torch valve gently.
7. Open the oxygen torch valve. The pressure readings on both oxygen gauges will drop to 0 and you will hear the oxygen gas being released from the welding tip.
8. Turn the oxygen pressure adjusting screw all the way out (counter-clockwise) to close the regulator.
9. Close the oxygen torch valve gently.
10. Store the hose and torch off the floor and away from objects that might damage them. Make sure the hose is not kinked, as this could cause damage and problems with gas flow.

You are handling precision equipment that is potentially dangerous. Follow the shutdown procedure as carefully as you would follow the assembly procedure. Both operations can be hazardous unless you do them correctly.

Disassembling the Oxy-Acetylene Setup

When cylinders are empty and must be replaced, or the outfit is to be transported a long distance or stored, the oxy-acetylene outfit should be disassembled.

Never disassemble the equipment if the gauges do not read 0, the lines have not been bled, or the cylinder valves are not tightly closed.

1. Disconnect the welding tip attachment from the torch handle and store the two pieces in a container free from oil or grease. Attach a fitting to the torch handle to protect the threads and seat.

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

2. Disconnect the hose from RFCVs on the torch handle. RFCVs may remain on the torch handle unless they need service or replacement. Store the handle and RFCVs in their proper container.
3. Disconnect the hose from RFCVs on the regulators. Again, RFCVs may remain on the regulators. Coil the hose and store it in a place free from dust, oil, grease and direct heat.
4. Disconnect the regulators from the cylinder valves. Carefully place each regulator with the attached RFCV in separate containers. Regulators are precision instruments and can be damaged from rough handling.
5. Place protective cylinder caps over the cylinder valves and hand tighten. Even if the cylinder is empty, install the cylinder caps. Empty cylinders should be marked with the letters MT and stored separately from full cylinders.

Although an instructor will demonstrate the procedures for assembling, testing, lighting, adjusting, shutting down and disassembling the oxy-acetylene setup, carefully read and understand the sequences before you attend the demonstration. After the instructor's demonstration, be prepared to answer questions and perform the steps as

described. Do not take shortcuts, and never take safety for granted. Oxy-acetylene equipment is very dangerous if used improperly.

Self-Test B-5.3: Use Oxy-Acetylene Equipment

Complete Self-Test 5.3 and check your answers.

If you are using a printed copy, please find Self-Test A-5.3 and Answer Key in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2985#h5p-17 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=2985#h5p-17)

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Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-7: Use oxy-fuel equipment (Steamfitter)*. Crown Publications, Queen's Printer for British Columbia.

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Self-Test B-5.1: Describe Oxy-Acetylene Equipment

Complete Self-Test B-5.1 and check your answers.

1. _____ is not a fuel gas.
   a. Natural gas
   b. MAPP gas
   c. Oxygen gas
   d. Acetylene gas

2. Which gas has the highest flame temperature?
   a. Acetylene gas
   b. Propane gas
   c. MAPP gas
   d. Natural gas

3. What is the first step in putting out a fire in the hoses of an oxyacetylene outfit?
   a. Use a fire extinguisher on the hoses.
   b. Close only the acetylene cylinder valve.
   c. Close only the oxygen cylinder valve.
   d. Close both the oxygen and acetylene cylinder valves.

4. The critical point of free acetylene is_____psi (_____kPa) pressure at 21°C (70°F); if the temperature is increased, the pressure becomes critical at a_____pressure.
5. The safety devices on an acetylene cylinder are _____activated.
6. Oxygen cylinder valves are opened _____, acetylene cylinder valves are opened _____.
7. Liquid fuel cylinders are designed to allow the liquid to _____when the cylinder valve is opened and gas escapes.
8. When cylinders are too low on gas to be used, they should be marked _____.
9. Cylinder valves should always be _____open momentarily before the regulator is attached, and_____ _when your work is finished.
10. To increase the working pressure, the pressure-adjusting screw is turned _____.
11. A grooved hex nut indicates a(n)_____regulator.
12. The gauge with the higher numerical calibrations indicates_____pressure.
13. The gauge with the lower numerical calibrations indicates_____pressure.
14. The colour of an oxygen hose is usually _____.
15. The colour of the fuel gas hose is usually _____.
16. An RFCV placed between the torch and hose has the arrow pointing toward the _____; between the hose and regulator, it is pointing toward the_____.
17. When you are using the combination torch for the cutting process, the_____valve is used to adjust the amount of oxygen mixed with acetylene for preheating.
18. If a flashback occurs, the_____and_____valves must be shut down as soon as possible.

Answer Key: Self-Test B-5.1 is on the next page.

Answer Key: Self-Test B-5.1

1. c. Oxygen gas
2. a. Acetylene gas
3. d. Close both the oxygen and acetylene cylinder valves
4. 28, 193; lower
5. Heat
6. All the way; ¼ to ½ turn
7. Boil off or evaporate
8. MT
9. Cracked; closed
10. Clockwise
11. Acetylene
12. Cylinder
13. Working
14. Green or black
15. Red
16. Torch; hose
17. Preheat oxygen
18. Torch; cylinder

Self-Test B-5.2: Describe Cutting, Brazing and Soldering Techniques

Complete Self-Test B-5.2 and check your answers.

1. If cutting 13 mm (½ in.) plate or thicker, hold the cutting tip _____ to the plate.
2. The cutting oxygen lever should be depressed when the metal has been preheated to a _____ colour.
3. The vertical lines created on the cut edge by the cutting action on metal are called _____.
4. Name four factors that can affect the quality of an oxyacetylene cut:

   _____

   _____

   _____

   _____

5. What is required prior to welding on closed containers, or on any structure where flammables or other explosive substances are likely to be present?
   a. tests for combustibility must be performed.
   b. area must be flushed with hot water and detergent to remove chemicals.
   c. fire safety watch should be posted, and the area should be protected from sparks and flames.
   d. Tests for combustibility must be performed by a qualified person and posted for review.
6. Never cut or weld on _____, as it explodes when heated.
7. List three reasons why flux is used in preparing a joint for soft soldering:

   _____

   _____

   _____

8. The active range for soft solder fluxes is between _____°C and _____°C (or _____°F and _____ °F).
9. According to the American Welding Society, brazing, also known as hard soldering or silver brazing, is a process that is performed above _____°C (or _____°F).
10. According to the American Welding Society, soldering, also known as tinning or sweating, is a process that takes place below _____°C (or _____°F).
11. A "B" size acetylene tank holds the equivalent of _____ft^3 of gas (@ 14.73 psia).
12. Acetylene is unstable when stored at pressures exceeding 15 psig. To ensure its safe storage, a porous material is contained within an acetylene cylinder and the gas is dissolved in a liquid such as _____.

Answer Key: Self-Test B-5.2 is on the next page.

Answer Key: Self-Test B-5.2

1. Perpendicular or vertical (at 90°)
2. Cherry-red
3. Drag lines

    - Working pressure settings
    - Amount of preheat flames
    - Angle of torch tip relative to metal
    - Tip size
    - Speed of cutting torch across metal
    - Control of torch by operator

4. d. Tests for combustibility must be performed by a qualified person and posted for review.
5. Concrete

    - Remove minor surface impurities
    - Prevents formation of oxides
    - Aids in capillary action

6. 93 °C to 316°C (200 °F to 600 °F)
7. 449 °C (840 °F)
8. 449 °C (840 °F)
9. 40 ft^3
10. Acetone

Self-Test B-5.3: Use Oxy-Acetylene Equipment

Complete Self-Test B-5.3 and check your answers.

1. When you turn the pressure-adjusting screw on the regulator all the way out, it the _____regulator.
2. The lines are said to be _____ when the cylinder valves are open, working pressures are set, and the torch valves are closed.
3. An acetylene cylinder valve outlet for the regulator is left-hand threaded and _____threaded as an extra precaution against improper setup.
4. An oxygen cylinder valve outlet for the regulator is right-hand threaded and _____ threaded as an extra precaution against improper setup.
5. Before you light a torch, you should always check for _____in the lines.
6. The only thing that should be used to create a spark for lighting a torch is a _____
7. A flame that has an excessive amount of acetylene compared to a neutral flame is called _____ flame.
8. When oxygen is added to the acetylene flame, the flame changes colour from _____ to _____ .
9. Name the three types of oxyacetylene flame that can be produced.

   _____

   _____

   _____

10. When shutting down the flame, first close the _____ torch valve.

Answer Key: Self-Test B-5.3 is on the next page.

Answer Key: Self-Test B-5.3

1. Closes
2. Pressurized
3. Internally (female)
4. Externally (male)
5. Leaks
6. Striker
7. A carburizing or reducing flame
8. Yellow-red; blue
9.
    - Neutral flame
    - Carburizing (reducing) flame
    - Oxidizing flame
10. Acetylene

PART VI

B-6 USE WELDING EQUIPMENT

Plumber Apprenticeship Program – Level 1

Person in Welding Mask While Welding a Metal Bar (https://www.pexels.com/photo/person-in-welding-mask-while-welding-a-metal-bar-73833/) (Pixabay/Pexels) Pexels License (https://www.pexels.com/license/)

B-6 Use Welding Equipment Introduction

Terminology

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

- **alternating current (AC):** An electric current that changes direction back and forth many times per second. It is commonly used in homes and buildings. (Section B-6.3)
- **amperes (A):** The unit used to measure electric current, or how much electricity is flowing through a circuit. (Section B-6.3)
- **arc flash:** A painful eye injury caused by exposure to the intense light and radiation from a welding arc. (Section B-6.1)
- **arc length:** The distance between the welding electrode and the metal being welded. (Section B-6.4)
- **arc voltage:** The voltage present in a welding circuit after the arc is struck and the current is flowing. (Section B-6.3)
- **cracking:** Breaks or splits that form in a weld or metal because of stress. (Section B-6.4)
- **current:** The flow of electricity through a circuit, measured in amperes (A). (Section B-6.3)
- **DCEN (direct current electrode negative):** A welding setup where the electrode is connected to the negative side of the power source, causing more heat to be concentrated in the workpiece. (Section B-6.3)
- **DCEP (direct current electrode positive):** A welding setup where the electrode is connected to the positive side of the power source, causing more heat to be concentrated in the electrode. (Section B-6.3)
- **dimensional faults:** Problems with a weld where the size or shape is different from what the design requires. (Section B-6.4)
- **direct current (DC):** An electric current that flows in one direction only, from the negative to the positive side of a circuit. It is commonly produced by batteries and some welding machines. (Section B-6.3)
- **distortion:** A change in the shape of metal caused by heating and cooling during welding. (Section B-6.4)
- **electrode angle**: The direction or tilt of the electrode when it is held during welding. (Section B-6.4)
- **flux:** A coating on a welding electrode that helps protect the molten metal from air and keeps the arc stable during welding. (Section B-6.3)
- **grounded:** Connected safely to the earth so that electrical current can flow away and reduce the risk of electric shock. (Section B-6.1)
- **hot cracking:** Cracks that form in the weld metal while it is still very hot and starting to cool. (Section B-6.4)
- **incomplete penetration:** A welding problem where the weld metal does not fully reach or join the bottom of the joint. (Section B-6.4)
- **inert gas:** A gas that does not react chemically and is used to prevent unwanted reactions such as oxidation or explosions. (Section B-6.1)

- **lack of fusion:** A welding defect where melted metal does not properly join to the metal beside it. (Section B-6.4)
- **lockout:** A safety procedure that ensures equipment is completely shut off and cannot be turned on during maintenance or repair. (Section B-6.1)
- **overlap:** Extra weld metal that spills over the edge of a weld without properly joining to the base metal. (Section B-6.4)
- **polarity:** The direction of electrical flow in a welding circuit, which affects how heat is distributed between the electrode and the workpiece. (Section B-6.3)
- **porosity:** Small holes or bubbles in a weld caused by trapped gas. (Section B-6.4)
- **purging:** The process of removing air or hazardous gases from a space by replacing them with another gas or liquid. (Section B-6.1)
- **residual stress:** Stress that remains inside metal after it has been heated and cooled. (Section B-6.4)
- **respirator:** A protective device worn over the nose and mouth to filter harmful fumes, gases, or particles from the air. (Section B-6.1)
- **self-contained breathing apparatus (SCBA):** A type of respirator that supplies clean air from a tank carried by the user. (Section B-6.1)
- **shielded metal arc welding (SMAW):** A welding process that uses an electric arc between a coated electrode and the metal to join materials. (Section B-6.1)
- **slag inclusion:** Pieces of solid material (slag) that become trapped inside the weld. (Section B-6.4)
- **speed of travel:** How fast the welder moves the electrode along the metal while welding. (Section B-6.4)
- **structural discontinuities:** Flaws or breaks in a weld that weaken the metal. (Section B-6.4)
- **toxic fumes:** Harmful gases or airborne particles produced during welding that can cause illness or injury when inhaled. (Section B-6.1)
- **undercut:** A groove or dip along the edge of a weld that makes the joint weaker. (Section B-6.4)
- **ventilation:** The movement of fresh air through a space to remove harmful fumes, gases, or heat. (Section B-6.1)
- **voltage:** The electrical pressure that pushes current through a circuit, measured in volts (V). (Section B-6.3)
- **volts (V):** The unit used to measure voltage, or the electrical pressure that pushes current through a circuit. (Section B-6.3)

B-6.1 Describe Safety Requirements and Precautions for Arc Welding

Safety Rules for Operating Electric Welding Machines

The greatest electrical hazard for welders comes from electric welding machines. For this reason, every time you work with these machines, you must follow all the standard safety precautions.

All switches must be clearly marked, all tools and equipment must be properly ***grounded***, and metal ladders must be nowhere near any source of electrical power.

Maintenance of Equipment

The welder who is about to use a machine is responsible for ensuring that the welding machine is in a safe operating condition. The wiring, switches, controls, and cables must all be thoroughly checked before use, and preventive maintenance (such as internal cleaning and lubrication) must be carried out at regular intervals.

In most welding shops, the power supply for arc welding equipment is 230 V, 460 V, or 575 V. These are high voltages that can easily deliver severe or fatal shocks. When performing any internal preventive maintenance work on electric welding equipment, observe the following rules:

1. All troubleshooting and maintenance of welding machines must be done only on dead circuits. Make sure that the main power supply disconnect switch is open and locked out.
2. All work on main power lines, junction boxes, and fuses may only be carried out by a qualified electrician, in accordance with the requirements of the Canadian Electrical Code. As a welder, your maintenance responsibilities end with your welding machine.

Power Circuit Ground

When you connect an electric welding machine to its main power source, it is extremely important to ensure the main power circuit is properly grounded. Without proper grounding, any stray current that develops could give you or another welder a severe or fatal shock. If you have one hand on an inadequately grounded machine in which a current is flowing and accidentally touch a grounded metal object such as a switch box, you become part of the electric circuit. The resulting electric shock could be fatal.

Welding Cables

The cables on a welding machine should be checked every time the machine is used. You should never use electric

current that exceeds the rated capacity of the welding cables on your machine. This is uneconomical but, more importantly, it causes overheating and rapid deterioration of the insulation. Faulty insulation is a hazard. If exposed sections of cable come in contact with any grounded metal object in the welding circuit, they could create an arc, which could in turn ignite any flammable materials in the area.

Make inspection of the cables a standard part of your inspection of welding equipment prior to use. If the cables are in good condition, you can use them. In other cases:

1. Be sure the main power source is disconnected and locked out.
2. If there are surface cracks in the insulation, repair them with electrical tape before starting the machine.
3. If there are breaks in the insulation that expose any wire, do not try to repair it. Replace the cable with one that is in good condition.

Fire Prevention

The electrical welding processes such as ***Shielded Metal Arc Welding* (SMAW)** pose as great a fire hazard as the oxy-fuel welding processes. Observe the following points:

1. **Housekeeping:** Ensure that your workplace is as free as possible of combustible materials before you begin to weld.
2. If flammable materials cannot be removed from the work area, be sure they are protected adequately from sparks and slag before you start to weld. Use welding blankets.
3. Do not weld anywhere near containers of flammable liquids.
4. Know the locations and type of fire extinguishers in your immediate work area and their operating procedures.

Eye Protection for the Electrical Welding Processes

When you weld using an electrical process such as SMAW, you must take extreme care to protect your eyes. The infrared and ultraviolet rays that are the products of the arc welding process can cause serious and sometimes permanent injury to your eyes.

The burn that results from the exposure of inadequately protected eyes to the welding arc is known as ***arc flash***. Even a one-second exposure at a distance of 0.5 m (20 in.) is enough to burn the eyes.

Never look at an arc with the naked eye. If you receive an arc flash, immediately report it to your instructor. WCB stipulates a minimum distance of 12 m (40′) between an arc and the naked eye.

Helmets

To protect your eyes, face and neck during arc welding, you must wear a helmet or use a hand shield equipped with a dark filter lens. These lenses come in a range of different shades, each with a different number. Your choice of lens depends on the level of current you are using, since this determines the intensity of the arc. Table 1 lists lens shade

numbers recommended for different current settings. These are suggestions only. The sensitivity of your eyes may require that you use a darker lens.

Table 1: Recommended Lens Shades for Level of Current

Level of Current	Lens Shade
Below 30A	No. 6
30-70 A	No. 9
70-200 A	No. 10
200-300 A	No. 11
300-400 A	No. 12
Over 400 A	No. 13

If your eyesight requires them, use wide vision or clear magnifying lenses. These special lenses fit behind your filter lens.

Always check the shaded lens in your face shield or helmet before you start to weld to make sure it is not cracked or broken. If it is cracked or chipped, replace it immediately.

If you are in a shop where arc welding is being done, wear flash goggles as protection from arc flash. Similarly, if you are welding near another welder, wear flash goggles in addition to a helmet or face shield to avoid the risk of arc flash anytime your helmet is raised.

Arc Burn

The infrared and ultraviolet radiation that occurs with arc welding can cause damage to improperly protected eyes and cause severe burns to your body. For this reason, you must wear the proper protective clothing and equipment when using the SMAW process.

The amount of protective clothing you require depends on how much welding you are doing and on the welding positions you use. At the very least, when you are performing SMAW, all parts of your body must be covered. Use a flame-resistant leather jacket, aprons and sleeves and, for some jobs, leggings and anklets. Your standard protective clothing for arc welding must also include a peaked cap, leather gloves and safety boots.

For arc welding of any kind, your clothing should be dark to reduce the reflection of the arc. If you suffer burns as a result of arc welding, see your doctor at once.

Hearing Protection

In a welding shop or on a construction site, the noise from weld cleaning, chipping, grinding and hammering, as well as from welding machines and power tools, can cause hearing damage.

The signs of hearing damage can be a constant ringing in the ears, hearing loss, temporary deafness and, in extreme cases, permanent deafness. Hearing loss may occur so gradually that you may not be aware it is happening.

You need protection from both steady state and impact noise. In any shop or on any job site where the general or steady state noise level exceeds 90 decibels or where the impact noise levels are in excess of the maximum indicated by the

Regulation, you should wear Canadian Standards Association (CSA) approved ear plugs or earmuffs. Hearing protection devices are rated A, B and C to indicate the noise levels for which they are effective (Table 2).

Table 2: Noise Levels and Appropriate Hearing Protection

Steady State Noise for 8 hrs. (dBA)	Minimum CSA Class of Hearing Protector
85-95	C
96-105	B
106-115	A
Over-115	A muff and B plug
Impact Noise	A
	CSA Standard Z94.2-1974

Hearing protection devices can be rubberized earplugs that are inserted into the cavity of the ear or earmuffs, which fit over the ear (Figure 3). When selecting hearing protection devices, make sure that they are CSA approved. Earplugs should be clean, pliable and well-fitting, and earmuffs should be adjusted to fit snugly over your ears.

Figure 3 *Rubberized earplugs and earmuffs (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Neither headphones used with music systems nor cotton stuffed into your ears, will give you adequate protection from noise.

Fire and Explosion Prevention

Optional Resource: Real-World Incident

You may be interested in this real-world example from WorkSafeBC (2010): Explosion during welding operation (https://www.worksafebc.com/en/resources/health-safety/incident-investigation-report-summaries/explosion-during-welding-operation)

A worker was welding on an aluminum boat when a welding arc ignited undetected flammable vapours, causing an explosion that threw the worker several metres and damaged the structure.

This incident highlights the importance of proper hazard assessment, ventilation, and testing for flammable vapours before performing hot work.

Flammable Hazards

The flammable materials include acetylene, naphtha, turpentine and gasoline. When concentrations of fumes from flammable liquids are present, there is a great risk of these fumes being ignited by contact with an open flame or spark.

The symbol shown in Figure 4 should be located on all containers used for flammable materials.

Figure 4 *Flammable materials symbol*

Flying Sparks

One of the major fire hazards is flying sparks. Unlike flame, the effects of which are confined to the immediate area of the work, sparks travel fast and far. A spark can travel over 9 m (30′) and hold its heat several seconds after landing. Sparks can lodge themselves in cracks and start smouldering fires that may not burst into flames until after you have left the area.

Never weld where sparks may come into contact with flammable vapours, liquids or materials. Sweep floors clean and, if they are wood, wet them down before you light the torch. If there is a possibility that sparks might pass through cracks in walls or floors, cover the holes or move the work.

If you can move your work, set it up in an area that is free from flammable materials. If you cannot move the work, move the flammable material to another area. If neither the work nor the flammable material can be moved, use sheet metal or fireproof guards to keep sparks close within the area of your work. Set pans of water or sand where they will catch dripping slag and pieces of hot metal that might fall.

After you set up the sheet metal or asbestos guards, have someone check to see if sparks are flying over or around them. When you change the direction of flame toward the work, the direction and range of sparks may change. Make periodic checks to see that you are providing enough protection in the right places.

Fire Watchers

Welding and cutting operations should be carried out in areas free from combustible materials. When work must be done near flammable material, the National Fire Protection Association (NFPA) (https://www.nfpa.org/) states that you must have a designated fire watcher.

The NFPA also requires the following:

- Fire watchers shall have fire extinguishing equipment readily available and be trained in its use, including practice on test fires.
- Fire watchers shall be familiar with facilities and procedures for sounding an alarm in the event of a fire.
- Fire watchers shall watch for fires in all exposed areas and try to extinguish them only if the fire is obviously within the capacity of the equipment available; if it is not, the fire watcher shall sound the alarm immediately.
- A fire watch shall be maintained for AT LEAST HALF AN HOUR after completion of cutting or welding operations to detect and extinguish possible smouldering fires.

Compressed Gas Cylinders

The most common sources of explosive hazards in welding shops are the compressed acetylene and oxygen cylinders used in the oxy-fuel processes. The contents of these cylinders must always be identified on the cylinder. The cylinders must be handled correctly, in accordance with regulations and they must, if possible, be stored in an upright position.

The symbol indicating an explosive hazard is shown in Figure 5 and should be located on all containers or materials that are explosive.

Figure 5 *Explosive hazard symbol*

Containers That Previously Held Flammable Material

If containers have previously held flammable materials, welding or cutting them could cause an explosion. Certain preparatory methods of cleaning and ***purging*** must be used before welding or cutting is attempted.

One method for removing flammable materials is to steam or boil the container in a caustic solution, a method that is usually too slow, costly and uncertain for commercial work. It may entail days or weeks of processing since lap seams, laminations in the plate of the vessel, or open roots or welds made from both sides may contain pockets of combustibles that are difficult and time consuming to remove.

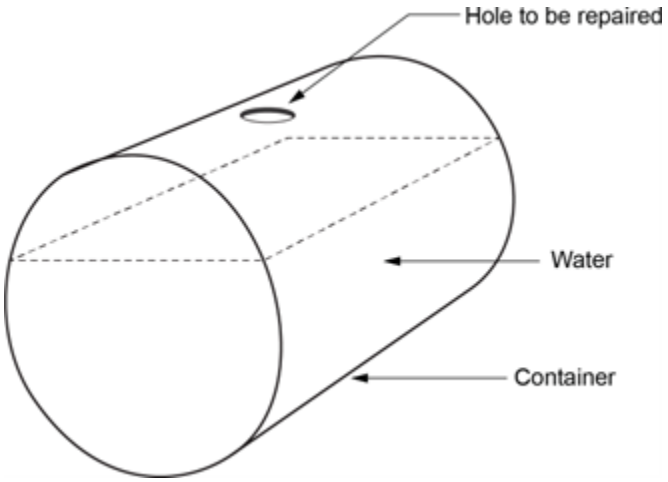

Figure 6 *Displacement of air with water* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

A second and less expensive method is to fill the container with water. The water displaces the air in the container so

that an explosion cannot be supported. The container is filled to overflowing, then water is removed to a level just below the hole to be repaired (Figure 6). The air in the container is then checked with a gas detector to ensure that no explosive vapours remain.

There must be a vent hole in the container that is large enough to allow the vapours to escape. Sometimes it will be impossible to leave the vent open, particularly for containers that are positioned on their side (Figure 7). In cases such as these, you have to make sure the hole to be welded is large enough to act as a vent.

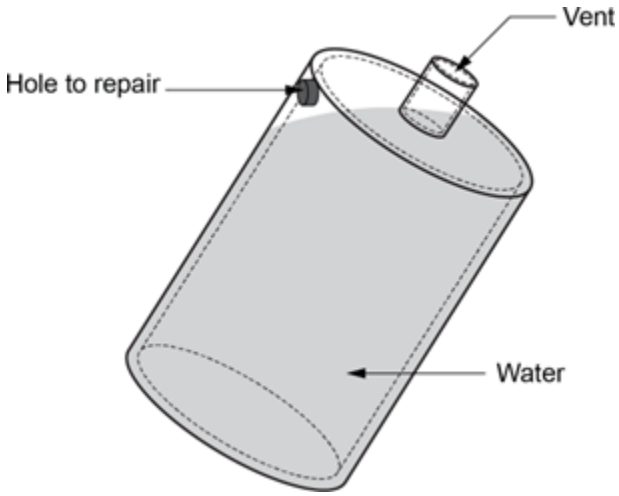

Figure 7 *Water displacing air (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Purging is a third method to rid containers of flammable gases. The container is completely filled with an ***inert gas*** such as nitrogen, argon or helium, which does not explode. These gases displace the air or oxygen which is explosive.

When using this method, you must know whether your purging gas is heavier or lighter than air. If the purging gas is argon, which is heavier than air, you must fill the container from the bottom (Figure 8).

If the purging gas is nitrogen or helium, which is lighter than air, you must fill the container from the top. A vent must be left open to allow the air to escape. Enough purging gas must be used to remove all the air. The procedure should be done in an area free of drafts or wind that would tend to disperse the purging gas.

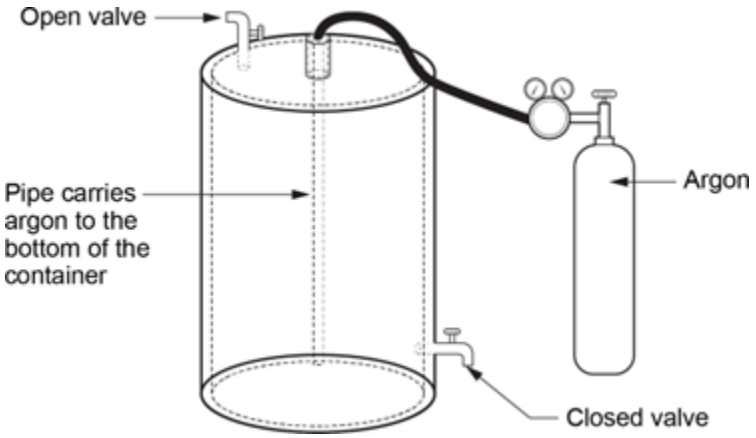

Figure 8 *Purging with inert gases heavier than air (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

This method is expensive for ordinary use, but for jobs such as the purging of acetylene manifold systems, this is the best suited method since no moisture or heat is involved.

Steaming is the fourth and most common method of making containers safe for welding or cutting. This process consists of opening all vents and blowing in live steam under pressure until all dangerous traces of combustibles are gone. The container must be welded while it is still hot and full of steam. After cooling begins and air has been drawn into the container, it is no longer safe to weld or flame cut.

The length of steaming time depends on the size and pressure of the steam line, the size of the container and the container's previous contents. As an extra safety precaution, the container can be filled with inert gas after it has been steamed clean.

Before you begin to weld or flame cut after cleaning or purging the container, you should always test the container using an explosive vapour detector.

Figure 9 *Toxic hazard symbol*

Toxic hazards include the fumes or airborne particles present during welding or produced as a byproduct of welding. The symbol used on containers of toxic materials is shown in Figure 9.

The toxic materials that are most commonly associated with the welding process are in Table 3.

Table 3: Hazardous Substances and Health Effects Associated with Welding

Substance	Common Source or Use	Health Effects
Asbestos	Used as insulation for pipes.	Highly toxic. Exposure can cause **asbestosis** and **lung cancer**.
Beryllium	Used in plating.	Inhalation of fumes can cause coughing, lung inflammation, breathing difficulty, fatigue, weight loss, and heart disease after long exposure.
Cadmium	Alloyed with silver or brass; used in silver brazing alloys, plating, or paint coating on some electrodes. Cadmium-coated metals may resemble galvanized metals.	Exposure to fumes can cause breathing difficulty, weakness, general illness, lack of appetite, nausea, metallic taste, chest pain, coughing, decreased urine output, and possibly death from respiratory failure.
Carbon dioxide	Used as a shielding gas in some welding processes.	In confined areas, excessive amounts can cause suffocation. May also break down into carbon monoxide in poorly ventilated areas.
Carbon monoxide	Byproduct of welding with shielding gas; also emitted by gasoline-powered welding machines.	Colourless and odourless gas. Early symptoms include headache, dizziness, and mental dullness. Severe exposure can cause unconsciousness and death by suffocation.
Carbon tetrachlorine and trichloroethylene	Commonly used as degreasing agents.	Exposure can cause abdominal pain, nausea, vomiting, dizziness, confusion, irregular pulse, falling blood pressure, jaundice, and reduced urine output.
Chlorine	Used in wood pulp industries and water or sewage treatment plants.	Causes burning in eyes, nose, and throat. Higher exposure may cause nausea, choking, chest pain, lung fluid buildup, and suffocation. Contact with liquid or vapour may cause burns.
Cyanide	Used for hardening some steels.	Can cause effects ranging from mild allergic reactions to severe poisoning and death.
Fluoride	Found in fluxes used when welding or brazing stainless steel, nickel, aluminum, and magnesium.	Exposure can cause coughing, bronchitis, breathing difficulty, and fluorosis, which changes bone structure.
Lead	Found in pipes, paint, electrodes, solders, and sheet materials.	Inhalation causes lead accumulation in organs and bones. Symptoms include metallic taste, nausea, vomiting, gum discoloration, and long-term nervous system damage.
Manganese	Used as a deoxidizer and strengthener in steel.	Fumes can cause coughing, bronchitis, fever, headaches, muscle pain, chills, dermatitis, and liver enlargement.
Mercury	Found in plating and some paints.	Exposure can cause abdominal pain, excessive salivation, metallic taste, diarrhea, coughing, and reduced urine output.
Nitrous gases	Produced by the arc or flame during welding processes.	Can cause breathing difficulty and rapid fluid buildup in the lungs several hours after exposure.
Phosgene	Produced when carbon tetrachloride or trichloroethylene is heated or exposed to ultraviolet radiation.	Causes throat irritation, chest tightness, breathing difficulty, lung inflammation, and possibly death from respiratory failure.
Ozone	Produced by welding arcs and ultraviolet radiation during electrical welding processes.	Causes irritation of the eyes, nose, and throat.
Teflon	Found in pipe linings and tap-valve seals.	When heated above 390 °C (728 °F), it produces highly toxic gases that cause weakness, numbness, throat pain, and breathing difficulty.
Zinc	Found in galvanized plating and brass; zinc chloride used as flux.	Exposure to fumes can cause *metal fume fever*, with symptoms such as headache, chills, fever, chest tightness, and stomach upset.

Note. Welding fumes from metals such as aluminum, chromium, copper, iron, nickel, titanium, and vanadium are generally not toxic at typical welding concentrations but may become harmful at higher levels.

Ventilation

Adequate ***ventilation*** must be provided when ***toxic fumes*** from materials such as lead, zinc, cadmium, beryllium and Teflon are present in harmful concentrations.

Ensure that booths or welding screens do not hinder air movement needed for ventilation. Welding booths require a minimum air movement of 30 metres (100 linear feet) per minute.

Although many gases can be identified by their smell, you can never totally rely on your sense of smell. Deadly hydrogen sulphide, for example, is easily recognized by its odour of rotten eggs at low concentrations, but in higher concentrations it becomes odourless. The only reliable method of detecting dangerous gases is to use special detection equipment. These detectors test the air for the presence of explosive vapours and are commonly called explosimeters. Other types of detectors are designed to test the air for the presence of toxic gases such as chlorine or hydrogen sulphide.

Working in Confined Areas

Welding or cutting in confined areas such as tanks, boilers, pressure vessels, vaults and holds of ships requires special attention to safety. The following special precautions are necessary for working in confined areas:

- Check air upon entering.
- Ensure adequate ventilation, especially when using low-hydrogen or stainless-steel electrodes.
- Never use oxygen.
- Keep cylinders outside the confined area.
- Have a helper outside with a lifeline, if necessary.
- Pay special attention to leaks.
- Light your welding or cutting torches outside and have them handed in, if possible.
- Never take welding or cutting torches inside until pressures have been regulated.
- Do not keep torches inside the confined area for any length of time.
- Check for harmful concentrations of ozone during inert gas welding.
- Check for explosive vapours that may be present or produced by the welding.
- Wear appropriate respiratory protective equipment, if necessary.
- Never enter a confined area to rescue personnel overcome by fumes or lack of oxygen without summoning help first; make sure you wear the appropriate breathing apparatus if you do enter.

WorkSafeBC Note: Welding Fumes

Welding fumes can cause serious short- and long-term health effects. Always ensure proper ventilation and follow exposure control procedures.

You may be interested:

- Ask an officer: Controlling the risk of welding fume exposures (https://www.worksafebc.com/en/about-us/news-events/campaigns/2024/March/ask-an-officer-controlling-risk-welding-fume-exposures) (WorkSafeBC, 2024)
- Controlling Exposure Risks from Welding and Cutting Processes (https://www.worksafebc.com/en/resources/health-safety/books-guides/controlling-exposure-risks-welding-cutting-processes) (WorkSafeBC, 2024b)

Respiratory Protective Equipment

Respirators can provide protection against toxic fumes. There are three types of respirators that you may be required to use. The in-line respirator (Figure 10) draws air from a line (fresh air source). A filter in the supply line removes pipe scale, water, oil, mist and noxious vapours. A pressure- reducing valve prevents the pressure of the air from exceeding 170 kPa (25 psi).

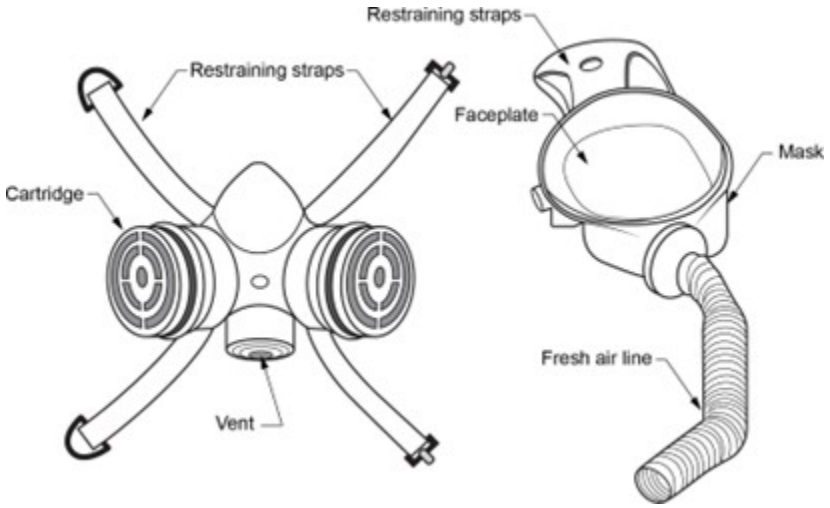

Figure 10 *Cartridge respirator and air-line respirator (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Air-line respirators must be worn during welding or flame cutting operations done either in the presence of toxic fumes

or in confined spaces where oxygen levels in the air are inadequate. Typical operations of this kind include the repair of leaks in pipes or tanks containing toxic chemicals or repair work to the inside of large tanks or vessels.

A second type of respirator used for similar operations is the ***self-contained breathing apparatus* (SCBA)**. Rather than using air from a fresh outside source, this unit draws air from an oxygen cylinder strapped to the worker's back.

The ***cartridge-type respirator*** (Figure 10) is used only for emergency escape. The cartridge in the respirator is able to neutralize the toxic gases for a very short time, allowing you just enough time to get out of the area. In work settings where there is a danger of toxic gas leaks, workers carry this type of respirator on their person at all times. Cartridges are available for different gases, and most types of cartridge provide protection against a range of gases.

Figure 11 *OV/P100 cartridge-type respirator (Jcallah/Wikimedia Commons)* CC BY-SA 4.0 (*https://creativecommons.org/licenses/by-sa/4.0*)

Employees required to wear respirators should keep their equipment clean and sterilized. When not in use, the equipment should be stored in closed containers. The equipment should be inspected regularly for wear or damage. A program should be set up to control the selection, fitting, testing and maintenance of the equipment.

Self-Test B-6.1: Describe Safety Requirements and Precautions for Arc Welding

Complete Self-Test 6.1 and check your answers.

If you are using a printed copy, please find Self-Test A-6.1 and Answer Key in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=3037#h5p-18 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=3037#h5p-18)

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- Sprinkler Fitter (Harmonized 2018)
- Plumber: Competency B-7 Use Welding Equipment
- Steamfitter: Competency B-5 Use Welding Equipment

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B-6.2 Identify Types of Welds, Positions, Joints and Symbols

Identify Weld Types

There are five types of welds used in non-pressure welding (Figure 1):

- Bead weld
- Tack weld
- Fillet weld
- Groove weld
- Plug and slot weld

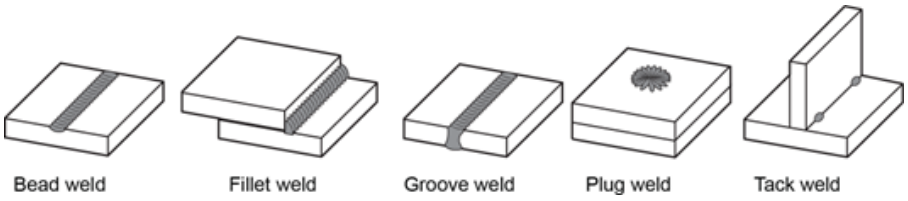


Figure 1 *Weld types for non-pressure welding (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Bead Welds

Bead welds are single-pass deposits of weld material used to build up the surface of metal or to replace metal on worn surfaces. Bead welds used for this application are commonly called ***hardsurfacing or hardfacing***.

Tack Welds

Tack welds are a series of short welds used to hold the joint assembly in place during the *fit-up procedure* (Figure 2). Each tack weld is a short (sometimes temporary) weld approximately 13 mm ($\frac{1}{2}$„) in length. Tack welds are usually deposited at both ends of the joint and at approximately equal intervals along the length of the joint.

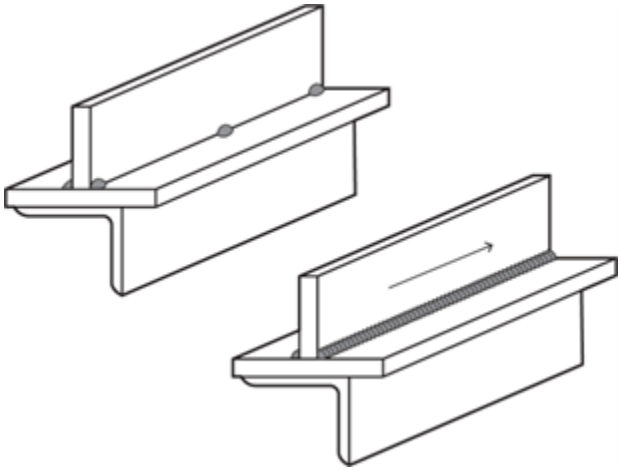


Figure 2 *Tack welds (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

On tee joints, tack welds are often used along the opposite side of the weld to prevent the upright plate from leaning toward the weld (Figure 3).

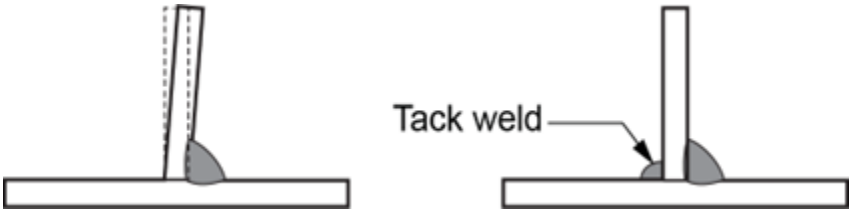


Figure 3 *Tack weld (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Fillet Welds

Fillet welds are used extensively on lap, tee, and corner joints where they join two pieces of metal that are usually at right angles (90°) to each other. A fillet weld consists of one or more beads or layers that are roughly triangular in cross-section. The features of a typical fillet weld on a tee joint are shown in Figure 4.

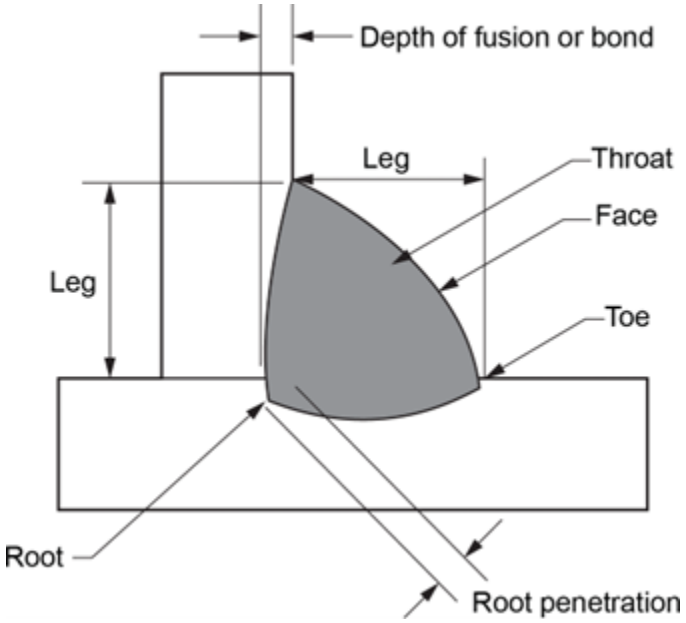


Figure 4 *Ideal fillet weld (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The ideal fillet weld is characterized by:

- Joint faces at right angles (90°)
- Face that is flat or slightly convex
- Toes that merge smoothly with the surface of the joint members
- Legs of equal length

In many cases, fillet welds are more economical than groove welds, in that they are easier to assemble and require less edge preparation. They generally require more weld material and are less able to withstand high stress loads.

Fillet welds are not considered capable of carrying stress loads unless their length is at least four times the size of the weld. Stress-carrying fillet welds connecting material up to 25 mm (1″) thick should not be less than 10 mm ($\frac{3}{8}$„) in size.

Groove Welds

Groove welds fill in the gap or groove between two pieces of metal. Groove welds are most commonly used on butt joints, although the weld on an open corner joint or on specially prepared lap and tee joints can sometimes be considered a groove weld.

Groove welds consist of a root bead, a hot pass, fill passes and a cap (Figure 5). The number of passes will vary, depending on the thickness of the material. On thinner metal, the hot pass and fill pass can be combined into one pass and, in some cases, a single pass is adequate for the entire weld.

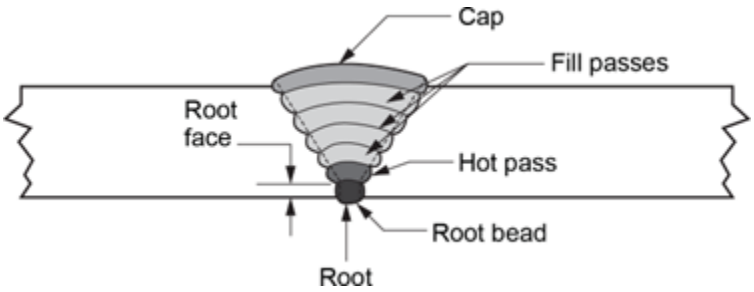


Figure 5 *Groove weld (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The significant dimensions of groove welds are shown in Figure 6. These include the ***root opening***, the ***root face (or landing)***, the included angle, the thickness and the throat. On bevelled joints, the bevel angle is important and, on joints with a J preparation, the ***root radius*** is significant.

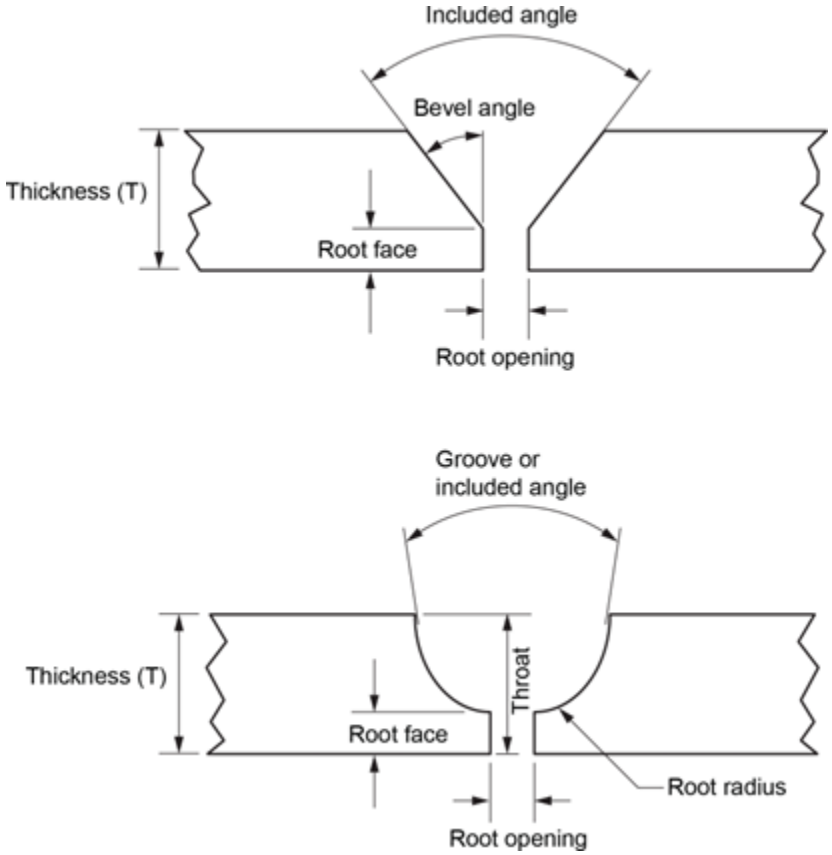


Figure 6 *Groove weld dimensions (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The size of the root opening, the root face, the included angle, and the root radius all have bearing on the amount of weld material required and on the depth of penetration. For example, too large a root opening, face or included angle will result in excessive penetration and the deposition of unnecessary weld metal, while dimensions that are too narrow will make full penetration extremely difficult, if not impossible. If the root radius on a U-joint is too great, an excessive amount of weld material will be deposited and the possibility of uncontrollable distortion increases.

The selected dimensions for these dimensions will depend on the material thickness, electrode size and the welding process.

Groove Weld Size and Profile

The size of ***groove welds*** is determined by the depth of weld penetration in the groove or gap between the two pieces. In Figure 7, the weld size in A (where penetration is complete) is the same as the thickness of the plate. Where penetration is incomplete, as in B, the weld size is the depth of the penetration. In C (where the plates differ in thickness and there is complete penetration), the weld size is the thickness of the thinner plate.

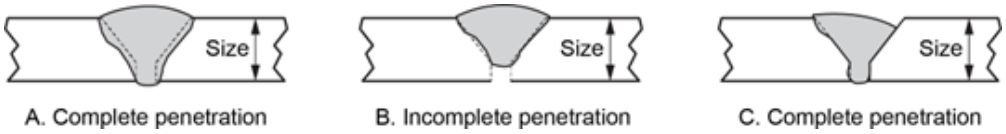


Figure 7 *Groove weld sizes (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Metal deposited above the surface of the plate is called reinforcement. Profiles of groove welds show the amount of reinforcement at the centre of the weld bead (Figure 8). This reinforcement must not exceed 3 mm ($\frac{1}{8}$„) as excessive reinforcement is uneconomical and contributes nothing to the strength of the weld. It decreases the working strength of the joint because stresses concentrate at the toe of the weld.

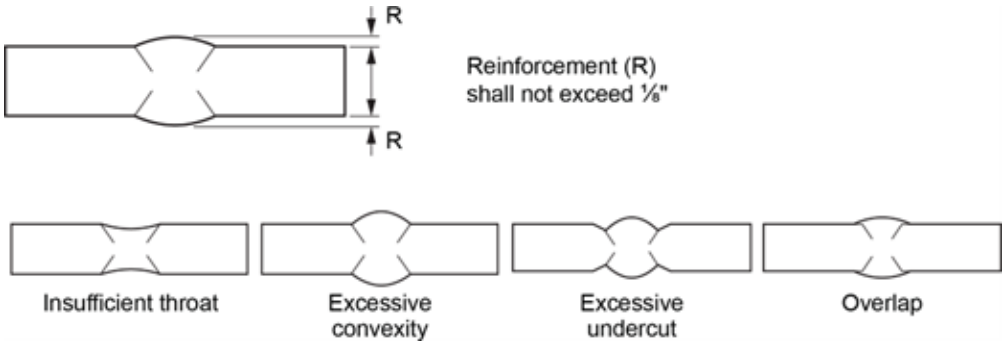


Figure 8 *Groove weld profiles (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Reinforcement may be removed by gouging or it must be built up uniformly from the surface of the parent metal to the maximum 3 mm ($\frac{1}{8}$„) at the centre of the weld. There must be no valley or groove along the edge or in the centre of the weld.

The width of a groove weld should not extend more than 3 mm ($\frac{1}{8}$„) beyond the shoulder or edge of the joint on either side. Extra deposit beyond this is uneconomical because there is no corresponding increase in joint strength.

If you're unsure which weld to use, start by identifying the **joint type** first.

Five Basic Joint Types

There are five basic ***weld joints*** used in welding (Figures 9 and 10). Within these five, however, are many variations and the selection of a particular joint or variation is based on four important factors:

- The load applied to the weld (for example, compression, torsion, bending, or fatigue)
- The way the load is applied (for example, sudden, variable, or steady)
- The thickness of the base metal
- The cost of the joint preparation and welding time

The five basic weld joints are defined below:

Butt Joint: A joint that joins two pieces of metal in the same plane.

Corner Joint: A joint that joins two pieces of metal at right angles, formed at the ends of both pieces in an L shape.

Edge Joint: A joint that joins two pieces of metal that are turned up at the edges; also known as a flange joint.

Lap Joint: A joint that joins two pieces of metal that overlap one another.

Tee Joint: A joint that joins two pieces of metal at right angles, forming a "T" shape.

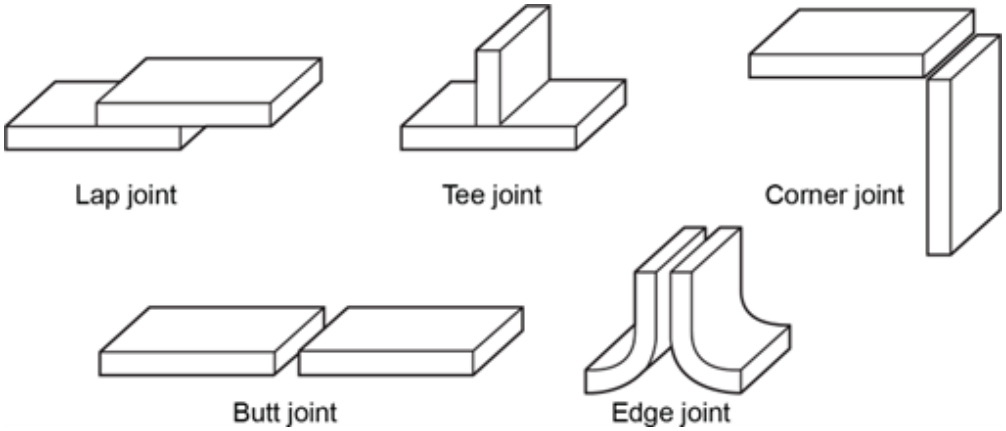


Figure 9 *Five basic joints (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

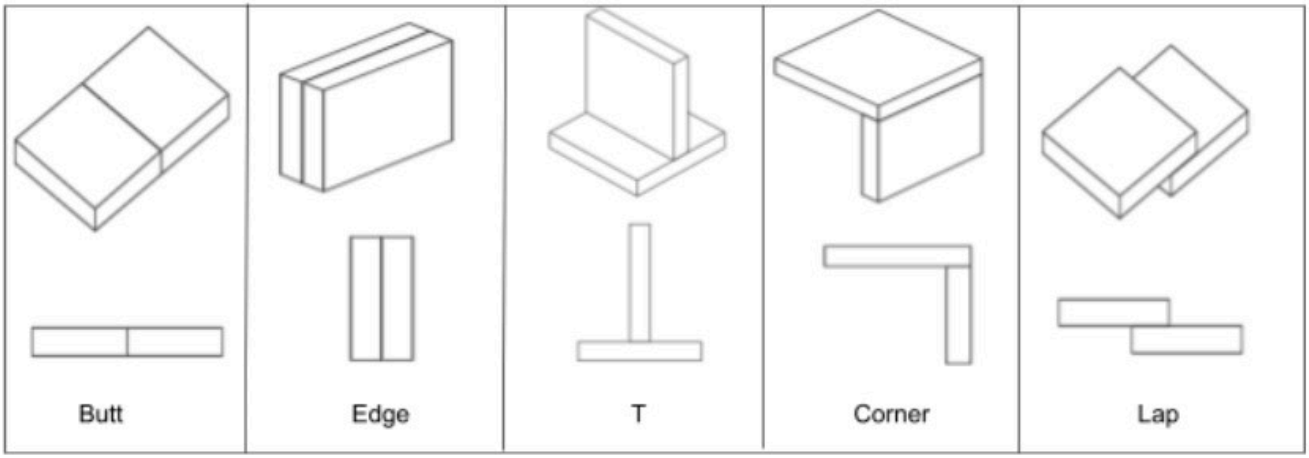


Figure 10 *Basic joint types (Cameron Kjeldgaard/OpenWashington) CC BY 4.0 (http://creativecommons.org/licenses/by/4.0)*

Variations in Joint Design

Variations in the five basic designs are a result of the different preparations that can be applied to the edges of the joint. Edge preparation is necessary on thicker material to ensure full penetration of the joint.

Tee Joints

The ***square tee joint*** requires no edge preparation and is widely used because it is relatively inexpensive and easy to fit. On thicker material, the edges may be prepared with a single bevel, double bevel, single J or double J (Figure 11).

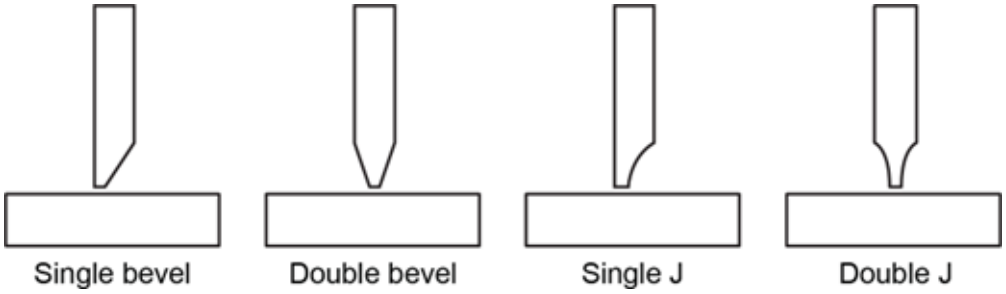


Figure 11 *Edge preparations for tee joints (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Tee joints that are welded on only one side (single-welded) are satisfactory for only light static loads. For heavy or fluctuating loads, tee joints need to be welded on both sides (double-welded) to increase their strength.

Tee joints are relatively easy to design and they provide maximum access for welding, however, there is a high possibility of distortion. An additional drawback is the expense of tee joints in terms of the weld material, especially on larger tee joints and on joints that need to be welded from both sides.

Lap Joints

Lap joints require little or no edge preparation. On thicker material, a single bevel is all that is usually required. Lap joints are often selected for welds between two materials that have different thickness.

For welds that do not require great strength, a single lap joint may be selected to provide a "tight" joint. However, single lap joints must not be used for welds that will be subjected to fluctuating, bending or twisting loads. For these types of loads, the joint can be welded from both sides, or a double lap joint can be selected (Figure 12).

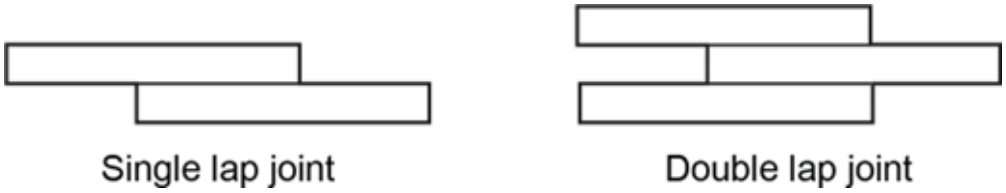


Figure 12 *Variations on lap joints (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Lap joints have two significant drawbacks. As with tee joints, the material requirements are high, so maximum tensile strength can only be achieved when the overlap is five times the thickness of the thinner member. Also, under stress loading, the joint tends to lose its strength.

Corner Joints

There are two types of ***corner joints***, the open corner and the closed corner (Figure 13).

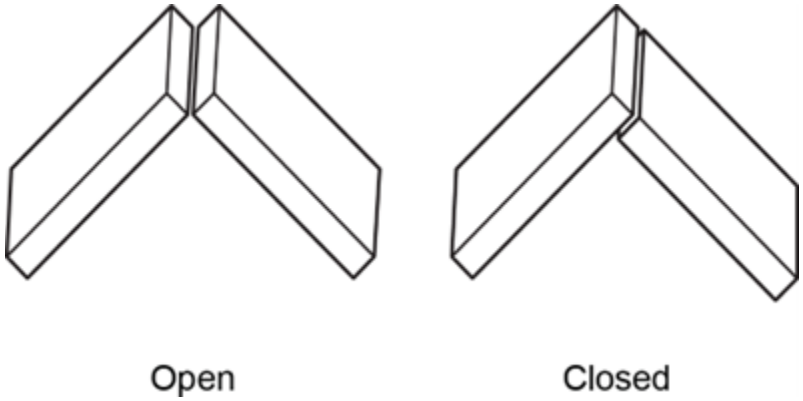


Figure 13 *Types of corner joints (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The open corner joint is more frequently used than the closed corner. Penetration is usually excellent, resulting in a full strength weld. With the closed corner, penetration is impossible on all but light-gauge sheet metal. On thicker material, edge preparation is required (Figure 14). In addition to the edge preparation, a small opening is often left between the two pieces in order to ensure full penetration.

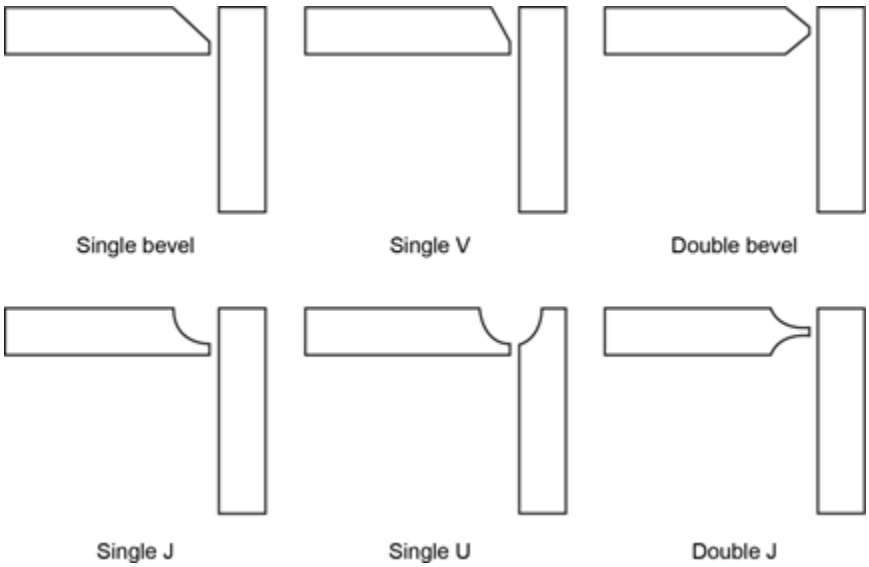


Figure 14 *Edge preparation for corner joints (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Although square corner joints are relatively easy to prepare and assemble, the variations using the bevel, the J and the U preparations require more skill and time to accurately fit the joint.

Corner joints are not satisfactory for heavy stress loading, particularly if welded from only one side. They are not normally used in construction, especially where the tension from bending is concentrated at the root of the weld. For some applications, corner joints may also be welded from the inside to increase their strength, a procedure that significantly increases the cost of the weld.

Edge Joints

Edge or flange joints are most commonly used on light-gauge material such as sheet metal. The edges of the sheet metal are turned up in a device called a *brake*. The turned-up edges reduce the danger of burn through on thin materials and at the same time help to prevent distortion. On thin materials, no additional filler metal is required. If selected for plate, the edges must be prepared with one of the variations shown in Figure 14 in order to ensure sufficient penetration.

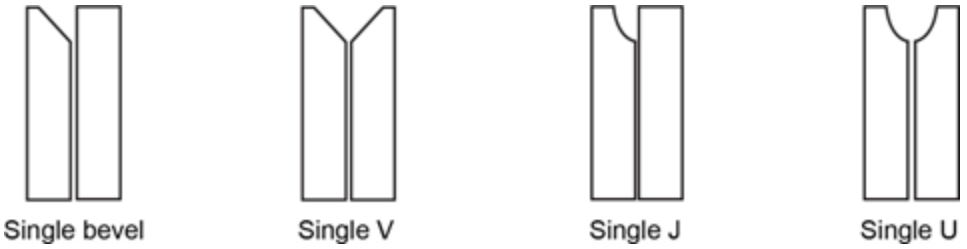


Figure 15 *Edge joints (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Butt Joints

Butt joints are the most widely used of the five designs. Like tee joints, butt joints provide maximum accessibility for welding. They use a minimum of weld material and, with 100% penetration, they are effective for all types of stresses. They are the preferred joint for resisting fatigue stresses if complete penetration is assured. The strength of correctly prepared and welded butt joints compares very favourably with the strength of the parent metal.

On thin metal, complete penetration and full strength can be achieved using a square butt joint without extensive edge preparation. On thicker metal, edge preparation becomes increasingly extensive. Two basic designs are used (Figure 16), the bevel and the J. These edge preparations result in eight butt joint variations.

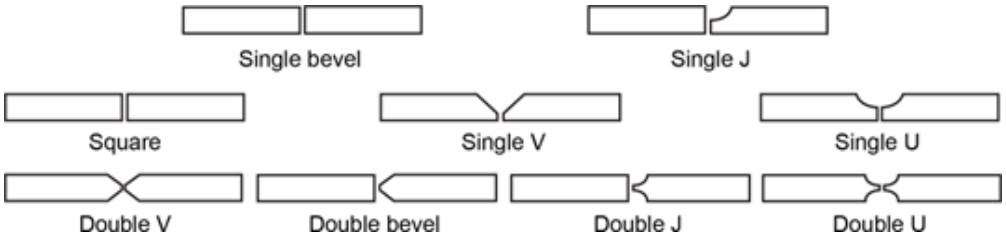


Figure 16 *Edge preparation on butt joints (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

When joints are prepared and welded from both sides, they are called ***double joints***. When welded from only one side, they are called ***single joints***. To ensure complete penetration, a backing strip or plate is often required.

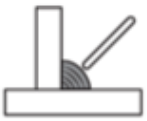
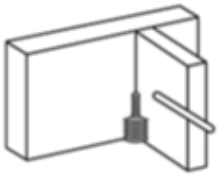
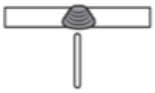
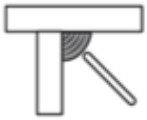
The drawbacks of the butt joint are primarily in the skill and accuracy required of the welder in fitting and welding the joint. Of the five joints, the butt joint is the most difficult to master. These joints require considerable experience to become proficient in preparing and welding because they often require extra time for back gouging or extra material for backing.

Welding Positions

There are four basic welding positions: flat, horizontal, vertical and overhead. Welding techniques for the four positions vary according to the ease of depositing the metal. Welding in the flat position is generally faster and less tiring than the other three positions and, whenever possible, you should try to place your workpiece in the flat position.

The term "***position welding***" refers to welding in the flat position. The term "*welding out of position*" refers to welding in any of the other three positions. Table 1 and Figure 17 show the four positions that are used.

Table 1: Welding Positions

Position of Weld	Groove	Tee-joint Fillet
Flat		
Horizontal		
Vertical		
Overhead		

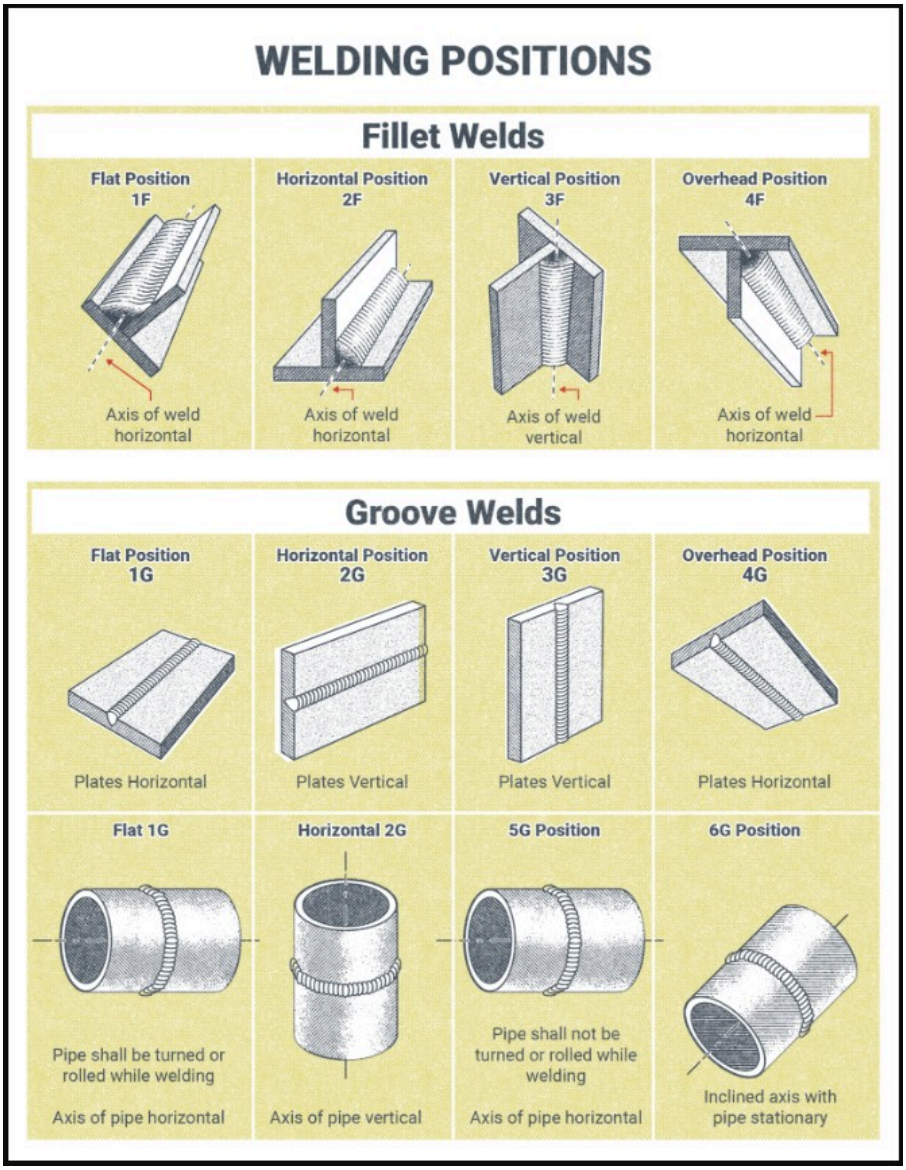


Figure 17 *A welding position is determined by the orientation of the weld axis and weld face. Welding position is a critical factor that influences required welding technique, electrical settings, and electrode selection. (Nicholas Malara/OpenWashington) CC BY 4.0 (http://creativecommons.org/licenses/by/4.0)*

Flat Position

In the flat position, the workpiece is positioned so that the joint is parallel to the floor and the electrode generally points downward. For butt joints on plate, the two pieces are simply placed on a flat surface. For lap and tee joints the two pieces of plate must be supported in an angled position so that the actual joint is parallel to the floor (Figure 18). With corner joints, the ends of the plate are positioned on a flat surface so that the two pieces meet at the top to form a small tent.

Figure 18 *Joints in the flat position (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Horizontal Position

Welds in the horizontal position are also parallel to the floor, but they are done along a vertical surface. Weld metal is deposited from the upper side of the joint. For butt joints, the electrode is held horizontally (parallel to the floor), but for the other four joints, it is usually either slightly higher or lower than horizontal, depending on the technique used. For butt joints, the two plates are supported in the vertical position, but the lap, tee and edge joints can be set up and welded on a flat surface. With horizontal welds, the main difficulty is that gravity causes the molten puddle to drip from the lower side of the weld.

Vertical Position

In the vertical position, the plate to be welded is positioned vertically and the weld itself is vertical. The direction of travel may be up or down, but the majority of vertical welding is usually done from bottom to top. The electrode points slightly upward. As with horizontal welding, gravity causes the molten metal to pull away from the edges of the bead and, unless the weld puddle is correctly controlled, molten metal will drip.

Overhead Position

The overhead position is the reverse of the flat position in that the weld is done from the underside of the plate with the electrode pointing upward rather than downward. Overhead welding is considered the most difficult to master. In the overhead position, the force of gravity pulls the molten metal from the toe of the weld bead to the centre of the bead where it can drip or form icicles.

Abbreviations for Weld Position and Weld Type

Abbreviations can be used to indicate the type of weld and the welding position. A fillet weld is often abbreviated to an F, and a groove weld to a G.

Each weld position is designated with a number as follows:

- Flat position (1)
- Horizontal position (2)
- Vertical position (3)
- Overhead position (4)

For example, 1G indicates a groove weld in the flat position; 3F indicates a fillet weld in the vertical position, and 4G would indicate a groove weld in the overhead position.

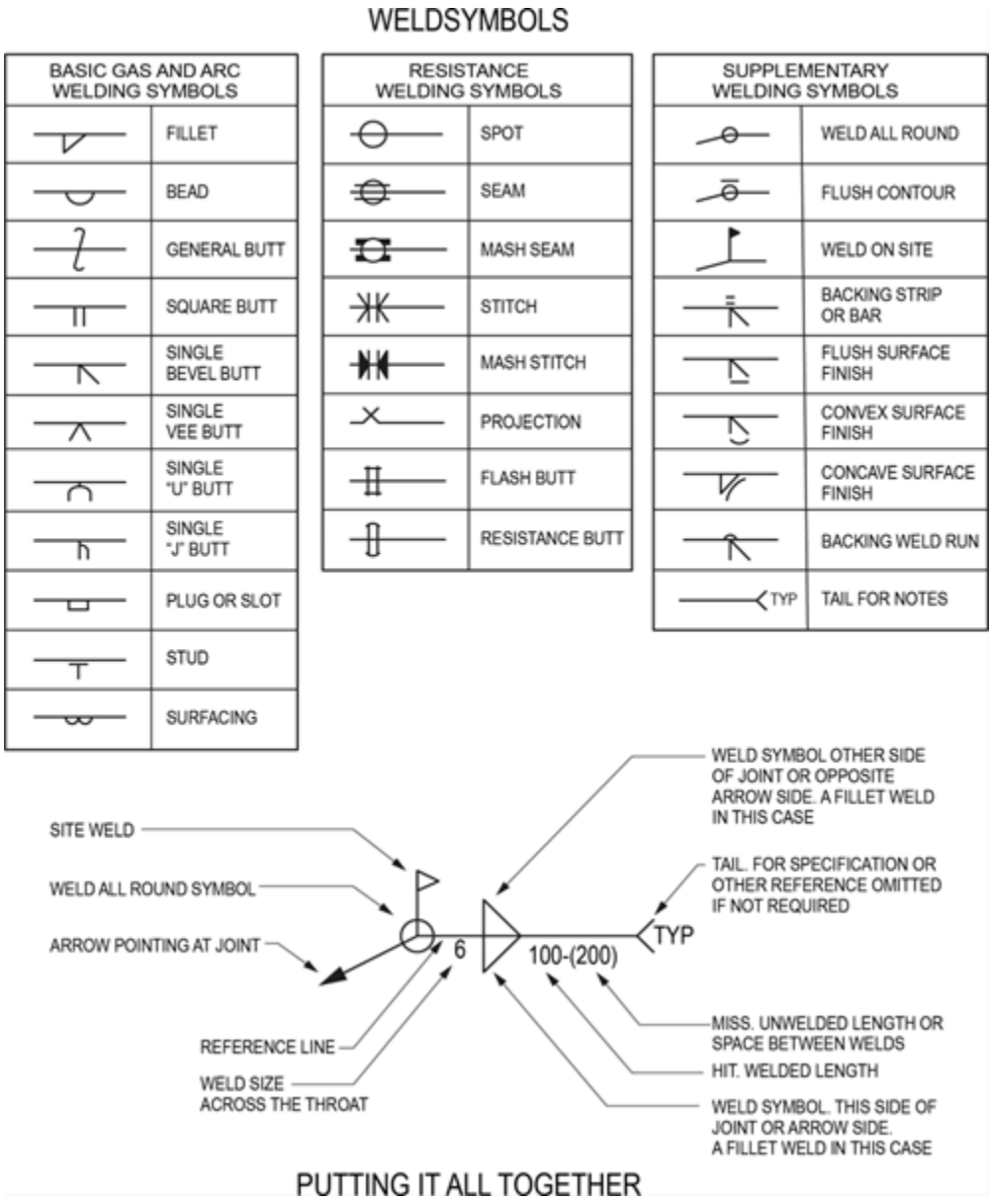


Figure 19 *Weld symbols (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Additional Demonstration Videos and Resources

The following videos provide additional demonstrations of common weld types and joint configurations. These resources are intended to reinforce the concepts introduced in this section and to help you visualize proper welding techniques, positioning, and weld profiles in practice.

- Fillet Welds (Tee / Lap / Corner Joints): *Welding SMAW – How to weld a fillet* (https://www.youtube.com/watch?v=rZGCbBty4zM) [10:49] by IMAT (2019)
- Groove Weld (Butt Joint): *Welding SMAW – How to weld a flat V-groove (https://www.youtube.com/watch?v=RGmgFtS5Np0)*[17:13] by IMAT (2019)
- Fillet + Groove Practice (Combined Context): *Tacking up practice welds for fillet and groove welds. Excellent practice exercise.* (https://www.youtube.com/watch?v=CBb780iu1fA)[7:15] by Mark Prosser Welds (2019)
- SMAW Fillet Weld (More Technical / Reinforcement): *ARCademy: Fillet Welds SMAW* (https://www.youtube.com/watch?v=fAc1elsA2R0)[9:52] by American Welding Society (2021)

Self-Test B-6.2: Identify Types of Welds, Positions, Joints and Symbols

Complete Self-Test 6.2 and check your answers.

If you are using a printed copy, please find Self-Test A-6.2 and Answer Key in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=3042#h5p-19 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=3042#h5p-19)

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Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-5: Use cutting, brazing and soldering equipment (Plumber)*. Crown Publications, Queen's Printer for British Columbia.

Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-6: Use oxy-fuel cutting equipment (Plumber)*. Crown Publications, Queen's Printer for British Columbia.

Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-6: Use soldering and brazing equipment (Steamfitter)*. Crown Publications, Queen's Printer for British Columbia.

Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-7: Use oxy-fuel equipment (Steamfitter)*. Crown Publications, Queen's Printer for British Columbia.

Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-7: Use welding equipment (Plumber)*. Crown Publications, Queen's Printer for British Columbia.

Rupik, D., Colameco, D., Kjeldgaard, C., Ridge, D., Oostman, S., & Fulton, K. (n.d.). *Introduction to welding*. Washington State Board for Community and Technical Colleges. https://openwa.pressbooks.pub/welding1/

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- **Figure 10** Basic Joint Types (https://openwa.pressbooks.pub/welding1/chapter/wa15-1/) (Figure 15.1) by Cameron Kjeldgaard, for WA Open ProfTech, © SBCTC (http://sbctc.edu/), is used under a CC BY 4.0 (https://creativecommons.org/licenses/by/4.0/) license.
- **Figure 17** Open vs. Closed Root (https://openwa.pressbooks.pub/welding1/chapter/wa15-1/) (Figure 15.4) by

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B-6.3 Describe the Arc Welding Process and Equipment

Principles of SMAW

***Shielded metal arc welding* (SMAW)** is commonly referred to as *stick welding* or *electric arc welding*. An electric arc is the bridge of light and heat that develops when an electric current is forced to leap across a small gap that has been formed in an electric circuit. In the SMAW process, the welding equipment is designed to maintain this arc, and the metals are fused by the intense heat the arc generates.

The flow of electricity in an electric circuit is comparable in many ways to the flow of water in a pipeline. Water flows from a tap because there is pressure in the system. This pressure forces the water to flow through the pipes. The greater the pressure, the more water will flow through a given pipe. The pressure of water in a system is measured in kilopascals (kPa) or in pounds per square inch (psi). The flow of water is measured in cubic metres per hour (m^3/h) or in cubic feet per hour (ft^3/h).

The electricity that flows through the conductors of an electric circuit does so because there is electrical "pressure" created by a generator at the power source. This electrical pressure is called ***voltage*** and is measured in ***volts* (V)**. The flow of electricity is called ***current*** and is measured in ***amperes* (A)**.

To do useful work, an electrical current must flow through the conductors in a closed electrical circuit. If for some reason this circuit is broken (or opened), the flow of electricity will stop. Electrical pressure (*voltage*) will continue to exist while the generator runs, and current will resume as soon as the circuit is completed (closed) again. An arc welding circuit is basically an electric circuit that the welder can close and open as required.

Figure 1 *Shielded metal arc welding Lincoln Excalibur 7018 1/8″ (Prowelder87/Wikimedia Commons)* CC BY-SA 4.0 (*https://creativecommons.org/licenses/by-sa/4.0*)

Applications of SMAW

Almost any requirement for welding mild and stainless steel and cast iron can be accomplished using the SMAW process. Its uses include:

- Shipbuilding
- Locomotive and boiler making
- Structural work
- Engineering applications
- Building
- Maintenance and repair of industrial and farm equipment
- Light gauge welding
- The assembly of automobiles
- The welding of pipelines

Figure 2 *Gas pipeline welding (Hamid Soufi/Wikimedia Commons) CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0)*

Power Source

The welding machine that provides the source of power for arc welding is an extremely important part of the process. Power sources for SMAW may supply either ***alternating current (AC)*** or ***direct current (DC)***. They also have controls so that the welder can vary the current to meet the requirements of different welding tasks, materials, and positions.

Alternating Current

With AC, the direction of current flow rapidly reverses 120 times per second. A complete direction change from zero to maximum volts at one pole, then back to zero volts and up to maximum voltage at the other pole is called *a* ***cycle*** and occurs 60 times per second. Most electrical utility companies distribute alternating current at 60 cycles per second. This means that 60 times a second the voltage reaches a maximum in one direction, and 60 times per second it reaches a maximum voltage in the other direction.

Some of the characteristics of alternating current can be represented in the form of a ***sine wave*** diagram (Figure 3).

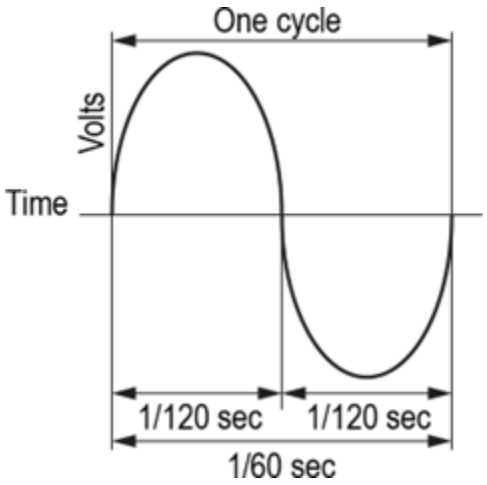


Figure 3 *Alternating current sine wave (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

In comparison with the rapid fluctuations of alternating current, DC current flows from one pole continuously without fluctuation (Figure 4).

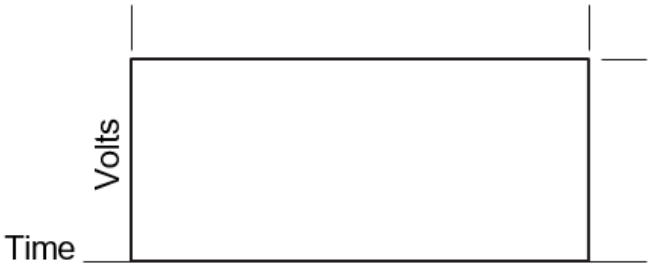


Figure 4 *Direct current level (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Alternating current may be ***single-phase* AC** (Figure 5) or ***three-phase* AC** (Figure 6).

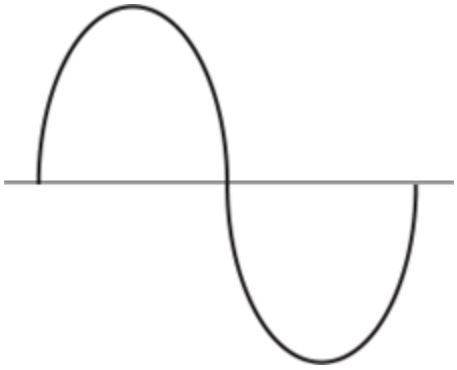


Figure 5 *Single-phase AC (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

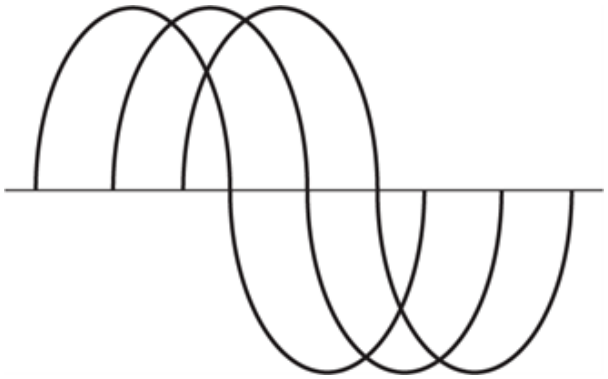


Figure 6 *Three-phase AC (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Single-phase AC power is useful for most domestic and light industrial operations. However, as Figure 5 shows, there is a considerable period of time during each cycle when less than maximum power is being delivered. This makes single-phase power inefficient for heavy industrial uses, including some welding applications.

Three-phase AC power is more often used for industrial jobs. Three-phase AC power utilizes three single-phase currents timed to start at regular intervals from each other (Figure 6). The advantage of three-phase power is that even though one phase may be delivering only minimum power, one of the other two phases will be delivering nearly maximum power. Welding machines that use three-phase power are generally more compact and produce a smoother arc than single-phase machines.

Direct Current

With ***direct current***, the electrons in a circuit flow in one direction only from the negative to the positive pole. This type of current is produced by DC generators and by batteries.

Polarity

Electron flow in an electrical circuit is always from the negative pole to the positive. However, the practical effects of this for welding are more important with DC welding current (Figure 7). With direct current, the electron flow is in one direction only and, depending on how you connect the circuit, the current flow can be made to affect the heat of the ***electrode*** or of the workpiece.

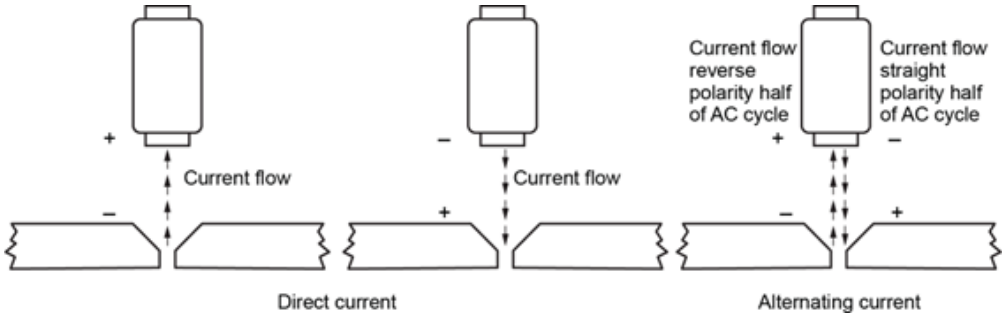


Figure 7 *Effects of polarity (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The ***polarity*** of a DC welding circuit can be used in two ways:

- **DCEN** (DC electrode negative) connects the welding circuit so that the electrode is attached to the negative pole of the power source to concentrate heat in the workpiece (Figure 8)
- **DCEP** (DC electrode positive) connects the welding circuit so the electrode is attached to the positive pole of the power source to concentrate heat in the electrode

When using coated electrodes in SMAW, DCEN (negative) generally allows for faster welding speeds and for higher filler rod deposit. It provides a medium depth of penetration. With DCEP (positive), the heat can be concentrated at the electrode. With this polarity, you can achieve a deeper penetration in the weld, but the welding speed is slower.

Controls

On most DC motor and engine-driven generators for SMAW, there are controls for both current and voltage levels. That way, the welder can alter the shape of the volt-amp curve and adjust the characteristics of the arc to suit the requirements of a particular welding task. These machines are called ***dual-control machines***.

The controls may be of the tapped type (offering a range of specific settings) or the continuous control type that allow for infinite setting adjustment. On the tapped or stepped type of control, the dial must be set precisely on a given setting. Current values between settings cannot be obtained, and the device may suffer damage if you attempt to place the dial between settings. Instead, the fine adjustments that you require to accommodate the metal thickness, electrode size and type, and welding position for a given job are secured by using the fine adjustment control.

On machines with dual continuous controls, the ***coarse adjustment dial*** (sometimes known as the *job selector dial*) allows for continuous variation of current level. The second of the two controls allows for fine adjustment of the current and voltage. By manipulation of the two dials together, the slope of the volt-amp curve can be adjusted for any particular current level within the output range of the machine.

Fuel-Engine-Driven AC and AC/DC Welding Machines

A fuel engine can also be made to drive an alternator to produce AC current. As with the transformer/rectifier described earlier, some alternator machines feed the current into a rectifier to make DC current available in the same machine. The control devices on these welding machines are essentially the same as those described for the DC generators.

The Arc Welding Circuit

The SMAW welding circuit consists of:

- A power source
- A ground cable and clamp
- An electrode cable
- A welding electrode and electrode holder
- The workpiece

When the electrode is touched to the workpiece and then withdrawn a short distance, the arc is struck and the electrical circuit is completed. The current flows through the electrode, across the arc, through the workpiece, and through the ground clamp and cable, then returns to the power source.

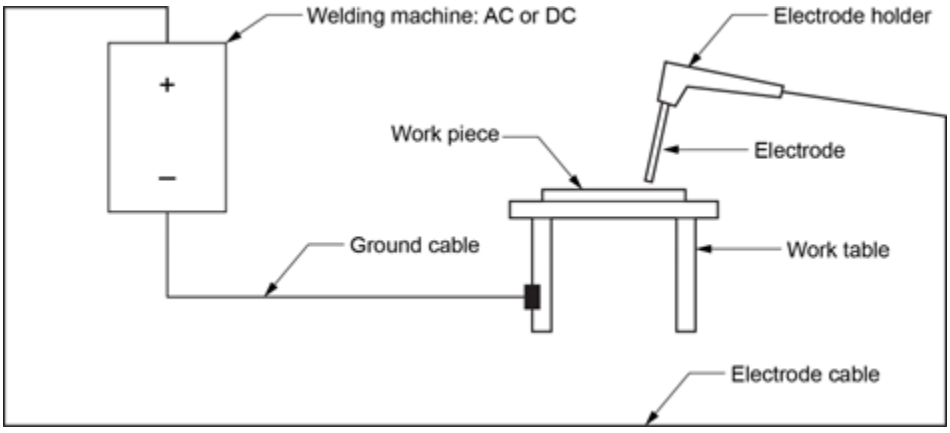


Figure 8 *Arc welding circuit (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The SMAW Process

When the power source for a welding circuit is turned on, but before the arc has been struck, the circuit is open. At this point, the voltage or the potential in the circuit is at its maximum and is called the "***open-circuit voltage.***" The moment the welder strikes the arc, the circuit is closed (completed), the voltage drops to what is called the "***arc voltage***," and the high current in the welding circuit flows.

As the current crosses the arc from the electrode to the workpiece, tremendous heat is generated (anywhere from 5532 °C to 6632 °C). The heat melts the end of the electrode and the parent metal in the workpiece directly beneath the arc, forming a pool of molten metal. As the electrode melts, small particles of molten metal are carried across the arc stream and deposited in the molten pool on the parent metal, forming the ***weld deposit***. This weld deposit is actually a mixture of the melted electrode and the melted parent metal. At the same time, the force of the arc digs into the workpiece and provides the necessary depth of penetration for the weld.

Electrodes

The electrodes used in the SMAW process are not bare but are covered with a ***flux***. They have a core that consists of either a solid metal wire or a metal tube containing metal powders. The metal core conducts the electric current to the arc and provides the ***filler metal*** for the weld joint. This filler metal is deposited as the electrode is gradually consumed and as the welder moves the arc over the workpiece at the correct arc length and travel speed.

The coating of the electrode helps keep the arc stable and concentrated on a precise point on the weld. As the chemicals in the electrode coating are vapourized, they provide the shielding required to protect the molten metal from contamination by the atmosphere, hence the name "*shielded metal arc welding*."

Welding electrodes are both fragile and expensive, so they require careful treatment. This treatment must be exercised both before and during the use of an electrode.

Handling of Electrodes Before and After Use

Handle electrodes with great care to avoid breaking or cracking the coating. An electrode that has received damage to the coating will usually perform poorly and, if pieces of the coating are actually missing, the result may be slag inclusion in the weld.

Because electrodes with very different properties may look the same, correct handling of electrodes also includes marking them accurately after the package has been opened. It is equally important to collect and clearly mark unused electrodes that are being returned to storage. Do not risk producing a weld that does not meet specifications because you used the wrong electrode. An electrode that is not clearly identified should be considered unusable.

Storage of Electrodes

A perfectly dry electrode is essential for a satisfactory weld. **The main requirement for storage of electrodes is keeping them dry.** In addition to being fragile, the composition of electrode coatings allows them to pick up moisture from the air. Prolonged exposure to moisture can result in disintegration of the coating. Even if the disintegration is not obvious, the heat of the arc will blow away portions of the coating. In either case, the electrode is rendered useless and must be discarded. Low-hydrogen electrodes must be thrown away if they have been directly exposed to water.

Moisture that is absorbed by an electrode contains hydrogen and, during welding, some of this hydrogen is transferred to the weld metal. This can lead to a number of problems with the weld. Depending on the composition of the base metal, these problems can include ***embrittlement***, ***porosity***, cracking of the weld, and a rough weld appearance. In

addition, welding with a moist electrode increases the arc voltage, increases weld spatter, and makes slag removal difficult.

Some electrodes (such as mineral-coated ones) are more prone to absorbing moisture than others.

The length of time electrodes can be exposed to the atmosphere varies from 30 minutes to 4 hours or longer, depending on the relative humidity of the atmosphere. For example, with low-hydrogen electrodes, the maximum exposure time is between two and four hours, depending on the relative humidity. With all electrodes, it is impossible to tell simply by visual examination whether they have absorbed dangerous amounts of moisture.

To protect electrodes from moisture, manufacturers ship them in air-tight containers. Sealed portable containers are used on the job for storing the supply of electrodes.

Electrode Ovens

Some electrodes can be safely stored in normal room conditions, provided that temperature and relative humidity do not exceed certain normal tolerances. ***Electrode ovens*** are widely used to guarantee a humidity-controlled environment for storing electrodes. Ovens are essential for the more sensitive low-hydrogen and hardsurfacing types and for special alloy electrodes such as stainless steel, brass, bronze, aluminum, ***inconel*** and ***monel***. Electrode ovens may be the large type found in welding shops capable of holding several hundred pounds of electrodes or the smaller field ovens that can be connected to an auxiliary power supply.

Ovens are also useful for restoring electrodes that may have been exposed to a certain level of moisture, but that can be rebaked to make them usable. Electrode manufacturers and suppliers provide information on storage and rebaking conditions for their electrodes and, if available, these recommendations should be followed.

Electrode Holder

The ***electrode holder*** (Figure 9) or "*stinger*" is the device used to carry the welding current to the welding electrode. It is also the means by which the welder holds the electrode while welding. The two most common types of electrode holder are the jaw type and the twist-head type. The jaw type grips the electrode between two jaws activated by a powerful spring. The twist-head type secures the electrode in place through the screw action of the head. The handle of any type of electrode holder is extremely well insulated to protect the welder against electric shock and heat.

Figure 9 *Electrode holders (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Because it is the part of the welding circuit that the welder actually contacts, the electrode holder must be kept clean and in good condition to minimize any risk of shock. Replace any damaged insulation and clean the grooves of the jaw to remove any weld spatter that has collected.

The connection between the welding cable and the holder is a vulnerable point in the welding circuit because it is constantly being flexed during welding operations. This connection is usually mechanical and must be inspected every time you weld.

Ensure that the connection is tight. Loose connections increase electrical resistance and cause additional heat that can wear down insulation. Check the connection for broken strands of cable, as these too can cause heat buildup and can deteriorate the insulation. Should the connection have broken strands, cut off the damaged end and make a new connection, either mechanically or by soldering or brazing, before you start any welding.

Ground Clamps

At the other end of the welding circuit is the ***ground clamp*** or *ground connection*, which is necessary to make the welding circuit complete.

Without a good ground connection, there can be a loss of power through increased resistance, a risk of fire from sparking, and increased danger of electric shock.

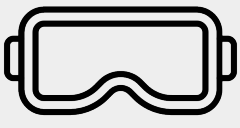
The ground connection may be attached to a welding table or bench that is equipped with a permanently bolted or tack-welded lug or with an insulated terminal. If welding is not being done on a welding bench, the ground may be connected to the workpiece by means of a clamp. Clamps are of different types, the most common being the spring-loaded, C-clamp, rotary clamp, and magnetic clamp.

Electrode Stubs

Electrodes should be used down to a stub length of 50 mm (2″) or less. These ***electrode stubs*** should be disposed of in fireproof metal containers. If you throw them on the floor, they create a slipping hazard.

Slag

The coating that forms on the top of an arc weld is called ***slag***. When it is first deposited it is very hot. It has to be removed after it has cooled and has become solid and hard. As you chip off slag, ensure that fragments do not hit you or anyone else.



Do not look directly into a laser beam! Looking directly into the beam may be hazardous to your eyes. A quick flash of the beam is not a problem, but prolonged exposure should be avoided. The instrument must be positioned either above or below the worker's line of sight.

Portable Grinders

Grinders are used to prepare metal for welding, clean fresh welds, and remove weld faults to be re-welded.

When the workpiece is too large to bring to a bench or pedestal grinder, you can grind it by using a portable grinder. Portable grinders may be powered by compressed air or by electricity and are classed as either straight grinders or angle grinders.

Straight Grinders

Straight grinders are so named because the drive shaft, which turns the grinding wheel, is aligned with the motor (Figure 10).

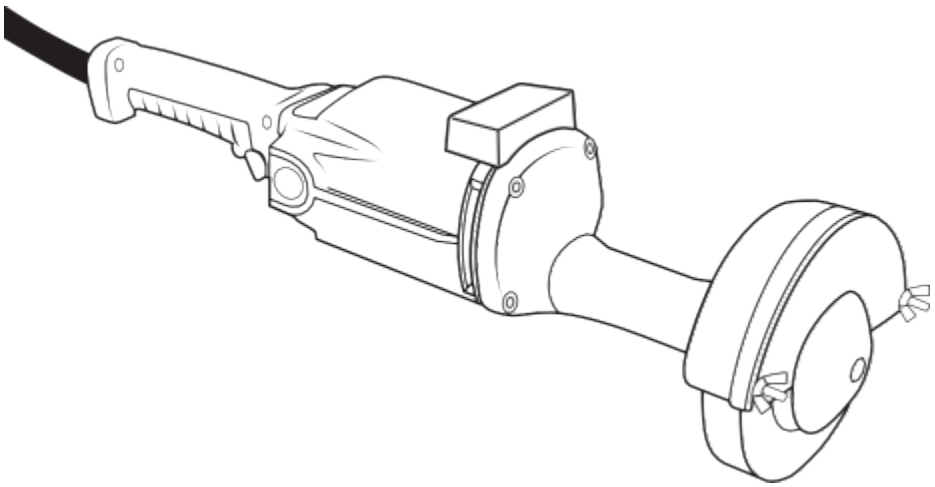


Figure 10 *Straight grinder* (*BC Industry Training Authority*, 2019). *CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Straight grinders are available in a variety of sizes and shapes. Larger ones are used for the quick removal of metal, while small models are used in hard-to-reach areas.

The larger models of straight grinders have a grinding wheel approximately 150 mm (6″) in diameter. You must hold these larger models with both hands.

Small ***pencil grinders (die grinders)***, as illustrated in Figure 11, are used to remove small metal burrs from freshly drilled holes, for elongating holes and slots and for preparing material for welding in tight places. These grinders turn at very high speeds (25 000 revolutions per minute [RPM] or more).

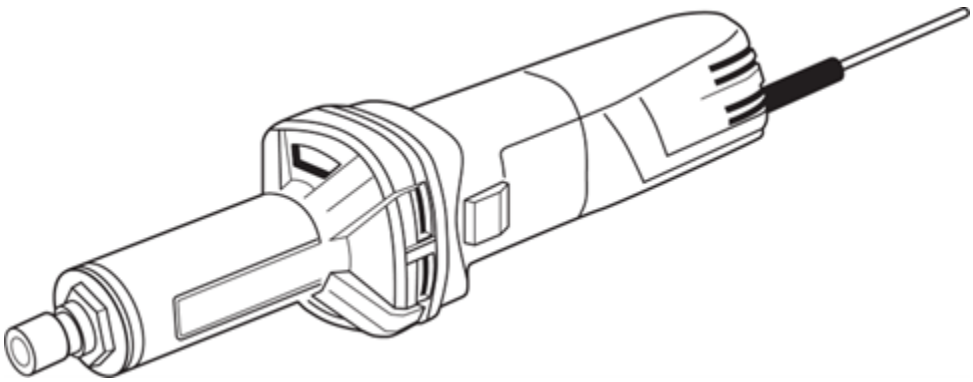


Figure 11 *Small straight grinder (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

These small grinders use a small grinding stone or a carbide cutting burr mounted on their shafts (Figure 12).

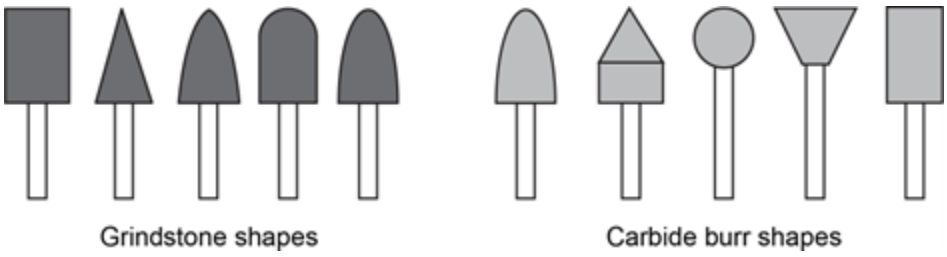


Figure 12 *Grindstone and carbide burrs (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Angle Grinders

Angle grinders have a grinding disk which rotates at 90° to the axis of the motor. This versatile tool comes in various sizes (Figures 13 and 14). Disks range in diameter from 75 mm (3″) to 225 mm (9″), and each disk type and size has its RPM rating identified. When you select a disk, make sure its RPM rating either matches or exceeds the RPM of the grinder.

Figure 13 *Angle grinder on concrete (Asurnipal/Wikimedia Commons) CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0)*

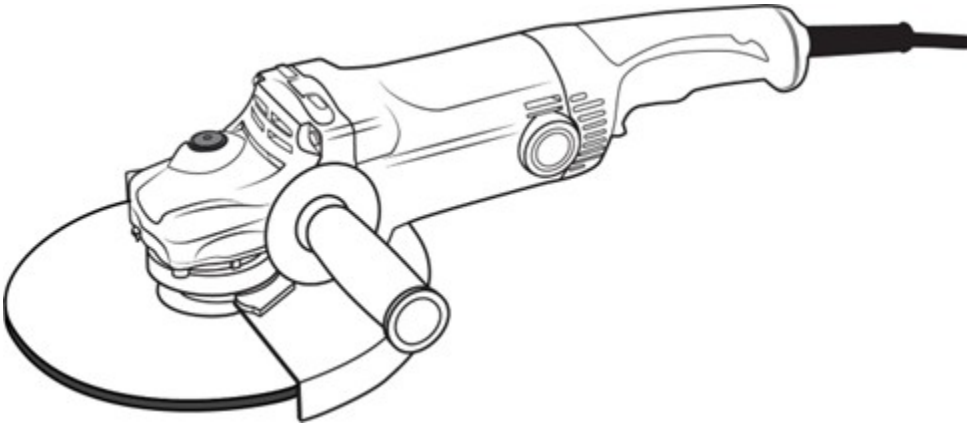


Figure 14 *Angle grinder (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

An angle grinder has a guard covering half the disk and it is held to the workpiece so that only the exposed portion of the disk makes contact with the workpiece.

Disks other than for grinding are available for angle grinders (Figure 15). With these disks, the angle grinder becomes much more than a grinding tool. It is a very versatile and useful tool.

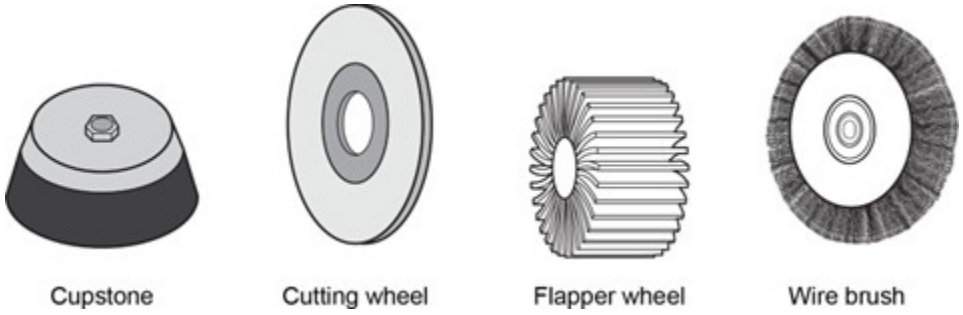


Figure 15 *Other disks for angle grinders (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Cables

Current is conducted from the welding machine to the electrode and electrode holder by the electrode cable and from the workpiece to the welding machine by the ground or work cable. These cables are made from insulated copper or aluminum wire. Aluminum wire has the advantage of weighing less than copper and can dissipate heat more quickly, but it can carry only about 60% of the current load of copper wire.

The electrode cable is specially designed to enable the welder to move the electrode and holder without putting undue strain on the cable.

A typical electrode cable (Figure 16) consists of thousands of hair-like wires braided into strands. These strands are themselves braided to form the conductor and are enclosed in a durable paper wrapping that allows the conductor to move easily inside the insulation when it is bent. Outside the paper is a layer of rubber insulation surrounded by a layer of woven fabric reinforcement to provide additional wear resistance. The outer layer is special composition rubber with a smooth finish, highly resistant to wear.

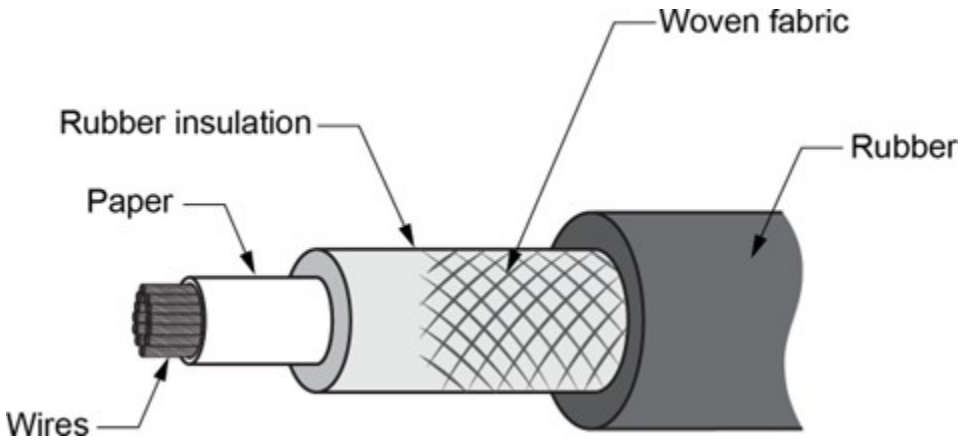


Figure 16 *Typical electrode cable (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

The ground cable does not usually undergo as much movement as the electrode cable, so less flexible but equally wear-resistant cable is used.

Summary

As you prepare to weld, remember these main safety points:

1. Always turn off your welding machine when it is not in use.
2. Wear gloves when handling arc welding equipment.
3. Keep all equipment dry and do not work in damp or wet conditions.
4. Make sure that the workpiece or workbench is properly grounded.
5. Do not overload the welding cables.
6. Remove the electrode from the electrode holder before putting the holder down.
7. Switch the welding machine off when your work is completed.

General Maintenance of Welding Machines

A welding machine must be maintained even when it is not in use. Make sure that equipment is stored where it will not be damaged when you are using other equipment. Protect portable welding machines from severe weather conditions.

Operate the machine as it was designed to be operated. When you use a machine, locate it so that it is well ventilated by cool, clean air. Keep it as far as possible from the dust of grinders and cutting machines. Keep it away from heaters and other heat-producing equipment and away from welding spatter. This will reduce the daily wear and tear.

Never use the current range or the polarity switch of a machine when there is a load on the circuit. Use these switches only when the machine is off or is idling before the arc is struck. Otherwise, the load may cause an arc in the switch and permanently damage the contacts.

Routine maintenance procedures that you can perform on welding machines include inspecting all cable connections to ensure that loose connections are not increasing wear on the equipment by adding to the circuit resistance. On portable fuel engine machines, check coolant levels and oil levels before each use.

Most AC-transformer-type welding machines have a forced air circulation cooling system powered by an electric motor connected to the primary circuit. As well as keeping the vent openings clear any time the machine is in operation so that the flow of air is unobstructed, remove the casing and thoroughly clean the passageways at least twice a year. In those units (such as motor-generator machines) that have air filters, inspect the filters regularly and clean them as required.

Storage

Store welding equipment in a dry location. Neatly roll cables in fairly large loops to reduce stress on the fibres and store them with like lengths so that they are easy to select for the job at hand.

Self-Test B-6.3: Describe the Arc Welding Process and Equipment

Complete Self-Test 6.3 and check your answers.

If you are using a printed copy, please find Self-Test A-6.3 and Answer Key in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=3046#h5p-20 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=3046#h5p-20)

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Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-5: Use cutting, brazing and soldering equipment (Plumber)*. Crown Publications, Queen's Printer for British Columbia.

Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-6: Use oxy-fuel cutting equipment (Plumber)*. Crown Publications, Queen's Printer for British Columbia.

Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-6: Use soldering and brazing equipment (Steamfitter)*. Crown Publications, Queen's Printer for British Columbia.

Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-7: Use oxy-fuel equipment (Steamfitter)*. Crown Publications, Queen's Printer for British Columbia.

Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-7: Use welding equipment (Plumber)*. Crown Publications, Queen's Printer for British Columbia.

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- **Figure 1** Shielded metal arc welding (https://commons.wikimedia.org/wiki/File:Shielded_Metal_Arc_Welding_.jpg) Lincoln Excalibur 7018 1/8″ by Prowelder87 on Wikimedia Commons is used under a CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0) license.
- **Figure 2** Gas pipeline welding, Azna 2017 (https://commons.wikimedia.org/wiki/File:Gas_pipeline_welding_,_Azna_2017.jpg) by Hamid Soufi on Wikimedia Commons is used under a CC BY-SA 3.0 (https://creativecommons.org/licenses/by-sa/3.0) license.
- **Figure 13** Faschina-concrete angle grinder-Betontrennschleifen-13ASD (https://commons.wikimedia.org/wiki/File:Faschina-concrete_angle_grinder-Betontrennschleifen-13ASD.jpg) [Angle grinder on concrete], by Asurnipal on Wikimedia Commons is used under a CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0) license.

B-6.4 Use Arc Welding Equipment

Achieving welds of high quality involves skill and concentration, which you will only develop through considerable practice. Consider the following five factors before each weld:

- Operator comfort and position
- Machine setting
- Arc length
- Electrode angle
- Speed of travel

Operator Comfort and Position

It is easier to weld if you are in a comfortable position and if you have a clear view of the area in front and behind the electrode. Most welders find that by placing their arms correctly, they can maintain control of the arc yet remain comfortable

If you are right-handed, grasp your right wrist with your left hand and place your left elbow on the welding bench. Use your left elbow as a pivot while you move the electrode along the metal. The usual direction for flat position welding for right-handed welders is from left to right. If you are left-handed, your arm positions and weld direction will be reversed.

Machine Setting

Before each weld using DC current, you must check that the polarity setting (either straight or reverse) is correct for the type of electrode you are using. With AC current, you have no choice of polarity, since the circuit is alternately positive, first on one side and then on the other.

You must also make sure that the current or amperage is correctly set for the electrode you are using, the type of joint, the weld position, the type of material to be welded, and the speed required for the weld. The current setting determines the welding temperature that will affect the quality and soundness of the weld.

Arc Length

The ***arc length*** (the distance of the electrode from the workpiece) is usually determined by the diameter of the electrode, with consideration to the welding position and the required amount of current. When the arc length is correct, the arc makes a distinct crackling sound. When it is too long, the crackling changes to a hissing sound.

Welding arcs that are too long prevent good penetration and fusion, permit the absorption of oxygen and nitrogen into the weld, and produce excessive weld spatter. In addition, they increase the possibility of arc blow.

Electrode Angle

Generally, the electrode should be held perpendicular to the base metal and then inclined 20° to 30° in the direction of travel (Figure 1). For some welds, however, the ***electrode angle*** is required to remain upright, perpendicular (90°) to the workpiece.

The correct angle is important in preventing *undercut* and slag inclusions. It also makes it easier for you to deposit weld metal and to achieve complete penetration and fusion.

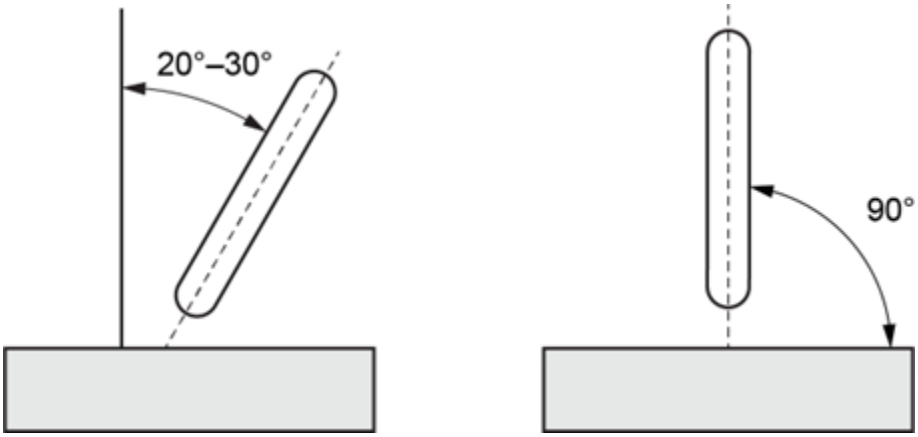

Figure 1 *Electrode angle* (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (*https://creativecommons.org/licenses/by-nc-sa/4.0/*)

Speed of Travel

Generally, the ***speed of travel*** should be such that 25 mm (1″) of electrode produces 25 mm (1″) of deposit. This speed is only an average and may need to be increased or decreased, depending on the welding position and the heaviness of the deposit required.

Weld Faults

There are three categories of weld defects:

- ***Dimensional faults*** vary from the specifications and requirements of the weld, including incorrect weld sizes and profiles
- Structural discontinuities, including such defects as *porosity*, undercut, incomplete penetration, and lack of fusion
- Defects in the mechanical properties of the metal, including reduced tensile strength, ductility, hardness or corrosion resistance

Defects in mechanical properties are not a factor that you can control.

Dimensional Defects

Incorrect Weld Size

Any variation from the specified weld size influences the distribution of stress in the weld. This will affect the strength of the weld. Welds that are undersized usually have insufficient throat (Figure 2), which substantially reduces the strength of the weld. Stresses concentrate at the centre of the weld, increasing the likelihood of joint failure. Undersized welds are usually the result of a fast rate of travel.

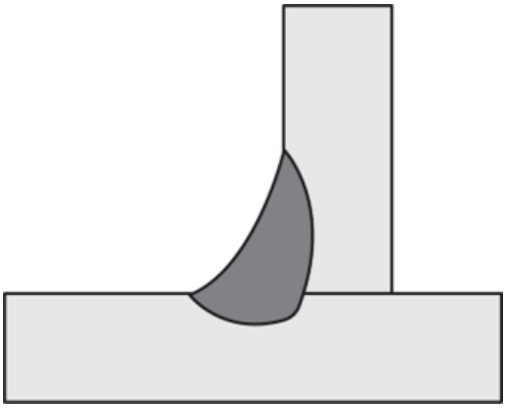

Figure 2 *Undersized weld (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Oversized welds display excessive convexity on fillet welds and excessive reinforcement on groove welds (Figure 3). These defects tend to produce notches at the toe of the weld where stresses will concentrate. The metal also tends to entrap slag and gases, creating a condition called porosity, which undermines the strength of the weld. Inadequate fusion of the weld and parent metal is also associated with excessive convexity or reinforcement.

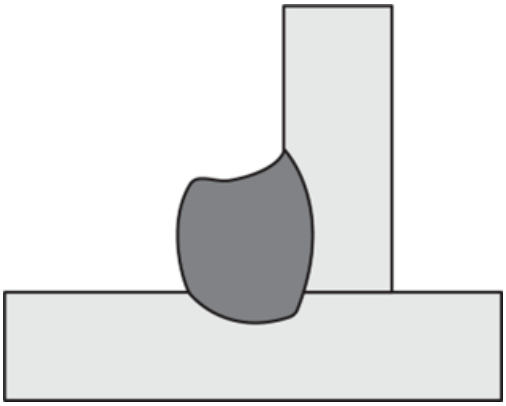

Figure 3 *Oversized weld (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Overlap

Overlap is a condition in which excess weld metal is deposited at the toe of the weld. It is most often a sign of poor fusion between the weld and parent metal (Figure 4). This condition is extremely serious, as stresses concentrate in notches that form at the toes of the weld. In fillet welds, overlap may also reduce the size of the weld.

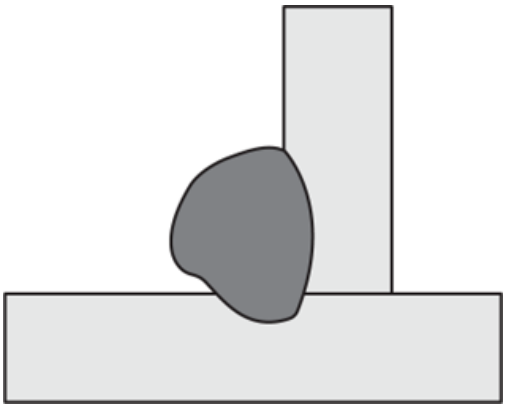

Figure 4 *Overlap (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Dimensional defects also include the distortion and warping that occur as a result of stresses from heating and cooling the metal during welding.

Structural Discontinuities in the Weld

Structural discontinuity incorporates a broad range of weld defects that include:

- Undercut
- Porosity
- Incomplete penetration
- Slag and gaseous inclusions
- Lack of fusion
- Cracking

While these defects often accompany other defects associated with size and profile problems, they may also occur in welds that conform to size and profile specifications.

Undercut

Undercut refers to a cutting away of the plate surfaces at the edge of the weld (Figure 5). A sharp recess forms in the

plate where the next layer or bead must fuse with the parent metal. At this point, plate thickness is reduced, weakening the joint. The possibility of joint failure is particularly high when the undercut occurs at the toe of the weld.

Undercut is generally caused by improper electrode manipulation, but too much current, too long an arc, or slow travel can also be contributing factors. On joints that are not very accessible, undercut may be very difficult to avoid.

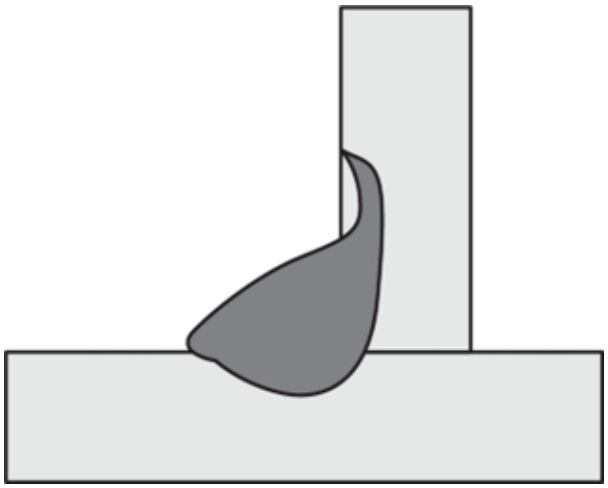

Figure 5 *Undercut (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Undercut can be corrected. When it occurs at the sidewall of the weld between passes, extra metal can be deposited in the recess before the next bead is deposited. At the surface of the weld where the defect of the weld is visible, additional metal can be used to fill up the recess.

Incomplete Penetration

Incomplete penetration is the failure of the weld metal and the base metal to fuse together at the root of the joint. On groove and fillet welds, this defect occurs when the areas above the root reach temperatures before the root. The molten metal forms a bridge across the joint and prevents the arc from reaching the root.

Incomplete penetration is most often caused by a joint design that is not suitable for the welding process selected. For single groove welds, this defect is most likely the result of one of the conditions shown in Figure 6 .

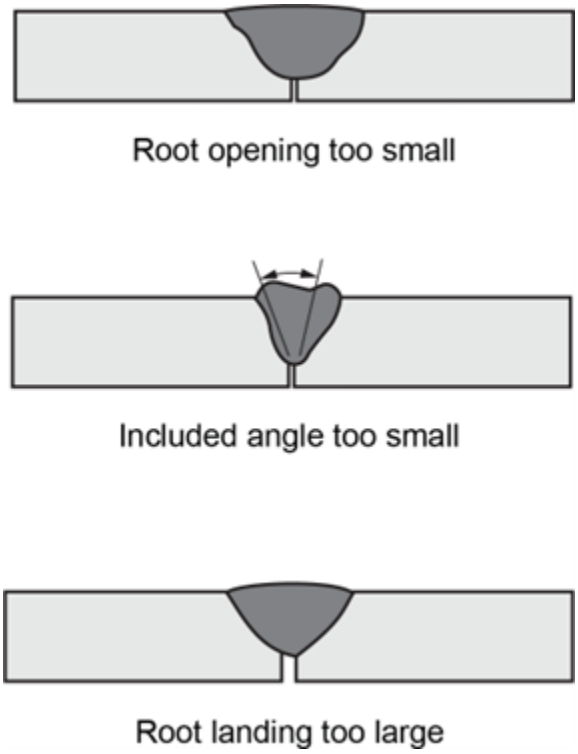

Figure 6 *Incomplete penetration (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Even when the joint is correctly designed, incomplete penetration may be caused by welding procedures. With a current that is too low, the weld metal is not able to reach the root of the joint or the arc is not strong enough to melt the base metal at the root. If the rate of travel is too fast, the metal is deposited on only the surfaces above the root. Electrode size is also an important factor, especially on the root bead. If the electrode is too large, it will not penetrate the narrow root opening.

Lack of Fusion

Lack of fusion is the failure of the welding process to fuse adjacent layers of weld metal or adjacent weld metal and base metal (Figure 7). This failure may occur at any point in groove and fillet welds. Overlap at the toe of the weld is often a sign of inadequate fusion.

Lack of fusion usually results from the following conditions:

- failure to heat the base metal or the previously deposited weld metal to the melting point, which usually occurs if the electrode is too small, the travel is too fast, or the current is too low
- failure to dissolve, by correct fluxing, the oxides or other foreign material on the surfaces to be welded

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

Porosity

Porosity refers to the presence of voids in the weld that do not contain any weld metal (Figure 8). Porosity may be distributed uniformly throughout the weld or may be clustered. Although excessive porosity has a serious effect on the mechanical properties of the joint, some welding codes allow for a specified maximum amount of porosity.

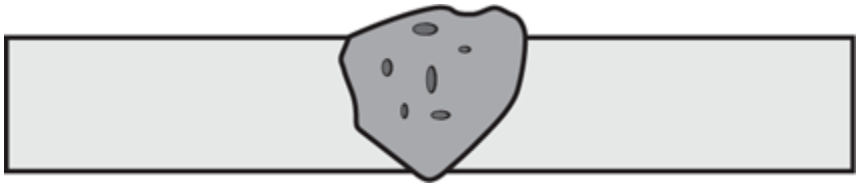

Figure 8 *Porosity (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

When pockets are concentrated at the root, they are often referred to as wormholes or piping. This condition is regarded as a special case of *incomplete penetration*.

Porosity results from the inclusion of gases in the weld. These gases are formed by the chemical reactions that take place in the weld as the metal is heated and cooled. Porosity generally occurs as a result of one of the following factors:

- Overheating or under-heating the weld metal
- Excessive sulphur or moisture in the base metal or electrode
- Current too high or too low
- Incorrect electrode manipulation
- Oil or other contaminants on the joint
- Defective or unsuitable electrodes
- Too long an arc
- Arc blow

Slag Inclusion

Slag refers to the metallic oxides and other solid compounds that are produced by chemical reactions during the welding process. Sometimes slag can become trapped in the weld. Like gaseous inclusions, they create porosity in the weld metal (Figure 9).

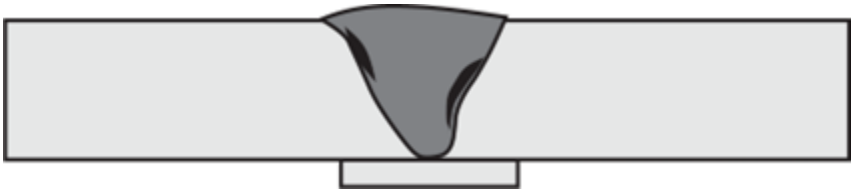

Figure 9 *Slag inclusion (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

In metal arc welding, slag formation occurs particularly when using coated electrodes or fluxes. The stirring action of the arc can force the slag into the molten metal or it can be pushed ahead of the arc and then be covered over by the weld metal. Because it is less dense than molten metal, slag tends to rise to the surface of the puddle, where it can be chipped away when the weld is cooled.

Several factors can prevent the release of slag from the weld metal, including:

- High viscosity of the weld metal
- Rapid cooling
- Too low a temperature
- Incorrect manipulation of the electrode
- Undercut on previous passes

Slag inclusions can generally be prevented by preparing the weld correctly before each bead is deposited, making sure to correct the contour so that the arc can penetrate the joint completely and making sure all slag is cleaned from the surface of the previous bead. You can help to promote the release of slag by ensuring that the weld metal becomes hot enough to reduce its viscosity (thickness) and by pre- and post-heating to slow down the cooling process.

Cracking

Cracks are considered the most dangerous weld defects. They occur because of stresses that exceed the ultimate strength of the metal. ***Cracking*** that occurs shortly after the weld metal has been deposited and is just beginning to solidify is termed "***hot cracking***." Some metals, especially the high alloy steels and other high-temperature alloys, are particularly susceptible to hot cracking. Cracking that occurs later, as the metal is approaching room temperature or after the weld has cooled completely is termed "cold cracking." Cold cracking is much less common than hot cracking.

External Cracks

Cracking that is visible or external usually occurs in the weld metal (Figure 10). External cracks may run across the face of the metal and sometimes extend into the base metal. These are known as transverse cracks. Longitudinal cracks run lengthways along the weld, usually down the centre of the weld deposit. Crater cracks form in the centre of the crater and may become a starting point for longitudinal cracking. Crater cracks are usually the result of interruptions in the welding procedure.

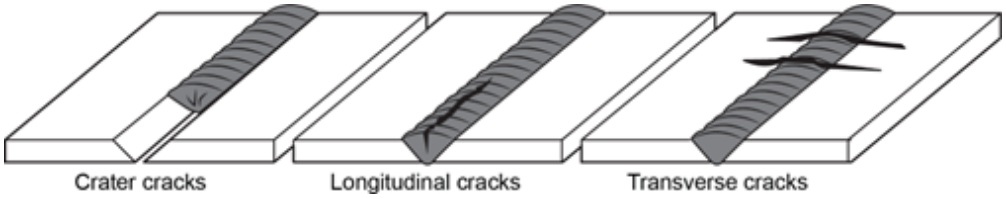

Figure 10 *Visible cracks (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

External cracks most often are caused by too much restraint on the joint, too rapid cooling (particularly on hardenable and brittle metals), too little deposit on weld passes, and by incorrect electrode selection. External cracks may also be caused by other defects such as porosity, lack of penetration, slag inclusion and incomplete fusion. By increasing the thickness of the deposit on the first bead, decreasing the speed of travel to allow more weld metal to build up, and correcting pre- and post-heat treatments, most cracking can be avoided.

Internal Cracks

Internal cracks usually occur within the heat-affected zone of the base metal (Figure 11). Underbead cracking (a type of internal crack) occurs almost exclusively in steel and is associated with the use of low-hydrogen electrodes. Hairline cracks at the toe of the weld are caused by hot cracking in (or near) the fusion zone of weld and base metal.

Internal cracks are found chiefly in metals that have been hardened and that are fairly brittle. They are often associated with other weld faults such as undercutting, lack of fusion, incomplete penetration and slag inclusions.

Internal cracking can be prevented by the use of low-hydrogen electrodes, correct pre- and post- heating procedures, and careful attention to correct fit-up and welding procedures.

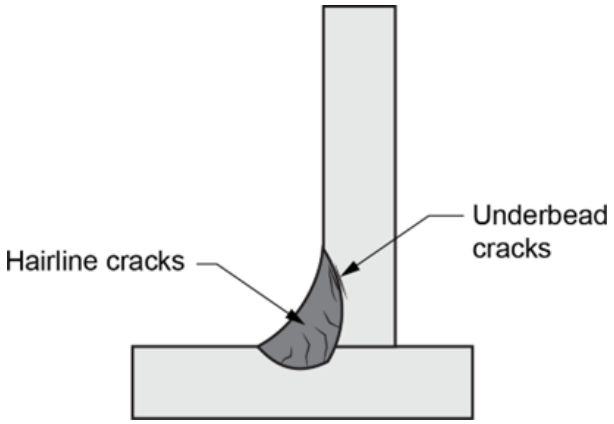

Figure 11 *Internal cracks (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Distortion and Stress

One of the primary welding problems is the control of ***distortion*** and ***residual stresses*** that can occur in metal as it is heated and cooled during the welding process. Distortion refers to a change in shape of the weld, while residual stress refers to the buildup of internal stresses within either the weld or parent metal. Excessive distortion may result in a weld that exceeds dimensional tolerances, while excessive stress may cause weld cracking.

The underlying cause of both conditions is the characteristic of metals to expand (become larger) when heated and to contract (become smaller) when cooled. If metals are allowed to expand and contract freely (with no restraint) neither distortion nor residual stress is likely to occur. If the metal is restrained in a way that prevents free expansion and contraction (as is the case with weldments), distortion and the buildup of internal stresses can develop.

An example of this can be seen in the butt joints shown in Figure 12. When heat is applied to the joint, the metal in the weld area expands but is restrained by the surrounding cooler metal. The heated metal must expand upward in the unrestrained direction. Upon cooling, this displaced metal contracts, pulling in the surrounding metal across the width. This pulling force causes the edges of the weldment to bow upward, resulting in distortion.

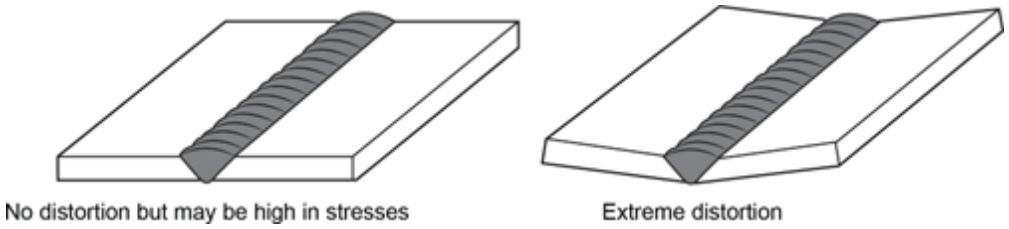

Figure 12 *Distortion in a butt joint (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

If, however, the edges of the weldment had been rigidly restrained to prevent movement, there would be little evidence of distortion, but the likelihood of residual stresses would be very high.

The susceptibility of a metal to distortion depends on its mechanical and physical properties. High- alloy steels are more prone to distortion than mild steels, and larger welds generally undergo more distortion than smaller welds.

Distortion Control

Methods used to minimize or eliminate distortion include:

- avoid over-welding
- deposit the greatest amount of weld metal in the shortest time
- distribute the heat input as uniformly as possible
- use mechanical methods
- preheat and post-heat when necessary

Avoid Over-Welding

Use the smallest permissible size on fillet welds and, where possible, use intermittent rather than continuous welds. On butt joints, select a joint design that uses a minimum of weld metal. A U-joint preparation is preferable to a vee preparation (Figure 13). If a single vee preparation is required, bevel to achieve the smallest permissible included angle.

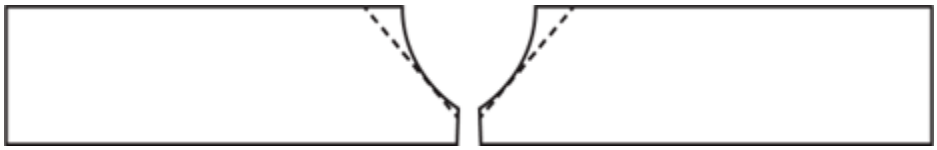

Figure 13 *U-joint uses less weld metal (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Deposit the Greatest Amount of Weld Metal in the Shortest Time

The slower the rate of welding, the more time there will be for the heat to spread ahead of the welding point. This diffusion of heat input greatly increases the chances of distortions, so a high rate of travel is usually recommended on joints that are susceptible to distortion.

Wherever possible, try to weld in the flat position and use electrodes as large as possible for the particular joint. Iron powder electrodes are particularly good as they have a high deposition rate.

On multi-pass welds, apply as few passes as possible to complete the joint. Many small passes cause more distortion than a few large passes. This is particularly true for welds that may be subject to transverse shrinkage. For welds prone to longitudinal distortion, the reverse is often the case, and the correct technique is to use multiple passes, each having a small deposit.

Distribute Heat Input as Uniformly as Possible

The rate of heating and cooling varies within the joint depending on how close the metal is to the point of welding. Expansion and contraction will not be uniform, further complicating the incidence of distortion. Behind the welding point, the metal is cooling and contracting. In front, the metal is heating and expanding. By maintaining a high rate of travel, the differences in heat input can be minimized, as shown in Figure 14.

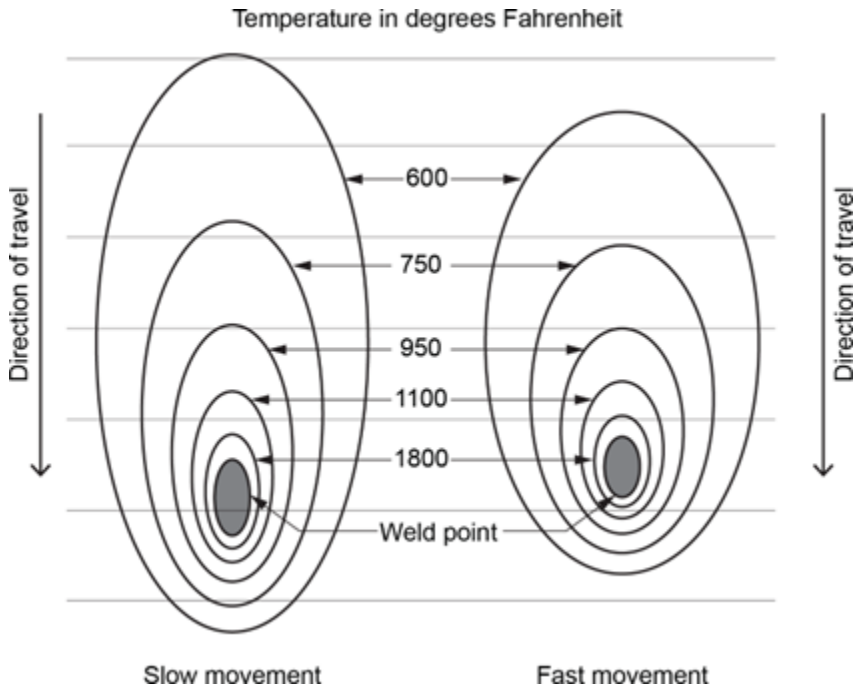

Figure 14 *Travel speed and heat input (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Other techniques to keep the heat input as uniform as possible include intermittent welding sequences, back-step sequences, skip sequences, and the starting of a weld at a distance from the end of the joint. These methods break up the weld into short sections and help to control distortion and the buildup of residual stresses. The principle is that the shrinkage set up by one weld is counteracted by the shrinkage forces in subsequent welds.

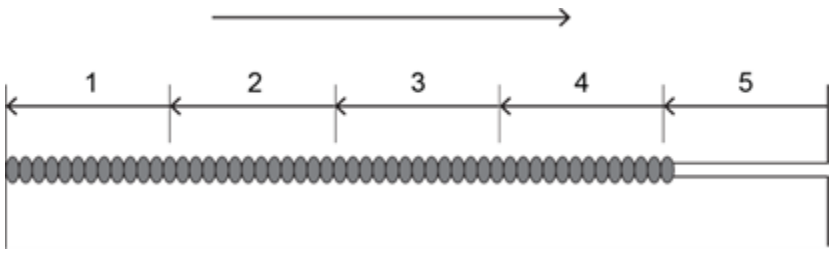

Figure 15 *Back stepping (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

In the back step sequence, the weld begins a short distance from the end, with the direction of travel toward that end (Figure 15). The second deposit is then begun the same distance in from the first deposit and runs into the first deposit. The third deposit runs into the second and so on along the seam.

With skip welding, weld deposits are applied incrementally on each side of the centre of the seam. The first weld is made at the beginning of the joint. A section is skipped, and the second weld is applied further down the seam. Sometimes the weld starts at the centre and the weld builds back from the centre, alternating from end to end (Figure 16).

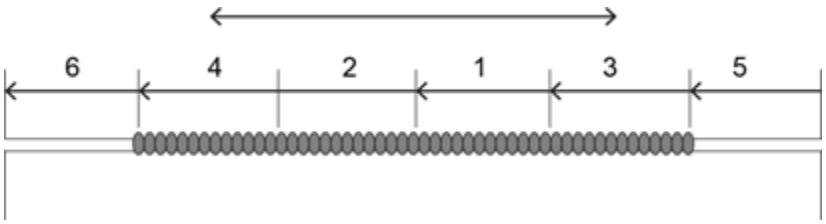

Figure 16 *Skip welding (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

On long seams, starting the weld a short distance in from the end controls longitudinal distortion. The first weld is applied back toward the end of the joint, then the main weld picks up from the starting point of the first weld and continues to the other end (Figure 17).

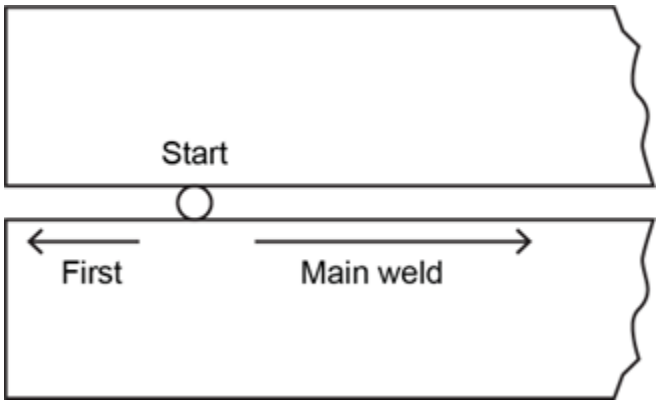

Figure 17 *Technique for long seams (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

On large sections of plating, the weld should begin at a central point and proceed outward, as shown in Figure 18. The aim is to maintain a welding sequence that is more or less symmetrical around the centre.

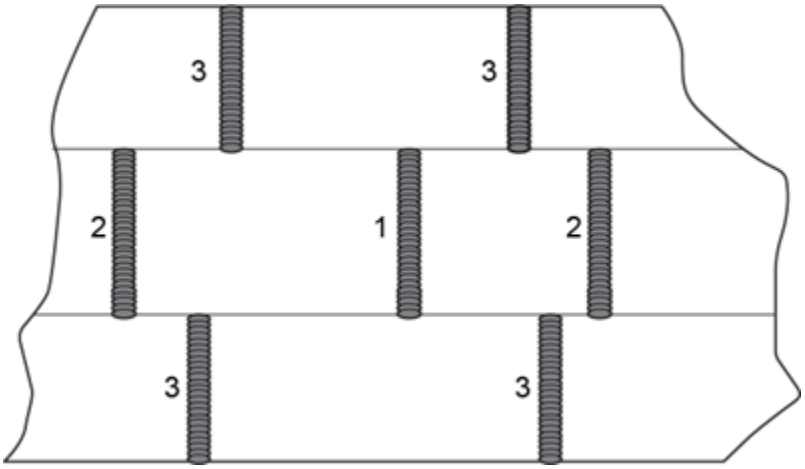

Figure 18 *Technique for plating (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Use Mechanical Methods

A variety of mechanical methods can minimize distortion including pre-bending, clamping and pre-spacing.

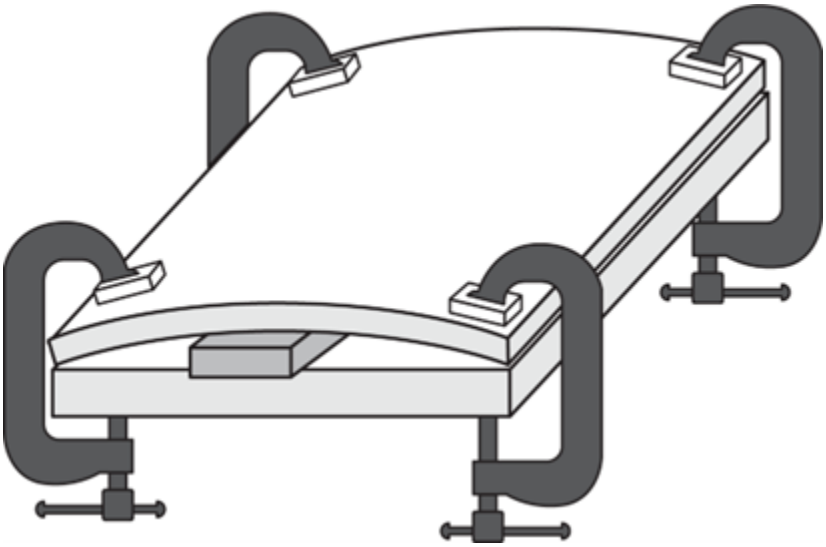

Figure 19 *Pre-bending (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

A weldment can be pre-bent and restrained through the use of clamps to compensate for warping in the other direction (Figure 19). Once the clamps are removed, shrinkage forces will pull the plate back to the desired alignment. The clamps must be spaced and aligned carefully to avoid the buildup of internal stresses.

Figure 20 shows the pre-spacing or offsetting of parts to be welded. Pre-spacing, like pre-bending, compensates for the distortion that will occur when the completed joint shrinks. As shrinking occurs, the vertical member on the tee joint will be pulled into correct (90°) alignment. Likewise, the two members of the butt joint will also be drawn upward to become properly aligned.

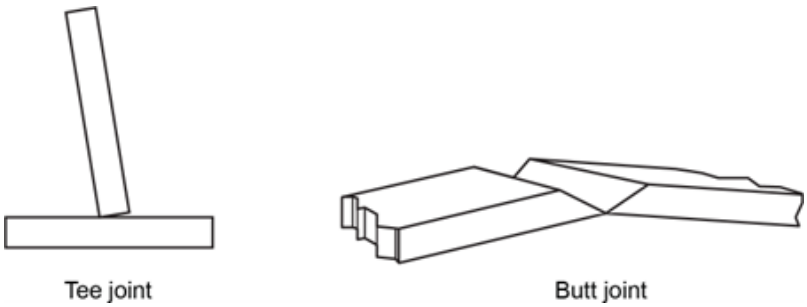

Figure 20 *Offsetting (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Pre-Heat and Post-Heat When Necessary

Pre- and post-heat techniques play an important part in controlling the buildup of internal stresses and distortion.

Preheating helps to distribute the expansion of the metal evenly throughout the weldment. Entire sections of the weldment may require preheating or, in some cases, preheating may be necessary only on specific sections (Figure 21). Preheating techniques require considerable care to ensure that heat is distributed uniformly throughout the metal and the structure is allowed to cool slowly.

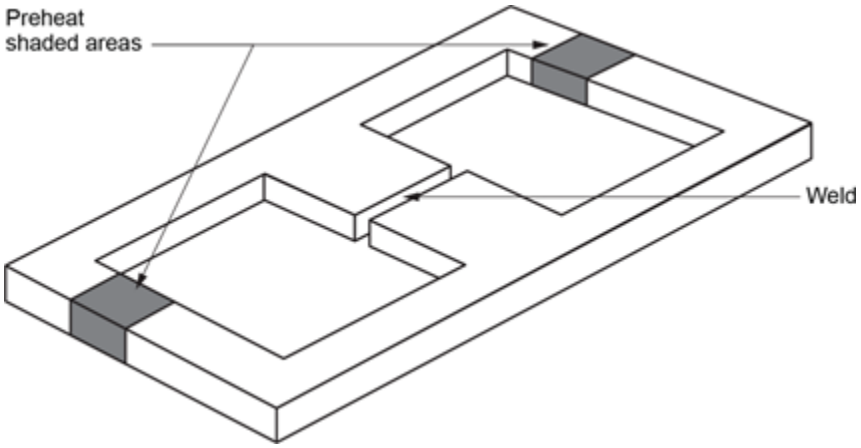

Figure 21 *Preheating on specific sections (BC Industry Training Authority, 2019). CC BY-NC-SA 4.0 (https://creativecommons.org/licenses/by-nc-sa/4.0/)*

Post-heating relieves residual stresses after the weld is completed. Heat treatments become increasingly important as you weld alloy steel, cast iron and other non-ferrous metals.

Self-Test B-6.4: Use Arc Welding Equipment

Complete Self-Test 6.4 and check your answers.

If you are using a printed copy, please find Self-Test A-6.4 and Answer Key in the Appendix at the end. If you prefer, you can scan the QR code with your digital device to go directly to the interactive Self-Test.

An interactive H5P element has been excluded from this version of the text. You can view it online here: https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=3050#h5p-21 (https://b-handmeasuringtools-bcplumbingapprl1.pressbooks.tru.ca/?p=3050#h5p-21)

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Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-5: Use cutting, brazing and soldering equipment (Plumber)*. Crown Publications, Queen's Printer for British Columbia.

Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-6: Use oxy-fuel cutting equipment (Plumber)*. Crown Publications, Queen's Printer for British Columbia.

Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-6: Use soldering and brazing equipment (Steamfitter)*. Crown Publications, Queen's Printer for British Columbia.

Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-7: Use oxy-fuel equipment (Steamfitter)*. Crown Publications, Queen's Printer for British Columbia.

Industry Training Authority. (2019). *Piping trades apprenticeship program: Level 1—Competency B-7: Use welding equipment (Plumber)*. Crown Publications, Queen's Printer for British Columbia.

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Self-Test B-6.1: Describe Safety Requirements and Precautions for Arc Welding

Complete Self-Test B-6.1 and check your answers.

1. What is the first rule to remember when dealing with victims of electrical shock?
    a. Pry or pull them loose with a non-conductive material
    b. Avoid touching the victim if he or she is still in contact with the source of power
    c. Send someone else to disconnect the power source
    d. Send for the first-aid attendant
2. Which of the following best describes storage of electrodes?
    a. Metal container
    b. Neat pile on the workbench
    c. Wooden container
    d. Neat pile on the floor
3. What should you do if you inspect your welding cables prior to welding and find breaks in the insulation?
    a. Ignore them
    b. Replace the cable before work
    c. Repair them with proper tape
    d. Flag them for repair after work
4. When should all troubleshooting and maintenance of welding machines must be done?
    a. Circuits show a line drop condition
    b. Circuit is disconnected and locked out
    c. Machine is not under load
    d. Circuits are open and unplugged
5. What is the recommended minimum distance from which the electric arc should be seen by the naked eye?
    a. 8 m (26′)
    b. 10 m (33′)
    c. 12 m (40′)
    d. 14 m (46′)
6. When arc welding, what eyewear must you use?
    a. Dark shaded sun glasses
    b. Welding goggles with filter lens
    c. A welder's helmet with filter lens
    d. Flash goggles
7. Lenses come in numbered shades. Which would you use for a higher current setting?
    a. No. 10
    b. No. 12
8. Which of the following best describes the protective clothing to be worn for arc welding?
    a. Dark
    b. Light
    c. Neutral
    d. Colours is not significant

9. Toxic fumes that result from welding are always identifiable by smell.
    a. True
    b. False
10. When your welding machine is on but you have finished welding, what must you do first?
    a. Remove your gloves and helmet
    b. Remove the electrode from its holder
    c. Disconnect the ground cable
    d. Disconnect the electrode cable)

Answer Key: Self-Test B-6.1 is on the next page.

Answer Key: Self-Test B-6.1

1. b. Avoid touching the victim if he or she is still in contact with the source of power
2. a. Metal container
3. c. Repair them with proper tape
4. b. Circuit is disconnected and locked out
5. c. 12 m (40′)
6. b. Welding goggles with filter lens
7. b. No.12
8. a. Dark
9. b. False
10. b. Remove the electrode from its holder

Self-Test B-6.2: Identify Types of Welds, Positions, Joints and Symbols

Complete Self-Test B-6.2 and check your answers.

1. There are five basic joint designs used in welding. The lap, tee, corner and edge are four of them. Name the fifth joint design.
    a. Plug
    b. Vee
    c. Bevel
    d. Butt
2. Which type of joint is shown in Figure 1?
    a. Plug
    b. Tee
    c. Butt
    d. Lap

Figure 1 *Image for question 2*

3. In order for lap and tee joints to support heavy or fluctuating loads, they need to be
    a. Welded from both sides
    b. Welded on only one side
    c. Single beveled
    d. Double beveled
4. Which of the following is the most commonly selected corner joint?
    a. Half open
    b. Closed
    c. Flanged
    d. Open
5. When are edge joints generally used?
    a. Sheet metal
    b. Pipe
    c. Heavy gauge metal
    d. Castings
6. Which edge preparation is used on the tee joint in Figure 2?
    a. Single U
    b. Single bevel
    c. Single J
    d. Single vee

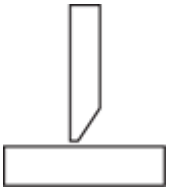

Figure 2 *Image for Question 6*

7. The butt joint shown in Figure 3 is a
    a. Single U
    b. Single J
    c. Double U
    d. Double J

Figure 3 *Image for question 7*

8. Which type of weld is most commonly used to weld lap, tee and corner joints?
    a. Groove weld
    b. Bead weld
    c. Fillet weld
    d. Plug weld
9. Groove welds typically are what kind of joints?
    a. Tee joints
    b. Lap joints
    c. Edge joints
    d. Butt joints
10. What typically determines the size of groove welds?
    a. Width between toes
    b. Depth of penetration
    c. Included angle
    d. Root radius
11. In Figure 4, A indicates the
    a. Root landing
    b. Root opening
    c. Thickness
    d. Bevel angle
12. In Figure 4, B indicates the
    a. Included angle
    b. Root landing
    c. Thickness
    d. Root radius
13. In Figure 4, D indicates the
    a. Root landing
    b. Included angle
    c. Bevel angle
    d. Root opening, gap
14. In what position would one weld a 1G?
    a. Fillet weld in the vertical position
    b. Groove weld in the flat position
    c. Gillet weld in the horizontal position
    d. Groove weld in the vertical position
15. In what position would one weld a 2G?
    a. A horizontal fillet weld
    b. A vertical groove weld
    c. A vertical fillet weld
    d. A horizontal groove weld
16. Which weld position is shown in Figure 5?

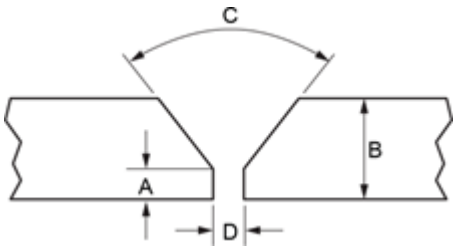

Figure 4 *Image for Question 12*

a. Flat
b. Horizontal
c. Vertical
d. Overhead

Answer Key: Self-Test B-6.2 is on the next page.

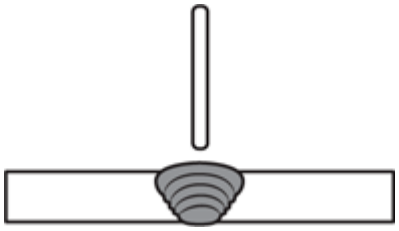

Figure 5 *Image for Question 16*

Answer Key: Self-Test B-6.2

1. d. Butt
2. d. Lap
3. a. Welded from both sides
4. d. Open
5. a. Sheet metal
6. b. Single bevel
7. a. Single U
8. c. Fillet weld
9. d. Butt joints
10. b. Depth of penetration
11. a. Root landing
12. c. Thickness
13. d. Root opening, gap
14. b. Groove weld in the flat position
15. d. A horizontal groove weld
16. a. Flat

Self-Test B-6.3: Describe the Arc Welding Process and Equipment

Complete Self-Test B-6.3 and check your answers.

1. Which of the following terms describes the mixture of melted electrode and melted parent metal created by the welding current flowing through the electrode and across the arc?
    a. SMAW
    b. The weld deposit
    c. The short circuit
    d. The workpiece
2. Which term describes the welding machine turned on but no arc established?
    a. Ohm's Law
    b. Short-circuit voltage
    c. Closed-circuit voltage
    d. Open-circuit voltage
3. In shielded metal arc welding, metals are fused by the heat from an electric arc that is maintained between the surface of the workpiece and which of the following electrodes?
    a. Covered electrode
    b. Bare electrode
    c. Neutral electrode
    d. Carbon electrode
4. In SMAW, what purpose does the electrode's flux coating serve?
    a. Keep the arc stable
    b. Keep the arc concentracted on the weld
    c. Provide the sheilding gases
    d. All of the above
5. Which term describes the electrical pressure or voltage in a welding circuit after the arc has been struck?
    a. Open-circuit voltage
    b. Line voltage
    c. Arc voltage
    d. Electrode voltage
6. Which of the following is not a consideration when you select a polarity?
    a. The type of coating material on the electrodes
    b. The temperature of the workpiece
    c. The welding position
    d. The types of material to be welded
7. Which of the following best describes direct current?
    a. Flows consistently from the positive to the negative pole
    b. Flows first from the negative to the positive pole, and then from the positive to the negative pole
    c. Flows consistently from the negative to the positive pole
    d. Is more dangerous than alternating current
8. Besides the jaw type, what is the most common type of stinger?

a. Spring type
b. Twist-head type
c. Clamp type
d. Jib type

9. What is the appropriate course of action if the cable connection to the electrode holder contains frayed or broken strands of wire?

    a. Repair the connection with electrical tape
    b. Put the cable permanently out of service
    c. Cut off the damaged end and make a new connection
    d. Turn the cable end for end

10. What is a probable result of using an electrode with broken flux coating?

    a. Slag inclusions
    b. Hard spots
    c. Porosity
    d. Lack of fusion

11. Which of the following electrodes need to be stored in an electrode oven?

    a. All mild steel electrodes
    b. Low-hydrogen, hardsurfacing, and special alloy electrodes
    c. Mild steel, low-hydrogen, and special alloy electrodes
    d. Mild steel, hardsurfacing, and special alloy electrodes

12. Which of the following terms describe common portable grinders?

    a. Angel grinders
    b. Bevel grinders
    c. Curved grinders
    d. Disk grinders

13. Which of the following PPE is required when using a portable grinder?

    a. Leather gloves
    b. A fireproof apron
    c. Eye protection
    d. A hard hat

Answer Key: Self-Test B-6.3 is on the next page.

Answer Key: Self-Test B-6.3

1. a. SMAW
2. d. Open-circuit voltage
3. a. Covered electrode
4. d. All of the above
5. c. Arc voltage
6. b. The temperature of the workpiece
7. c. Flows consistently from the negative to the positive pole
8. b. Twist-head type
9. c. Cut off the damaged end and make a new connection
10. a. Slag inclusions
11. b. Low-hydrogen, hardsurfacing, and special alloy electrodes
12. a. Angle grinders
13. c. Eye protection

Self-Test B-6.4: Use Arc Welding Equipment

Complete Self-Test B-6.4 and check your answers.

1. Which of the following best describes the amount of weld produced with 1″ of electrode when correct speed is used?
    a. 1″
    b. 1 1/2″
    c. 2″
    d. 3″
2. Which of the following best describes the correct angle for the electrode?
    a. 20–30° off perpendicular in direction of travel
    b. 20–30° off perpendicular away from direction of travel
    c. Perpendicular to work
    d. 45° off perpendicular in direction of travel
3. What What does a hissing sound during welding indicate?
    a. Electrode too far from work
    b. Electrode too close to work
    c. Electrode ideal distance from work
    d. Amperage is too high
4. What is the most common cause of undersized welds?
    a. Rate of travel that is too fast
    b. Welding current that is too low
    c. Incorrect polarity
    d. Rate of travel that is too slow
5. Which weld defect is shown in Figure 1?
    a. Incomplete penetration
    b. Cracking
    c. Porosity
    d. Undercut

Figure 1 *Image for Question 5*

6. Which defect is shown in Figure 2?
    a. Porosity
    b. Cracking
    c. Lack of fusion
    d. Slag inclusion

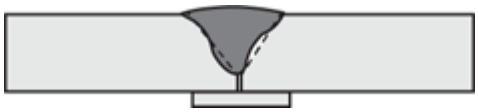

Figure 2 *Image for Question 6*

7. Which of the following is the major cause of incomplete penetration?
    a. Incorrect joint design
    b. Too small an electrode
    c. Failure to heat the base metal
    d. Rate of travel is too slow
8. Which of the following suffers from hot cracking?
    a. Mild steel
    b. High-alloy steel

c. Low-hydrogen electrodes
d. Joints that are cooled slowly

9. In which of the following conditions do crater cracks often occur?

a. Current is too low
b. Electrode is defective
c. Welding has been interrupted
d. Base metal has been preheated

10. Which of the following actions will help prevent slag inclusion?

a. Extending the arc length
b. Reducing the current setting
c. Using coated electrodes or fluxes
d. Cleaning all slag from the surface of the previous bead

11. Which of the following is the most common cause of undercut?

a. Too little current
b. Too rapid cooling
c. Improper electrode manipulation
d. Improper cleaning of base metal

12. Which of the following is the most common cause of distortion?

a. Porosity in the weld metal
b. Pre- and post-heat treatments
c. Hot cracking in the weld metal
d. Uneven expansion and contraction within a metal

13. Which of the following is a mechanical means of preventing distortion?

a. Pre-bending
b. Multi-pass welding
c. Intermittent welding
d. Back-step sequences

14. Which of the following butt joint preparations is most prone to angular distortion?

a. U-butt joint
b. Double vee joint
c. Square butt joint
d. Single vee butt joint

15. Which of the following terms describe a serious defect in which excess weld metal is deposited at the toe of the weld and is most often a sign of poor fusion between the weld and parent metal?

a. Overlap
b. Porosity
c. Undercut
d. Distortion

Answer Key: Self-Test B-6.4 is on the next page.

Answer Key: Self-Test B-6.4

1. a. 1″
2. a. 20–30° off perpendicular in direction of travel
3. a. Electrode too far from work
4. a. Rate of travel that is too fast
5. c. Porosity
6. c. Lack of fusion
7. a. Incorrect joint design
8. b. High-alloy steel
9. c. Welding has been interrupted
10. d. Cleaning all slag from the surface of the previous bead
11. c. Improper electrode manipulation
12. d. Uneven expansion and contraction within a metal
13. a. Pre-bending
14. d. Single vee butt joint
15. a. Overlap

Glossary - Block B: Tools and Equipment

“endless” hand chain

A continuous loop of chain used to operate a chain hoist. Pulling the chain in one direction raises the load, while pulling it in the opposite direction lowers it. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

abrasive cut-off wheel

A circular cutting wheel made of abrasive material that grinds through metal or other hard materials instead of cutting with teeth. It is commonly used on power saws or grinders to cut metal. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

abrasive disk blade

A circular cutting disk made from abrasive material that grinds through metal or other hard materials instead of cutting with teeth. It is commonly used on chop saws or grinders to cut metal. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

absolute limit of approach

The minimum safe distance that equipment must stay away from live electrical power lines. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

acetone

A straw-coloured, stable liquid that is flammable, volatile and strong smelling, placed inside acetylene cylinders; safely absorbs and stores acetylene gas under pressure. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

acetylene

A fuel gas made from carbon and hydrogen that burns very hot when mixed with oxygen and is commonly used for welding, brazing, and cutting metal. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

acetylide

A highly unstable and explosive compound that can form when acetylene gas reacts with certain metals, particularly copper or copper alloys. Because acetylides can detonate from shock or heat, materials such as copper and red brass are not used in acetylene equipment. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

adjustable base jack

A scaffold base support with a threaded stem that can be adjusted up or down to level the scaffold and distribute weight evenly on the ground. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

adjustable or sliding choker hook

A type of choker hook that can move along a sling and be positioned where needed. It allows the sling to wrap around a load and tighten to form a choker hitch, helping hold the load securely during lifting. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

agamassan

A type of special porous, fire-resistant material used to help keep equipment safe from heat and flames (e.g., asbestos, charcoal or diatomaceous earth); saturated with acetone. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

air-impact wrench

A power tool that uses compressed air to quickly tighten or loosen nuts and bolts by delivering strong turning force in short bursts. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

air-line respirators

A type of respirator that supplies clean air through a hose from a safe external source, protecting the user from harmful fumes or low-oxygen environments. (Section B-6.1 (#chapter-b-6-1-describe-safety-requirements-and-precautions-for-arc-welding))

all-hardened

A type of saw blade that has been heat-treated so that the entire blade is hardened. This makes the blade very strong and resistant to wear, but also more brittle and less flexible than blades that are hardened only at the teeth. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

alloy

A homogeneous metal composed of two or more elements. (Section B-5.2 (#chapter-b-5-2-describe-cutting-brazing-and-soldering-techniques))

allround system

A modular scaffold system made of vertical posts and horizontal supports that connect at fixed points using special locking joints. The design allows scaffold sections to be assembled quickly and safely in many different shapes and heights. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

alternating current (AC)

An electric current that changes direction back and forth many times per second. It is commonly used in homes and buildings. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

amperes (A)

The unit used to measure electric current, or how much electricity is flowing through a circuit. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

angle drill

A power drill designed with the chuck set at a right angle to the motor so holes can be drilled in tight or hard-to-reach spaces; known by names like *Hole-Hawg*. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

angle grinder

A portable power tool that uses a rotating grinding wheel or disk to grind, cut, smooth, or polish metal and other materials. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

angle grinders

Power tools with a rotating disk set at a right angle to the motor, used for cutting, grinding, and shaping metal and other materials. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

angle pipe welding vise

A tool used to hold a pipe branch at a right angle to another pipe while it is being fitted or welded. (Section 1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

annealed

A condition where metal has been softened by exposure to high heat. When wire rope becomes annealed, it loses strength and hardness, making it unsafe for lifting or rigging operations. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

anode

The part of an electrical device or circuit where electric current enters. In plumbing and electrical systems, an anode is often a metal (like in a water heater) that is designed to corrode first to protect other parts from rust and damage. (Section C-2.2)

arc

A curved line that is part of a circle. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

arc flash

A painful eye injury caused by exposure to the intense light and radiation from a welding arc. (Section B-6.1 (#chapter-b-6-1-describe-safety-requirements-and-precautions-for-arc-welding))

arc length

The distance between the welding electrode and the metal being welded. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

arc voltage

The voltage present in a welding circuit after the arc is struck and the current is flowing. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

arc-joint pliers

adjustable pliers used to grip, hold, or turn objects. The jaws can be moved to different positions using a curved slot (arc joint), allowing the tool to open wider or narrower depending on the size of the object being held. They are commonly used for gripping pipes, nuts, and other parts in plumbing or mechanical work. Many trades people refer to these as Channellock pliers. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

Archimedes' principle

A scientific rule that explains why objects float or sink in liquids. It states that an object in a liquid is pushed upward by a force equal to the weight of the liquid it displaces. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

auger bit

A drill bit with a spiral shape and a pointed tip used for drilling deep, clean holes in wood. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

automatic levels

(also known as self-levelling levels); a surveying instrument that automatically adjusts itself to create a level line of sight. It contains an internal compensator that keeps the telescope level even if the instrument is slightly out of position. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

auxiliary hoist

An additional hoisting mechanism on a crane that operates independently from the main hoist. It is used to lift lighter loads, provide faster lifting speeds, or assist with positioning materials during lifting operations. (Section B-4.3 (#chapter-b-4-3-describe-lifting-and-hoisting-communication))

azimuth adjustment

A feature on an optical instrument that allows the telescope or sight to rotate horizontally. It is used to align the instrument with a specific direction or reference point when taking measurements, measuring angles or establishing layout lines. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

backfire

A small explosion that occurs when the flame briefly burns back into the torch tip during cutting or welding. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

backsight

A level reading taken on a point with a known elevation, such as a benchmark or turning point. It is used to calculate the height of the instrument before measuring other points. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

backsight (BS)

A level reading taken on a point with a known elevation, such as a benchmark or turning point. It is used to calculate the height of the instrument before measuring other points. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

balance (tool balance)

How the weight of a tool is distributed, which affects how comfortable and controlled it feels in the hand. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

ball-peen hammer

A hammer with a flat striking face on one side and a rounded ball-shaped end (peen) on the other; commonly used in metalworking for shaping metal, setting rivets, and striking tools such as chisels or punches. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

base plates

Flat metal plates placed under scaffold legs to spread the weight and help keep the scaffold stable. (Section B-3.2 (#chapter-b-3-2-use-ladders-and-elevated-platforms))

basin wrench

A special wrench with a long handle used to tighten or loosen nuts in hard-to-reach places, such as under sinks. (Section 1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

bead weld

A single-pass weld used to build up or repair the surface of metal. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

beehive spring

A coiled spring retainer used on some pneumatic hammers to hold the chisel or tool bit securely in place during operation. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

benchmark

A permanent reference point with a known elevation used in surveying and leveling. It provides a fixed starting point for measuring the height of other points. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

bevel

A slanted or angled edge cut into a material, often used to prepare surfaces for cutting, joining, or welding. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

bight

A curved section or loop formed in a rope without crossing the rope over itself. It is often used when tying knots or attaching the rope to another object. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

bird caging

A type of damage where the strands of a wire rope spread apart and form a cage-like shape. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

block

A collection of sheaves that provide a mechanical advantage in a lift. Often found at the hook. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

block-and-tackle

A lifting system made of two or more pulleys (called blocks) with a rope or cable threaded between them. It allows a heavy load to be lifted using less force by spreading the weight across multiple rope sections. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

bogeys (end-trucks)

Wheeled assemblies located at each end of an overhead travelling crane bridge that allow the crane to move along the runway beams or rails. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

boom (crane)

The primary arm of a crane. Acts as a lever and positions the block and hook to be directly over the load. (Section B-4.3 (#chapter-b-4-3-describe-lifting-and-hoisting-communication); Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

boom cylinder

The hydraulic control of a boom. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

boom lifts

A type of elevated work platform that uses a long, extendable arm to lift a worker in a bucket to high or hard-to-reach areas. The arm can move up, down, and sideways to position the worker safely. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

boom radius

Also referred to as operating radius, this horizontal distance from centre of rotation to the hook, is a function of boom angle and length. This concept is crucial to understanding safe crane capacity. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

boom trucks

A truck equipped with a hydraulic crane mounted on its chassis and a telescoping or articulating boom used to lift, move, and position heavy loads at construction or work sites. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

bosun's chair

A seat or platform suspended by ropes that allows a worker to sit safely while working at height, such as when performing maintenance or installation tasks. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

Bourdon pressure gauge

A device used to measure the pressure of a gas or liquid in a system. It uses a curved metal tube that straightens slightly when pressure increases, moving a needle on a dial to show the pressure reading. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

bowline knot

A knot used to create a fixed loop at the end of a rope that will not tighten or slip under load. It is commonly used in rigging and rescue situations because it is strong and easy to untie after use. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

bowline on a bight

A variation of the bowline knot that forms two secure loops in the middle of a rope without using the rope's end. It is

often used for lifting or supporting a person or load. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

bridle hitch

A rigging method that uses two or more sling legs attached to a single lifting hook to lift a load from multiple points, helping distribute the weight and keep the load balanced during lifting. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

bucket

The small platform or enclosed work area at the end of a boom lift where a worker stands while performing tasks at height. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

builder's level

a surveying instrument used in construction to measure height differences and ensure surfaces or structures are level. It usually includes a telescope and leveling screws that allow the user to establish a straight, level reference line across a distance. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

burr

A rough edge or small metal fragment left on a material after cutting, drilling, or machining. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

butt joint

A joint that joins two pieces of metal in the same plane, typically by welding along their adjoining edges. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

C-clamps

A clamp shaped like the letter "C" that is used to hold pieces of material tightly together or to hold something to a table while working. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

cable clips

A metal fastener used to secure the end of a wire rope back onto itself to form a loop. It consists of a U-bolt, saddle, and nuts that clamp the rope together. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

cam-out

When a screwdriver slips out of the screw head while turning it. This can damage the screw head and make the screw harder to tighten or remove. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

capillary action

The way a liquid (like melted solder) is pulled into small spaces between two surfaces without being pushed. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

carbide-tipped blade

A saw blade with small tips made of carbide, a very hard metal, attached to each tooth. The carbide tips help

the blade stay sharp longer and cut hard materials more easily. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

carbide-tipped drill bits

Drill bits with tips made of carbide, a very hard material that helps the bit stay sharp and drill through tough materials like masonry or hardened metal. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

carbon steel blade

A saw blade made from carbon steel that is strong and flexible, often used for cutting wood or soft metals. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

carburizing flame

A flame with excess acetylene that adds carbon to the metal and produces a cooler, softer flame used for brazing and working with certain metals. (Section B-5.3 (#chapter-b-5-3-use-oxy-acetylene-equipment))

carpenter's level

A measuring tool used to check whether a surface is level (horizontal) or plumb (vertical). It contains small tubes filled with liquid and an air bubble that moves to the center when the surface is straight. Carpenter's levels are commonly used in construction and carpentry. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

cartridge-type respirator

A respirator that uses replaceable cartridges to filter harmful gases or particles from the air, typically used for short-term exposure or emergency escape. (Section B-6.1 (#chapter-b-6-1-describe-safety-requirements-and-precautions-for-arc-welding))

casters

Small wheels attached to equipment so it can roll or move easily. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

centre head

An attachment used with a combination square that helps find the exact centre of round objects, such as pipes or rods. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

centre of gravity

The point in an object where its weight is balanced. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

centre point

The exact middle point of a circle or round object. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

centre punch

A pointed tool used to make a small dent in metal so a drill bit will start in the correct place. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

chain hoists (also known as chain falls or endless chains)

A lifting device that uses a chain and gears to raise or lower heavy loads. It is usually operated by pulling a hand chain, which turns gears that lift the load using a second chain attached to the hook. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

chain tongs

A tool that uses a chain wrapped around a pipe to grip and turn the pipe when tightening or loosening it. (Section 1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

chain wrenches

A wrench that uses a metal chain to wrap around and grip a pipe so it can be turned. (Section 1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

chalk line

A marking tool that uses a chalk-covered string to create long, straight lines on surfaces such as wood, metal, or concrete. The string is stretched tight and snapped against the surface to leave a straight chalk mark. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

chalk-line plumb bob

The weighted end of a chalk line tool that helps keep the string tight and straight. It allows workers to snap a straight chalk line on a surface for marking and layout. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

chamfer

A beveled edge that removes the sharp corner of a material, usually to make assembly easier or safer. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

chamfering

The process of **cutting or filing the sharp edge of a pipe or material at an angle** to make it smoother and easier to join. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

cherry picker

A type of boom lift with an extendable arm that raises a small platform so a worker can safely reach high work areas. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

chipping hammer

A tool used in welding to chip and remove slag from a weld after the metal has cooled; usually has a pointed tip and a chisel edge to reach tight areas around the weld. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

chisel combination blade

A combination saw blade with chisel-shaped teeth that cut wood cleanly and efficiently when ripping or crosscutting. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

choker hitch

A method of attaching a sling to a load by passing one end of the sling around the load and then hooking it back onto itself. This creates a tightening grip that helps hold the load securely during lifting. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

cleats

Flat wooden strips used as steps on some job-built ladders. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

clove hitch

A knot used to quickly attach a rope to a post, pole, or pipe. It is easy to tie and untie but can slip if the load changes or becomes loose. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

clutch drive screwdriver

A tool used to tighten or loosen screws that have a clutch-shaped slot in the head. The screwdriver tip fits the special slot so the screw can be turned without slipping. These screws are often used in equipment and machinery. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

coarse adjustment dial

(job selector dial); A control on a welding machine used to set the main current level for a specific welding task. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

combination square (or combination set)

A measuring tool used to check right angles (90°) and measure distances. It has a ruler and an adjustable head. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

combination wrench

A wrench that has an open end on one side and a box end on the other, both the same size. (Section 1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

combustion

The chemical process of burning that occurs when a fuel reacts with oxygen and releases heat and light. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

come-alongs (pullers)

A hand-operated device that uses a ratchet and lever to pull, lift, or tighten heavy loads. It works by tightening a chain or wire rope in small steps, allowing workers to move or position equipment safely. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

compensator

A mechanism inside an automatic level that automatically keeps the instrument's line of sight level. It adjusts the internal optics so accurate readings can be taken even if the instrument is slightly tilted. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

compound gauge

a pressure gauge that can measure both positive pressure and vacuum in the same instrument. It shows pressure above and below atmospheric pressure on the same dial. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

compound leverage pipe wrench

A pipe wrench designed with extra leverage to help apply greater turning force with less effort. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

compression hand bender

A handheld tool used to bend metal tubing by applying steady pressure around a curved form so the tubing bends without kinking or flattening. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

connectors

(quick couplers); Devices or fittings used to join two pieces of equipment, pipe, hose, or electrical components so they can work together properly. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

convex

A curved outward shape. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

coring machines (core drills)

Power tools used to cut large, round holes in materials such as concrete, brick, or stone using a hollow drill bit. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

corner joint

A joint that joins two pieces of metal at right angles at their ends, forming an L shape. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

corrosion

The gradual damage or weakening of metal caused by chemical reactions with the environment, such as exposure to moisture, air, or chemicals. In wire rope and rigging equipment, corrosion often appears as rust and can reduce the strength and safety of the metal. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

countersink bit

A drill bit used to widen the top of a hole so the head of a screw can sit flush with or below the surface of the material. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

counterweight

A supplementary ballast added to the weight of a crane to provide additional stability in a lift. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

coupler pins

Metal pins used to connect and secure scaffold frames or sections together. They fit into holes in the scaffold frames to keep the sections aligned and prevent them from separating during use. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

cracking

Breaks or splits that form in a weld or metal because of stress. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

crane

A machine used to lift and move heavy loads using a hook, cable, and boom. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting), Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

cribbing

Material used for dunnage or blocking under a load to allow for the attachment and removal of rigging. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

crimping

A method of joining pipe or tubing by squeezing a metal ring or fitting tightly around it with a special tool. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

critical point

The pressure or temperature at which acetylene becomes unstable and can break down suddenly, possibly causing an explosion. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

cross brace

A diagonal support that connects scaffold frames and helps keep the structure stable and rigid. (Section B-3.2 (#chapter-b-3-2-use-ladders-and-elevated-platforms))

crossbow loading

A dangerous rigging condition where a load is applied to the sides of a shackle instead of to the pin and curved body. This can weaken the shackle and may cause it to bend or fail during lifting. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

crosscut blade

A saw blade designed to cut wood across the grain. The teeth are shaped to make smooth and clean cuts. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

crosscut saw

A hand saw used to cut across the grain of wood. It has special teeth designed to slice through wood fibres. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

crosshairs

Thin horizontal and vertical lines inside the telescope of a surveying instrument. They intersect at the center and are used to aim precisely at a target or measuring rod when taking readings. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

current

The flow of electricity through a circuit, measured in amperes (A). (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

cutting faces

The flat or angled surface of a tool that does the cutting. It is the part of the tool that comes into contact with the material and removes small pieces as the tool is used. Cutting faces are found on tools such as chisels, drill bits, and cutting blades. (Section B-1.2 (#chapter-b-1-2-use-hand-tools))

cycle

One complete change in an alternating current where the voltage goes from zero to maximum in one direction, back to zero, and then to maximum in the opposite direction. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

datum

A fixed reference point or level used as a starting point for measuring heights or depths. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

DCEN (direct current electrode negative)

A welding setup where the electrode is connected to the negative side of the power source, causing more heat to be concentrated in the workpiece. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

DCEP (direct current electrode positive)

A welding setup where the electrode is connected to the positive side of the power source, causing more heat to be concentrated in the electrode. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

dead-blow hammer

A hammer designed to reduce rebound when striking a surface. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

deburring

The process of removing burrs or rough edges from metal, plastic, or other materials after cutting or drilling. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

demolition

The process of breaking down or removing structures. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

demolition hammer (jack hammer; chipping gun)

A heavy-duty power tool used to break, chip, or remove concrete, masonry, or other hard materials. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

dense-structure fine-grain wheel

A grinding wheel made with small abrasive grains packed closely together to produce smoother and more precise grinding. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

diagonal or side-cutting pliers

Tools used for cutting wire and small metal pins. The cutting edges are set at an angle near the pivot, which allows the user to cut close to a surface or in tight spaces. These pliers are commonly used in electrical and mechanical work. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

dies

Cutting tools used to create threads on the outside of a pipe or rod so it can be connected to fittings. (Section B-2.4 (#chapter-b-2-4-use-stationary-power-tools))

digital multimeter (DMM)

An electronic tool used to measure electrical values such as voltage, current, and resistance. It shows the readings on a digital screen and is commonly used to test electrical circuits and equipment. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

digital multimeters

An electronic tool used to measure electrical values such as voltage, current, and resistance. It shows the readings on a digital screen and is commonly used to test electrical circuits and equipment. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

dimensional faults

Problems with a weld where the size or shape is different from what the design requires. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

direct current (DC)

An electric current that flows in one direction only, from the negative to the positive side of a circuit. It is commonly produced by batteries and some welding machines. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

distortion

A change in the shape of metal caused by heating and cooling during welding. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

divider

A tool with two sharp points used to draw circles or measure distances on metal or other materials. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

dog everything

A safety instruction used in lifting and hoisting operations that means to secure or lock all controls and equipment so that no movement can occur. It ensures the load and machinery remain safely in place before workers approach or handle the load. (Section B-4.3 (http://4.3))

dog-legged

A condition where a rope, wire rope, or metal strand becomes bent sharply out of its normal straight alignment, creating an uneven angle that can cause extra wear or weakness in the material. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

double basket hitch

A lifting method that uses two basket hitches placed under a load to support it at two separate points. This arrangement helps distribute the weight evenly and keeps the load stable during lifting. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

double joints

Connections where two welds are made on both sides of the same joint to make it stronger and more secure. This helps the metal pieces hold together better and handle more stress. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

double saddle (fist grip) clip

A type of cable clip that has two saddles instead of a U-bolt. It grips both sides of the wire rope evenly and is often used for stronger or more secure wire rope connections. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

drain auger (snake)

A flexible tool used to clear blockages in pipes and drains. It is pushed into the pipe and rotated to break up or pull out the material causing the clog. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

draw filing

a finishing technique where a file is held sideways across the workpiece and pulled or pushed along the surface. This method removes small amounts of material and helps create a smooth, flat finish on metal surfaces. It is commonly used to improve surface quality after rough filing. (Section B-1.2 (#chapter-b-1-2-use-hand-tools))

drill press

A stationary machine that holds and drives a drill bit vertically into a workpiece to make accurate holes. (Section B-2.3 (#chapter-b-2-3-describe-stationary-power-tools-used-in-the-pipe-trades))

drop head threader

A pipe-threading tool with a head that can open or “drop” to quickly release the pipe after threads have been cut. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

drop stops

Safety devices installed on lifting equipment, such as trolleys or hoists, that prevent the load or trolley from accidentally falling or running off the end of a beam or track. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

drop-forged steel

Steel that is shaped using heavy pressure and heat to make it stronger. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

drum machine

A drain-cleaning machine that stores a long flexible cable inside a rotating drum. The cable is fed into a pipe to break up or remove blockages in drains and sewer lines. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

dry fit (or dry seal)

When pipe parts are assembled together without using sealant, glue, or thread compound. It is usually done to check that the pieces fit properly before the final installation. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

dual-control machines

A welding machine that has two controls—one for adjusting the main current level and another for making fine adjustments to voltage or arc characteristics. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

dumpy (4-pin) level

A dumpy level is a basic surveying tool used to measure height differences and check if surfaces are level. It has a short telescope mounted on a base that can be adjusted using screws. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

dunnage

Pieces of wood, metal, or other material placed under or between loads to support them, keep them off the ground, and prevent shifting or damage during storage or transport. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

edge or flange joints

connections where the edges of two metal pieces are bent (flanged) and then welded together. This type of joint is often used for thin metal and helps create a neat, sealed edge. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

effort (input force)

The force a person applies to move or lift an object. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

electrode

A metal rod used in welding that carries electric current and melts to provide filler metal for the weld. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

electrode angle

The direction or tilt of the electrode when it is held during welding. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

electrode holder (stinger)

A handheld device used in welding to hold the electrode and safely carry electric current to it during welding. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

electrode ovens

A heated storage unit used to keep welding electrodes dry and at the correct temperature to prevent moisture from affecting weld quality. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

electrode stubs

The short leftover pieces of welding electrodes that remain after most of the electrode has been used. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

electronic level

A digital measuring tool used to determine whether a surface is level or to measure angles and slopes; uses electronic sensors to detect the position and displays the reading on a digital screen for greater accuracy. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

elevation

The height of a point compared to a chosen reference level such as sea level. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

embrittlement

A condition where metal becomes hard and brittle, making it more likely to crack or break. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

end

(working end) The free end of a rope used to tie knots, bends, or hitches. It is the part of the rope that is manipulated during rope tying. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

end pattern pipe wrench

A pipe wrench with jaws angled at about 45 degrees, allowing it to be used in tight spaces. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

endless slings (also known as grommet slings)

A type of sling made as a continuous loop of rope, wire rope, or webbing with no fixed ends. Endless slings can be wrapped around loads in different ways for lifting and are often used because they distribute weight evenly and are flexible to position. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

equalizer bar

A lifting bar that helps spread the weight of a load evenly between multiple slings or lifting lines. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

eutectic alloy

A special type of metal mixture that melts and hardens at one exact temperature instead of over a range. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

explosive limits

The range of concentrations of a flammable gas or vapour in air within which combustion or explosion can occur if an ignition source is present. Below the lower explosive limit (LEL) the mixture is too lean to ignite, and above the upper explosive limit (UEL) it is too rich to burn. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

exposed ratchet drop head threader

A pipe-threading tool used to cut threads on the outside of pipes; it has a ratcheting handle for use in tight spaces, and the drop head holds the cutting dies that form the threads. The exposed design allows the cutting head to be easily seen and adjusted during use. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

extracted-tee drill

A special drill used to cut an opening in a pipe so a branch connection can be added without removing the pipe. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

eyebolt

A bolt with a looped head used as a strong attachment point for lifting loads. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

fastener

A device used to hold materials together, such as a nail, bolt, or screw. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

fatigue fractures

Breaks in wire rope wires caused by repeated bending, vibration, or stress over time. These breaks usually appear as clean, square-ended wire breaks and often occur near fittings or areas where the rope bends frequently. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

feed

The amount of pressure you apply to push a cutting tool into the material while drilling or grinding. (Section B-2.4 (#chapter-b-2-4-use-stationary-power-tools))

ferrous metals

Metals that contain iron and usually produce sparks when cut or ground, such as steel and cast iron. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

filler metal

Metal that is added during welding to help join two pieces together and form a strong weld. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

fillers

Pieces of material used to fill gaps between parts so everything fits tightly and securely. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

fillet weld

A weld used to join two pieces of metal at right angles, forming a triangular cross-section. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

fire standpipe

A fixed piping system in a building that supplies water for firefighting, allowing hoses to be connected on different floors. (Section B-2.4 (#chapter-b-2-4-use-stationary-power-tools))

flaring

The process of spreading the end of a pipe or tube outward so it can connect securely to a fitting. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

flashback arrestors

A safety device that stops flames from travelling backward through oxy-fuel equipment during a flashback. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

flashback explosion

A dangerous condition where the flame travels back through the torch and hoses toward the regulator, possibly causing an explosion. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

flutes (grooves)

The long channels cut into tools such as drill bits or taps. They help remove chips of material while cutting and allow cutting fluid to reach the cutting edge. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

flux

A coating on a welding electrode that helps protect the molten metal from air and keeps the arc stable during welding. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

foresight reading

A measurement taken with a level instrument on a point whose elevation is being determined. It is usually the

last reading taken before the instrument is moved. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

formwork

Temporary structures used to shape concrete while it hardens. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

framing square (or carpenter's square)

An L-shaped measuring tool used to check right angles (90°) and lay out lines on materials such as wood, metal, or pipe. It has two straight arms set at a right angle and is commonly used for measuring, marking, and squaring workpieces. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

fusion

A method used to join thermoplastic pipes by heating the pipe ends until they soften and pressing them together to form a strong joint. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

gain (tubing gain)

The small amount of extra length that appears when tubing or pipe is bent because the outside of the bend stretches slightly. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

gantry

A fabricated structural bridge-like crane operating on tracks or wheels at or near ground level. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

gantry crane

A type of crane that has a horizontal beam supported by two legs that move on wheels or rails. A hoist travels along the beam to lift and move heavy loads in workshops, warehouses, or construction sites. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

gasket

A seal placed between two surfaces to prevent leaks. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

gauge stems (sockets)

The threaded connectors on a pressure gauge that attach the gauge to a pipe, valve, or fitting. They allow the gauge to be securely connected so it can measure the pressure inside the system. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

geared pipe threader

A pipe-threading tool that uses gears to help turn the cutting dies around the pipe. The gears provide extra mechanical advantage, making it easier to cut threads on larger pipes with less effort. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

GO/NO-GO gauge

A measuring tool used to quickly check if a part is the correct size. One end (the “go” side) should fit into or onto the part if it is the right size, while the other end (the “no-go” side) should not fit. If the “go” side fits and the “no-go” side does not, the part is within the correct limits. (Section B-1.2 (#chapter-b-1-2-use-hand-tools))

grade (grinding wheel)

The measure of how strongly the abrasive grains are held together in a grinding wheel. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

grain density

The amount of abrasive grains packed into a grinding wheel. A wheel with high grain density has more grains close together, while a wheel with low grain density has fewer grains with more space between them. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

grinders

Power tools used to shape, smooth, or remove material from metal surfaces, often using a rotating abrasive wheel or disk. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

grinding wheel (or disk)

A round wheel made of abrasive material used to grind, shape, smooth, or sharpen metal and other materials. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

groove weld

A weld that fills the gap between two pieces of metal, typically used in butt joints. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

groover

A tool or machine used to form a groove around the end of a pipe so that mechanical couplings or fittings can be attached securely. (Section B-2.3 (#chapter-b-2-3-describe-stationary-power-tools-used-in-the-pipe-trades))

ground clamp (ground connection)

A device used to attach the welding circuit to the workpiece or work surface, completing the electrical circuit and allowing current to flow safely. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

grounded

Connected safely to the earth so that electrical current can flow away and reduce the risk of electric shock. (Section B-6.1 (#chapter-b-6-1-describe-safety-requirements-and-precautions-for-arc-welding))

guardrail

A protective rail along an edge that helps prevent people from falling. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

gullet

The curved space between two saw teeth that collects and clears chips or sawdust while cutting. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

gullet (saw tooth)

The curved space between two saw teeth that collects and clears chips or sawdust while cutting. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

hammer drill (rotary hammer, roto-hammer)

A power drill that combines rotating motion with a hammering action to drill into hard materials like concrete or masonry. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

hand level

A straight tool used to check whether a surface is level (horizontal) or plumb (vertical). It usually contains glass tubes with bubbles that show when something is straight. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

hardsurfacing (hardfacing)

A process of adding a layer of weld material to the surface of a metal to rebuild worn areas or to increase resistance to wear and damage. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

headache ball

A crane hook generally without a block. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

heat-treated

A process in which metal is heated and then cooled in a controlled way to make it stronger, harder, or more durable. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

heel

The back edge of a saw tooth that slopes downward after the cutting tip. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

heel (saw tooth)

The back edge of a saw tooth that slopes downward after the cutting tip. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

height of instrument (HI)

The height of the level instrument's line of sight above a known point or elevation. It is used to calculate the height of other points. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

hex key (Allen key) wrench

An L-shaped metal tool used to turn screws or bolts that have a hexagon-shaped hole. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

hexagonal wrench

A tool used to tighten or loosen pipes or fittings that have **six flat sides (a hexagonal shape)**. The wrench fits around the flats of the pipe fitting so it can grip firmly and turn the pipe without slipping. It is commonly used when working with hex-shaped pipe fittings and valves. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

hickory

A very strong hardwood commonly used to make tool handles. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

high stranding or unlaying (unwinding)

A condition where the strands of a wire rope begin to loosen, separate, or unwind from their normal twisted position. This can weaken the rope and may indicate damage or improper handling, requiring inspection or replacement. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

high-speed steel blade

A saw blade made from a special steel that stays strong and sharp even at high cutting speeds and temperatures. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

hoist line

Wire rope that controls the main block or jib block or hook. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

hoisting device

Equipment used to lift or lower loads, such as a crane or hoist. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

holding action

The force that keeps a fastener securely in place after it is driven into a material. It occurs when the surrounding material compresses around the fastener and presses tightly against it. (Section B-2.1 (#chapter-b-2-2-use-portable-power-tools))

hole saw

A circular cutting tool with teeth on the edge used with a drill to cut large round holes in materials such as wood, plastic, or metal. The center drill bit helps guide the saw while cutting. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

hook

The forward-leaning edge of a saw tooth that helps pull the blade into the material during cutting. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

hook (lifting)

A curved metal device used to connect lifting equipment to a load. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

hook-tooth blade

A band saw blade with teeth that lean forward to cut quickly and remove material efficiently. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

hot cracking

Cracks that form in the weld metal while it is still very hot and starting to cool. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

hot tapping

A method used to cut into a pipe while it is still in service and under pressure, allowing a new connection to be added without shutting off the flow inside the pipe. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

hot-work permit

A formal safety document that gives permission to perform work that produces heat, sparks, or flames (such as welding or cutting) and confirms that proper precautions are in place to prevent fire or injury. (Section B-5.3 (#chapter-b-5-3-use-oxy-acetylene-equipment))

hydraulic

A system that uses liquid pressure to move or lift objects or equipment. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

hydrometer

A measuring tool used to check the density of a liquid. It floats in the liquid, and the level where it sits shows the liquid's density or concentration. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

ice plugs

A temporary blockage of ice formed inside a pipe when the water in the pipe is frozen. The ice stops the flow of water so repairs or changes can be made without shutting off the entire system. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

incomplete penetration

A welding problem where the weld metal does not fully reach or join the bottom of the joint. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

inconel

A type of strong metal alloy made mainly from nickel that resists heat and corrosion, often used in high-temperature or harsh environments. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

indentation

A small dent or mark made in a surface. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

inert gas

A gas that does not react chemically and is used to prevent unwanted reactions such as oxidation or explosions. (Section B-6.1 (#chapter-b-6-1-describe-safety-requirements-and-precautions-for-arc-welding))

interference fit (wedging effect)

Occurs when two parts are pressed together so tightly that they stay in place without fasteners. The tight fit creates friction that holds the parts securely together. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

intermediate foresight (IFS)

A level reading taken on a point between the starting point and the next turning point. It is used to find the elevation of points that are not used to move the instrument. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

intermediate sight (IS)

A level reading taken on a point between the starting point and the final point. It helps measure the height or elevation of different points along the way. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

internal wrench

A tool used to grip and turn parts from inside a pipe or fitting. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

jam-proof ratchet threader

A pipe-threading tool that cuts threads on the outside of a pipe. It uses a ratcheting handle so the pipe can be threaded in tight spaces, and the jam-proof design helps prevent the tool from sticking while cutting threads. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

jib

Secondary arm of a crane. Used to extend boom for specific lifts. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

jib crane

A type of crane that has a horizontal arm (called a jib or boom) attached to a vertical support. The arm can rotate, allowing loads to be lifted and moved within a circular area. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

kerf

The width of material removed by a cutting tool such as a saw blade. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades); Section B-2.2 (#chapter-b-2-2-use-portable-power-tools))

kinks

A sharp bend in a wire rope that damages the rope and weakens it. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

lack of fusion

A welding defect where melted metal does not properly join to the metal beside it. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

ladder-jack scaffold

A temporary work platform supported by brackets attached to ladders. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

landing

A platform or surface at the top or bottom of a ladder where a person safely steps onto the ladder or off the ladder, rather than standing on the top of the ladder itself. (Section B-3.2 (#chapter-b-3-2-use-ladders-and-elevated-platforms))

lap joint

A joint that joins two pieces of metal by overlapping one piece over the other and welding along the edges of the overlap. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

LASER

Light Amplification by Simulated Emission of Radiation: A mixture of helium and neon gases is used to emit a very narrow beam of light that does not grow larger as it moves away from the source. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

laser level

A tool that projects a straight beam of light to create a level or vertical reference line. It helps workers align pipes, walls, or other structures accurately. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

lashing

An arrangement of wire rope and securing hardware such as U-bolt clips, meant to secure two or more objects together. Often used to temporarily secure a load, prior to a hoist. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

layout lines

Lines drawn on material to guide cutting, drilling, or shaping operations. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

lead angle

the angle at which a cutting edge meets the material being cut. It helps guide the tool into the material and affects how smoothly the tool cuts and removes material. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

level, or level (levelling rod)

level: Perfectly horizontal or flat, from side to side; or

level (or levelling rod): A long measuring rod used with an optical or laser level to measure height differences and determine elevations on a job site. The rod has marked scales that allow workers to read measurements from a distance.. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

levelling screw jacks

Adjustable metal supports placed at the base of a scaffold that can be turned to raise or lower the scaffold frame. They are used to level the scaffold on uneven ground and provide a stable foundation. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

levels

A tool used to check whether a surface or object is perfectly horizontal (level) or vertical (plumb). It helps ensure that structures, pipes, or equipment are installed straight and properly aligned. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

leverage

Using a long tool or handle to multiply force. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

lift plan

A written or discussed plan that explains how a load will be safely lifted and moved. It includes details such as the weight of the load, the equipment being used, the lifting path, possible hazards, and how workers will communicate during the lift. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

lifting point

The place on a load where the lifting equipment is attached. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

line level

A small level that hangs on a string line to check if the line is level. It is used for rough measurements such as setting fence posts or checking building lines. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

line of sight

A clear, direct view of the load and work area without obstructions. (Section B-4.3 (#chapter-b-4-3-describe-lifting-and-hoisting-communication))

linesman pliers

Strong pliers used for gripping, twisting, bending, and cutting wire. They have short jaws with flat gripping surfaces and sharp cutting edges near the pivot. These pliers are commonly used by electricians when working with electrical wires and cables. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

liquidus

The temperature at which 100% of the alloy is in a fluid, non-crystalline form. (Section B-5.2 (#chapter-b-5-2-describe-cutting-brazing-and-soldering-techniques))

load

The object or material being lifted or moved. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

load chart

Manufacturer's literature describing a crane's lift capacity under all possible configurations. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

load integrity

The condition in which a lifted load remains secure, stable, and properly contained so that individual items do not shift, separate, or fall during lifting, moving, or positioning operations. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

locking pliers

(Often referred to as vice-grips); adjustable pliers that can clamp tightly onto an object and stay locked in place until released. A screw on the handle adjusts the jaw opening, and a locking mechanism holds the pliers closed. They are commonly used to grip, clamp, or hold parts securely during mechanical or repair work. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

lockout

A safety procedure that ensures equipment is completely shut off and cannot be turned on during maintenance or repair. (Section B-6.1 (#chapter-b-6-1-describe-safety-requirements-and-precautions-for-arc-welding))

machine vise

A vise used on machines such as drill presses to hold a workpiece firmly while it is being drilled or cut. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

machined surface

A surface that has been precisely shaped or smoothed by a machine. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

main line

The primary lifting cable or hook on a crane used for most lifting operations. (Section B-4.3 (#chapter-b-4-3-describe-lifting-and-hoisting-communication))

manifold

A device that connects several gas cylinders together so they can supply gas through one main line. it helps provide a steady flow of gas when more than one cylinder is needed. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

manometer

A device used to measure the pressure of a gas or liquid. It often uses a tube filled with liquid, such as water or mercury, and the difference in liquid levels shows the pressure. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

Manual forklifts (also called pallet trucks or pallet jacks)

A hand-operated device used to lift and move loads placed on pallets. It uses a hydraulic mechanism and small wheels to raise the pallet slightly off the floor so it can be pushed or pulled across smooth surfaces. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

MAPP gas (methylacetylene-propadiene)

A stabilized fuel gas mixture used in oxy-fuel cutting, heating, and brazing. It produces a high-temperature flame, though slightly lower than acetylene, and is valued for its stability, safety in storage, and suitability for metalworking applications. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

masonry blade

A circular saw blade designed to cut hard materials such as brick, concrete, and stone. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

master link

A large metal link used to connect multiple slings or chains to a lifting hook. (Section B-4.2 (http://4.2))

maximum rate of removal (the draw limit)

The highest amount of gas you can safely take out of a cylinder in a short time. Taking out more than this can make the cylinder unsafe as liquid acetone will be drawn from the cylinder. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

mechanical advantage (MA)

How much a machine increases the force you put into it to make work easier. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

mechanical bending

A process that uses a machine or tool to permanently bend pipe or tubing into a desired shape without cutting it. (Section B-2.3 (#chapter-b-2-3-describe-stationary-power-tools-used-in-the-pipe-trades))

metal-cutting circular blade

A circular saw blade designed to cut metal using strong materials and specially shaped teeth. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

mitre

A joint made between two pieces of wood or other material at an angle of 90°, such that the line of junction bisects this angle. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

monel

A metal alloy made mainly from nickel and copper that is strong and highly resistant to corrosion, especially in marine environments. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

movable pulley

A pulley that moves with the load and helps reduce the effort needed to lift it. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

mudsill

A strong board placed on the ground to spread the weight of a scaffold and keep it from sinking. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

nail claw

(also called cat's paw); A short metal bar with a claw-shaped end used to pull nails out of wood. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

National Pipe Thread (NPT)

A standard type of pipe thread used in North America - ANSI/ASME standard B1.20.1. The threads are slightly tapered so they seal tightly when pipes are screwed together; sometimes still referred to as American Standard Pipe Thread (ASPT). (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

natural gas

A combustible fossil fuel composed primarily of methane that is used as a fuel for heating, cutting, and other industrial processes. In oxy-fuel operations, natural gas can be used as a fuel gas with oxygen to produce a flame for heating or cutting metal, although its flame temperature is lower than that of acetylene. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

needle-nose pliers

Pliers with long, narrow jaws that taper to a point. They are used to grip, bend, and hold small objects or wires, especially in tight or hard-to-reach spaces. These pliers are commonly used in electrical work, crafts, and small mechanical repairs. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

neutral flame

A flame with the right mix of oxygen and fuel so it burns clean and does not damage the metal. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

nipple

A short piece of pipe, usually threaded on both ends, used to connect two fittings or sections of pipe. (Section B-2.4 (#chapter-b-2-4-use-stationary-power-tools))

nipple chuck

A special chuck used on a threading machine to hold short pieces of pipe (nipples) securely while they are being threaded. (Section B-2.3 (#chapter-b-2-3-describe-stationary-power-tools-used-in-the-pipe-trades))

Nominal Pipe Size (NPS)

A standard system used to identify the size of pipes. The number refers to the approximate inside diameter of the pipe, even though the actual measurements may vary depending on the pipe wall thickness. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

offset pattern pipe wrench

A pipe wrench designed with jaws parallel to the handle so it can reach tight or awkward spaces. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

offset screwdriver

a tool used to tighten or loosen screws that have a star-shaped pattern with six points in the head. The shape helps the screwdriver grip the screw firmly, reducing slipping and allowing more turning force. Torx screwdrivers are commonly used in electronics, automotive work, and machinery. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

oiler

A device used to apply cutting oil to pipe threads or cutting tools to reduce heat, improve cutting performance, and help produce smooth, accurate threads. (Section B-2.3 (#chapter-b-2-3-describe-stationary-power-tools-used-in-the-pipe-trades))

open side vise

A vise designed to hold long pieces of pipe from one side while work is done on them. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

open-circuit voltage

The voltage in a welding circuit when the machine is on, but the arc has not yet been started. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

open-structure coarse-grain wheel

A grinding wheel with large abrasive grains spaced farther apart to remove material quickly. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

optical level

A surveying instrument that uses a telescope and leveling system to measure height differences and establish level lines over a distance. It is commonly used in construction and site layout work. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

optical level (builder's level or dumpy level)

Also known as 4-pin level; a surveying instrument with a telescope used to measure height differences and establish level reference points over long distances on construction sites. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

out-of-plumb

Not perfectly vertical or straight up and down. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

out-of-round

A condition where a grinding wheel is not perfectly circular, causing vibration during use. (Section B-2.4 (#chapter-b-2-4-use-stationary-power-tools))

outrigger

A support member that projects beyond the natural outline of a crane to provide additional support to prevent toppling. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

Overhead travelling cranes (also called bridge or gantry cranes)

A crane that moves along overhead beams or rails and uses a hoist to lift and move heavy loads across a workspace. (Section-B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

overlap

Extra weld metal that spills over the edge of a weld without properly joining to the base metal. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

overlapped

The part where two sections of a ladder slide over each other to make the ladder longer and stronger. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

oxidizing effect

The ability of oxygen to make materials burn faster and hotter by helping combustion happen more easily. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

oxidizing flame

A flame with too much oxygen that can cause metal to burn or become brittle. (Section B-5.2 (#chapter-b-5-2-describe-cutting-brazing-and-soldering-techniques))

oxy-acetylene

A system that uses a mixture of oxygen and acetylene gas to produce a high-temperature flame for cutting, welding, or heating metal. (Section B-5.3 (#chapter-b-5-3-use-oxy-acetylene-equipment))

oxyacetylene

A mixture of oxygen and acetylene gases used in metalworking to produce a very high-temperature flame for welding, cutting, brazing, and heating metals. The oxyacetylene flame can reach temperatures of about 3300 °C (6000 °F), making it one of the hottest fuel-gas flames used in the pipe trades. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

oxygen cylinder valve

A valve on top of an oxygen tank that opens and closes to control how much oxygen comes out. It keeps the gas safely inside the tank until you are ready to use it. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

parallel

When two lines or surfaces run in the same direction and stay the same distance apart, so they never meet. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

parallel (with the grain)

When two lines or surfaces run in the same direction and stay the same distance apart, so they never meet or cross. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

peen

The rounded end of a hammer head opposite the striking face. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

peening

Damage that occurs when wire rope repeatedly strikes or rubs against a hard surface, causing the wires or strands to flatten, distort, and become brittle over time. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

pencil grinders (die grinders)

Small, high-speed grinders used for detailed work, such as removing burrs, shaping metal, or working in tight spaces. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

pendant

Also called stay, a supporting line that maintains a constant distance between two points of attachment, such as a counterweight and a gantry or mast. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

penetration

The depth that the weld melts into the base metal. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

percussive force

A strong striking or hammering force produced by a tool that repeatedly hits a surface to break, chip, or penetrate material. (Section B-2.2 (#chapter-b-2-2-use-portable-power-tools))

perpendicular

When two lines or surfaces meet at a right angle of 90 degrees. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

perpendicular (against the grain)

When two lines or surfaces meet at a right angle (90°). One line goes straight up or across from the other. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

PEX

Cross-linked Polyethylene (PEX) is a type of flexible plastic pipe used for plumbing and heating systems. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

pick-and-carry

A lifting operation in which a crane or lifting machine raises a load and then moves it horizontally to another

location while the load remains suspended, usually carried low to the ground for safety. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

pipe dies

Cutting tools used to create threads on the outside of a pipe. These threads allow pipes and fittings to be screwed together to form a tight connection. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

pipe freeze kits

A tool used to temporarily freeze the water inside a pipe so repairs can be made without shutting off the entire water system. The frozen water forms a plug that stops the flow while work is done. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

pipe saddle drill

A mechanical fitting that attaches to a pipe to create a branch outlet connection. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

pipe sleeve

A protective pipe or opening that allows another pipe to pass through walls or structures. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

pipe taps and tapping

Pipe taps are cutting tools used to create internal threads inside a pipe or fitting. Tapping is the process of using a pipe tap to cut these threads so another threaded pipe or fitting can be screwed into it. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

pipe thread

A **spiral ridge** cut into the end of a pipe so it can screw into another pipe or fitting. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

pipe vises

A tool used to hold a pipe steady while it is cut, threaded, or worked on. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

pipe wrench

A wrench with sharp teeth designed to grip and turn round pipes. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

pitch

The distance between the teeth on a saw blade. It helps determine how fast and how smoothly the saw cuts. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

pitch (saw teeth)

The distance between the teeth on a saw blade. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

pitch (thread pitch)

The distance between corresponding points on adjacent threads, often measured as threads per inch (imperial) or millimetres (metric). (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

plan brace (gooser bar)

A metal support bar used on scaffolding to keep the scaffold frame square and stable. It connects parts of the scaffold to prevent the structure from twisting or shifting out of alignment. (Section B-3.2 (#chapter-b-3-2-use-ladders-and-elevated-platforms))

plastic (pasty) range

The temperature range where a metal is partly solid and partly liquid, making it soft and easy to shape. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

plastic nut basin wrench

A basin wrench designed specifically for tightening or loosening plastic nuts under sinks. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

plastic range

(Also called the *pasty* range); the temperature range between the solidus and liquidus of an alloy; some portion of the alloy is solid, but the majority is liquid. This is due to the alloy's components solidifying at different temperatures. (Section B-5.2 (#chapter-b-5-2-describe-cutting-brazing-and-soldering-techniques))

plug and slot weld

A weld used to join overlapping pieces of metal by filling holes or slots in one piece to fuse it to another. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

plumb

Perfectly **vertical or straight up and down**, like the direction gravity pulls. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

plumb bob

A pointed weight attached to a string that is used to find a perfectly vertical (plumb) line. When the weight hangs freely, the string shows a straight up-and-down direction. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

pneumatic

A system that uses air pressure to move or lift things. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

polarity

The direction of electrical flow in a welding circuit, which affects how heat is distributed between the electrode and the workpiece. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

polyolefins

A group of plastics made from simple chemical compounds called olefins. Common examples include polypropylene (PP) and polyethylene (PE). These plastics are lightweight, strong, and resistant to chemicals, so they are often used to make pipes, fittings, and other plumbing materials. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

porosity

Small holes or bubbles in a weld caused by trapped gas. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

portable

A tool or piece of equipment that is easy to carry and move from one place to another so it can be used in different locations. Portable tools are often cordless and may use a rechargeable battery. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

portable band saw

A handheld power saw that uses a continuous loop blade to cut metal, pipe, or other materials. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

portable power drive

A powered tool used to turn pipe-threading heads and cut threads on pipe quickly. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

position welding

Welding performed in the flat position where the weld is parallel to the ground. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

powder-actuated fastener

A hardened steel nail or pin that is driven into materials such as concrete or steel using a powder-actuated tool powered by a small explosive charge. (Section B-2.2 (#chapter-b-2-2-use-portable-power-tools))

powder-actuated tools

(Often called a Hilti gun or Ramset gun after their manufacturing companies); A power tool (like a nail gun) that uses a small explosive charge (similar to a firearm cartridge) to drive fasteners such as nails or pins into hard materials like concrete or steel; process is known as direct fastening or explosive fastening. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

power cut-off saw (chop saw)

A power tool that uses a rotating abrasive wheel or blade to cut metal, pipe, or other materials. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

power drives

A stationary machine that rotates pipe so tools can be used to cut, ream, thread, or groove the pipe more easily. (Section B-2.3 (#chapter-b-2-3-describe-stationary-power-tools-used-in-the-pipe-trades))

prick punch

A very sharp punch used to mark precise points on metal before drilling. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

propane gas

A flammable hydrocarbon fuel gas (C_3H_8) stored as a liquid in pressurized cylinders and widely used for heating and cutting operations. In oxy-fuel processes, propane is mixed with oxygen to produce a clean, controlled flame suitable for metal cutting and preheating, though its flame temperature is lower than that of oxyacetylene. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

protractor head

An attachment used with a combination square that helps measure and mark angles. It is marked in degrees so workers can lay out accurate angles. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

pry bar

(also called the crowbar or long bar); A long, strong metal bar used to lift, pry apart, or move heavy materials. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

prying

Using leverage with a tool to separate or lift materials apart. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

pulley

A wheel with a rope or cable that helps lift or move heavy loads. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

pulsation dampeners (snubbers)

Small devices attached to pressure gauges to reduce rapid pressure fluctuations. They help protect the gauge from damage and allow the pressure reading to remain steady and easier to read. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

purging

The process of removing air or hazardous gases from a space by replacing them with another gas or liquid. (Section B-6.1 (#chapter-b-6-1-describe-safety-requirements-and-precautions-for-arc-welding))

quick-change spring

A type of tool retainer used on pneumatic hammers that allows the operator to quickly install or remove a chisel or tool bit by pushing the spring aside. (Section B-2.2 (#chapter-b-2-2-use-portable-power-tools))

raker (tooth set)

A pattern of band-saw teeth where one tooth bends left, the next bends right, and the next stays straight to help clear chips while cutting. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

ram bending

A pipe-bending method where a hydraulic ram pushes the pipe against a forming die to create a bend. (Section B-2.3 (#chapter-b-2-3-describe-stationary-power-tools-used-in-the-pipe-trades))

rapidgrip wrench

A wrench with a spring-loaded jaw that allows quick gripping and ratcheting with one hand. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

raprench (rap-wrench)

A type of pipe wrench with a flat hammering surface used to loosen stuck pipes or fittings. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

ratchet torque wrenches

A tool used to tighten nuts or bolts to a specific amount of turning force (torque); works with a ratcheting handle so the user can tighten a fastener without removing the tool after each turn. When the correct torque is reached, the wrench usually clicks or releases to prevent over-tightening. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

reamer

A precision tool used to enlarge, smooth, or finish an existing hole or pipe end to an accurate diameter. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

reaming

The process of smoothing and slightly enlarging the inside of a hole or pipe to remove rough edges and improve fit. (Section B-2.4 (#chapter-b-2-4-use-stationary-power-tools))

reciprocating saw

(Also known simply as a r*ecip saw* or *Sawzall*); a power saw with a blade that moves back and forth quickly to cut through wood, metal, or plastic. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

reef knot

(or square knot); A simple knot used to tie two ends of a rope together. It is commonly used for securing bundles or light loads but should not be used for heavy lifting or critical rigging because it can slip under strain. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

reeving

The process of threading a rope or cable through pulleys or lifting equipment. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

refractive index

A measurement that describes how much light bends when it passes through a substance, such as a liquid or glass. It is used to help determine the concentration or composition of a liquid. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

refractometer

A handheld measuring tool used to check the concentration of liquids, such as antifreeze, by measuring how light bends (refracts) when it passes through the liquid. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

refractometers

A handheld measuring tool used to check the concentration of liquids, such as antifreeze, by measuring how light bends (refracts) when it passes through the liquid. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

regular teeth

A band-saw tooth pattern with evenly spaced teeth designed for smooth cutting. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

regulator

A device that controls the pressure of gas flowing from a cylinder to ensure safe and consistent operation. (Section B-5.3 (#chapter-b-5-3-use-oxy-acetylene-equipment))

reinforcement

Extra weld metal deposited above the surface of the base metal to strengthen the weld. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

residual stress

Stress that remains inside metal after it has been heated and cooled. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

resistance (load force)

The force that must be overcome to move or lift a load. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

respirator

A protective device worn over the nose and mouth to filter harmful fumes, gases, or particles from the air. (Section B-6.1 (#chapter-b-6-1-describe-safety-requirements-and-precautions-for-arc-welding))

retainer

A device used on tools such as pneumatic hammers to hold a tool bit, chisel, or attachment securely in place during operation. (Section B-2.3 (#chapter-b-2-3-describe-stationary-power-tools-used-in-the-pipe-trades))

reverse flow check valve (RFCV)

A device that prevents gases from flowing backward into hoses or cylinders, helping to reduce the risk of fire or explosion. (Section B-5.3 (#chapter-b-5-3-use-oxy-acetylene-equipment))

reverse flow check valves (RFCV)

A safety device installed in oxy-fuel equipment that allows gas to flow in only one direction and prevents gases from flowing backward into hoses or cylinders. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

rigging

The equipment and methods used to attach and lift loads safely with cranes or hoists. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

rip blade

A saw blade designed to cut wood along the grain. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

rip blades

A saw blade designed to cut wood along the grain. The teeth are shaped to remove wood quickly and make long, straight cuts. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

ripsaw

A hand saw used to cut **along the grain of wood**. Its teeth are shaped to remove wood fibres as it cuts. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

rivet

A metal pin used to permanently fasten materials together. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

roll groover

A machine that uses rollers to press a groove into the end of a pipe so it can be connected with mechanical couplings. (Section B-2.4 (#chapter-b-2-4-use-stationary-power-tools))

roll grooving

A process used to form a groove around the outside of a pipe by pressing it between rolling wheels. The groove allows special couplings to be attached so pipes can be joined together without threading or welding. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

rolling hitch

A knot used to attach a rope to another rope, pole, or object so it grips tightly when pulled lengthwise. It is commonly used to take strain off a loaded rope or to secure a line that may be under tension. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

root face (or landing)

The flat surface at the edge of a joint that remains uncut to support the weld and control penetration. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

root opening

The gap between two pieces of metal at the joint, which allows weld metal to penetrate and fuse the pieces together. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

root radius

The curved surface at the base of a joint preparation (such as a U-groove) that helps control weld penetration and allows smoother flow of weld metal. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

rope lay

The length along the rope in which one strand makes a complete revolution around the rope. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

rosebud (torch tip)

A multi-port torch tip used with an oxy-fuel torch to produce a large, soft flame for heating or preheating metal. It distributes the flame through several small openings, allowing heat to be spread evenly over a wider area than a standard welding or cutting tip. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

rotary draw bending

A pipe-bending method where the pipe is clamped to a rotating die and pulled around it to form a smooth, accurate bend. (Section B-2.3 (#chapter-b-2-3-describe-stationary-power-tools-used-in-the-pipe-trades))

round stock

A solid piece of metal shaped like a cylinder (round bar) that is used to make parts or components. It is often measured, cut, or machined in metalworking and pipe trades. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

rungs

The round bars on a ladder that you step on when climbing. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

sabre saw (jigsaw)

A handheld power saw with a narrow blade that moves up and down to cut curves or shapes in wood, metal, or plastic. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

saddle (pertaining to hook)

The curved bottom part of a lifting hook where the load should sit. The saddle is the strongest part of the hook and is designed to safely support the weight. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

safe working load

safe working load (SWL) – The maximum weight that lifting equipment can safely lift without breaking or failing. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

safety catches

A spring-loaded latch attached to a hook that closes the opening of the hook to prevent a sling, rope, or chain from accidentally slipping off during lifting. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

safety collar

A U-shaped metal collar used on pneumatic hammers with a spring retainer to help keep the tool bit securely in place and prevent it from becoming loose during operation. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

safety factor

A margin of safety used to ensure equipment can handle more than the expected load. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

scaffold

A temporary structure that allows workers to safely reach high work areas. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

scissor lift

A machine that raises workers straight up using folding supports that move like scissors. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

scribe / scribing

To scratch a thin line on metal using a sharp tool so that it can be cut, drilled, or shaped accurately. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

scriber (or awl)

A sharp, pointed tool used to scratch or mark precise lines on metal or other hard materials before cutting, drilling, or machining. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

scrubbing

Wear and damage that occur when a wire rope rubs repeatedly against another surface or against itself. This rubbing can cause the wires and strands to shift out of place and wear down over time. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

sectional drain cleaning machines

A drain-cleaning machine that uses several short sections of cable connected together to clear blockages in pipes. Each section is added as needed, allowing the cable to reach farther into the drain. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

self-contained breathing apparatus (SCBA)

A type of respirator that supplies clean air from a tank carried by the user. (Section B-6.1 (#chapter-b-6-1-describe-safety-requirements-and-precautions-for-arc-welding))

self-feeding multi-spur bit

A drill bit designed for wood that pulls itself into the material and cuts quickly with several sharp cutting edges. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

self-fluxing

A property of some metals or filler materials that allows them to clean and protect the joint without needing a separate flux, helping the molten metal flow properly during brazing or soldering. (Section B-5.2 (#chapter-b-5-2-describe-cutting-brazing-and-soldering-techniques))

self-supporting

Able to stand on its own without leaning against another structure. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

semi-high-speed steel blade

A saw blade made from steel that is harder than carbon steel and can handle faster cutting speeds. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

serrated jaws

Jaws with small teeth or ridges that help grip an object so it does not slip. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

shackle

A U-shaped metal connector with a removable pin used to attach slings, ropes, or chains to a load or lifting device during rigging and hoisting operations. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

shank (shaft)

the long, straight part of a tool that connects the working end (such as a blade or tip) to the handle. It helps transfer force from the handle to the cutting or working part of the tool. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

sheave

A grooved shell or pulley used to redirect force upon a hoist line. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

sheet bend

A knot used to join two ropes together, especially when the ropes are different sizes or materials. It forms a secure connection that is commonly used in rigging and rope work. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

shielded metal arc welding (SMAW)

(Also commonly called *stick welding* or *electric arc welding*); A welding process that uses an electric arc between a coated electrode and the metal to join materials. (Section B-6.1 (#chapter-b-6-1-describe-safety-requirements-and-precautions-for-arc-welding))

shots (sightings)

The readings taken through a level instrument when looking at a leveling rod to measure height or elevation. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

side grinder

A handheld power tool that uses a rotating grinding wheel or disk mounted on the side of the motor to grind, cut, or smooth metal and other materials. It is commonly used for metal work and pipe preparation. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

side-loading

A dangerous condition in which a portion of a crane hoist acts horizontally; force on a boom other than a true vertical lift that the boom is designed for. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

signal person

A trained worker who gives hand signals or radio instructions to a crane operator during lifting operations. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

sills

Flat pieces of wood or other material placed under scaffold supports to spread the load and provide a stable base on the ground. (Section B-3.2 (#chapter-b-3-2-use-ladders-and-elevated-platforms))

simple machines

Basic devices, such as levers, pulleys, and inclined planes, that make work easier by changing the size or direction of a force. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

sine wave

A smooth, wave-shaped pattern that shows how alternating current (AC) rises and falls over time as it changes direction. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

single basket hitches

A lifting method where a sling is passed under or through a load and both ends of the sling are attached to the lifting hook, forming a “basket” that supports the load from underneath. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

single joints

A joint that is welded from one side only, where the weld is applied to one side of the materials being joined. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

single-phase AC

A type of alternating current that uses one electrical wave and is commonly used in homes and small buildings. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

sink machines

A portable drain-cleaning machine used to remove clogs in sinks, floor drains, and small pipes. It rotates a flexible

cable (snake) inside the pipe to break up or pull out blockages. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

sintered

A process where powdered metal or ceramic particles are heated until they fuse together without fully melting. The result is a solid but slightly porous material that can be used to filter gases or absorb heat, such as in flashback arrestors in oxy-fuel equipment. (Section B-5.1 (#chapter-b-5-1-describe-oxy-acetylene-equipment))

skip-tooth blade

A band-saw blade with widely spaced teeth that helps clear sawdust and is useful for cutting softer materials. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

slag

A hard residue left on a weld after metal is melted and fused together. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

slag inclusion

Pieces of solid material (slag) that become trapped inside the weld. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

sling

A strong strap, rope, or chain used to lift heavy objects. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

slip-proof loop

A loop tied in a rope that will not tighten or slide when weight or tension is applied. It helps keep loads secure during lifting or pulling. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

slip-resistant safety feet

Rubber or textured ends attached to the bottom of a ladder that help prevent it from sliding and keep it stable on the ground. (Section B-3.2 (#chapter-b-3-2-use-ladders-and-elevated-platforms))

slug wrench (or striking wrench)

A short, heavy wrench designed to tighten or loosen large nuts and bolts. It has a thick handle end that can be hit with a hammer to apply extra force when turning stubborn or tightly fastened parts. It is commonly used in heavy construction and industrial work. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

snap-spin

A quick turning motion of a hand wheel used to tighten or loosen chuck jaws on a pipe or tool. (Section B-2.4 (#chapter-b-2-4-use-stationary-power-tools))

snatch block

A pulley with a side plate that opens so a rope or cable can be placed over the wheel without threading the entire

line through it. Snatch blocks are commonly used to change the direction of a pull or to increase lifting or pulling power. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

snub line

A rope or line attached to a load to help control its movement and prevent it from swinging while it is being lifted or moved by a crane. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

soapstone

A soft, chalk-like material used to **mark lines on metal or other surfaces**, especially in welding or metalworking. The marks are easy to see and can be wiped off after the work is finished. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

socket wrench

A wrench that uses removable sockets to fit over nuts or bolts and turn them. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

softeners

Protective padding placed between a sling and the sharp edges or corners of a load. Softeners help prevent damage to the sling and reduce wear or cutting while lifting. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

solidus

The temperature at which 100% of the alloy is in a solid, crystalline form. (Section B-5.2 (#chapter-b-5-2-describe-cutting-brazing-and-soldering-techniques))

sorting hooks

(shake-out hook): A long, narrow hook used in rigging to pick up or separate steel plates, beams, or other stacked materials. Its thin shape allows it to slide between tightly stacked pieces so they can be lifted safely. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

spade bit

A flat drill bit with a pointed tip used to drill larger holes in wood. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

spalled concrete

Concrete that has chipped, cracked, or broken away from the surface, often due to impact, weathering, or stress. (Section B-2.2 (#chapter-b-2-2-use-portable-power-tools))

spark guard

A protective shield mounted near a grinding wheel that helps deflect sparks, dust, and debris away from the operator during grinding. (Section B-2.3 (#chapter-b-2-3-describe-stationary-power-tools-used-in-the-pipe-trades))

speed

How fast a machine or tool rotates, usually measured in revolutions per minute (RPM). (Section B-2.4 (#chapter-b-2-4-use-stationary-power-tools))

speed governor

A device that controls the maximum speed of a machine or motor to keep it running at a safe and steady rate. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

speed of travel

How fast the welder moves the electrode along the metal while welding. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

spiralling (pipe cutting)

A cutting problem that occurs when a pipe cutter does not stay in a straight line around the pipe. Instead of following the same groove, the cutter wheel gradually moves along the pipe in a spiral pattern, resulting in an uneven or angled cut that is not square to the pipe; sometimes referred to as a barber's pole. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

spirit level

A tool used to check if something is level or plumb. It has a small bubble inside a liquid-filled tube. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

spirit vial

A small, sealed tube filled with liquid and an air bubble. It helps show when a tool or instrument is level. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

spreader bar

A bar used to keep lifting slings apart and evenly distribute the load. (Section B-4.2 (http://4.2))

spreader bars (beams)

A strong bar used during lifting to keep slings apart and help balance the weight of a load. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

spreaders

Bars on a step ladder that hold the legs apart so the ladder stays stable. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

spud wrench

(also called *monkey wrench*); A wrench used in construction that has a pointed end to help align holes and a wrench end to tighten bolts. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

square cut

A cut made at a 90-degree angle to the length of a pipe or material. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

square head (or set square)

The adjustable head of a combination square that is used to check or mark 90° (square) and 45° angles. It often includes a small spirit level and a scriber for marking lines. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

square tee joint

A tee joint in which the edges of the materials are not beveled or prepared, allowing the pieces to meet at a right angle without additional edge preparation. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

stable load

A load that remains balanced and does not shift or tip when lifted. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

stadia lines

Two short horizontal lines located above and below the main crosshair inside the telescope of a surveying instrument. They are used to estimate distance by comparing the spacing between the lines with markings on a measuring rod. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

standard combination blade

A saw blade that can be used for both ripping and crosscutting. It is made to handle general cutting jobs. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

standing part

The long, main portion of a rope that is not actively used to tie the knot. It carries most of the load when the rope is under tension. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

station (STA)

A specific point or location along a line where measurements or readings are taken. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

steam-tracing tubing

Steam tracing: A method of using steam pipes to keep other pipes warm so fluids do not freeze.

Steam-tracing tubing: Small tubing that carries steam along a pipe to keep the pipe and its contents warm, helping prevent liquids from cooling, thickening, or freezing. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

steel rule

A straight measuring tool made of steel that is used to measure short distances and draw straight lines. It usually has markings in millimetres and inches for accurate measurements. (Section B-1.1 (http://1.1))

stick boom

A type of boom lift with a straight, telescoping arm that extends outward and upward to reach high work areas.

It moves in a direct line rather than bending at joints like an articulated boom. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

stillson pattern pipe wrench

A classic pipe wrench design invented by Daniel Stillson that uses adjustable serrated jaws to grip pipes. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

straight grinders

A type of grinder where the grinding wheel is in line with the motor shaft, used for precise work and hard-to-reach areas. (Section B-6.3)

straight pattern pipe wrench

A common pipe wrench design with straight jaws used for gripping and turning pipes. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

strap wrench

A wrench that uses a rubber or fabric strap to grip and turn round objects without damaging them. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

striker

A tool used to safely ignite a welding torch by producing a spark. (Section B-5.3 (#chapter-b-5-3-use-oxy-acetylene-equipment))

structural discontinuities

Flaws or breaks in a weld that weaken the metal. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

stubbies (stubby screwdrivers)

Short screwdrivers with a compact handle and shaft. They are designed for tightening or loosening screws in tight or confined spaces where a regular-length screwdriver would not fit. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

studs

Short rods or fasteners, often threaded on both ends, used to join or secure parts together. (Section B-2.4 (#chapter-b-2-4-use-stationary-power-tools))

superstructure

The supporting framework or structure above the base of lifting equipment that holds and supports hoists, cranes, or other lifting devices during operation. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

swaging

A process used to change the shape or size of a pipe or tube end, usually to make it fit inside another pipe. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

sway brace

A support bar that helps keep a scaffold stable and prevents it from wobbling. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

swing

The hazard area associated with the radius of the crane's carrier and counterweights; this should be a flagged-off area during crane operation and considered a no-go zone. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

swivels

A rotating connector used in lifting and rigging that allows a hook, chain, or sling to turn freely. This helps prevent twisting of the lifting equipment while a load is being lifted or moved. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

tack weld

A short weld used to hold parts in place during fit-up before final welding. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

tag lines

A rope attached to a suspended load that workers hold to guide and steady the load, helping control its direction and rotation during lifting or positioning. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

tagline

Guy-wires used to control crane loads from unwanted rotation or swinging, allowing ground workers to control the load from a safe distance. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

tang (file tang)

The narrow-pointed section at the end of a file that fits into the handle. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

tangent chart

A printed chart on some pipe layout tools that helps workers find angles and measurements when laying out cuts or fittings on pipe. It uses tangent values to calculate distances needed for accurate pipe layouts. (Section B-1.1 (http://1.1))

tapered thread

A thread that gradually decreases in diameter along its length to create a tighter seal as it is tightened. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

telescope (surveying)

In a surveying instrument, the telescope is the tube used to look at a distant target or measuring rod to determine height or alignment. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

temper (metal)

The hardness and strength created in metal by heat treatment. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

tempered steel

Steel that has been heat-treated to increase hardness and durability. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

theodolite level

A precision surveying instrument used to measure horizontal and vertical angles. It uses a rotating telescope mounted on a base and is commonly used in construction, engineering, and land surveying to establish accurate positions and alignments. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

thermoplastic pipe

A type of plastic pipe that softens when heated and hardens again when cooled. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

thimble

A metal fitting placed inside the eye (loop) of a wire rope or fibre rope to protect it from wear and crushing. The thimble helps the rope keep its shape and prevents damage when the rope is attached to hooks, shackles, or other rigging hardware. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

thread

A spiral ridge formed on a bolt, screw, or pipe used for fastening or sealing. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

thread gauge (or screw pitch gauge)

A measuring tool used to identify the size and spacing of threads on bolts, screws, or pipes. It helps determine the thread pitch so the correct fastener or fitting can be used. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

threader

A tool used to cut threads onto the outside of a pipe or rod so that fittings or other threaded parts can be screwed onto it. Threaders are commonly used in plumbing and pipe installation. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

three-jawed chuck

A clamping device on a drill that uses three jaws to hold a drill bit or other tool securely in place while it spins. The jaws tighten or loosen together to keep the bit centered. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

three-phase AC

A type of alternating current that uses three electrical waves working together to provide a steady and powerful

supply of electricity, often used in industrial settings. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

thumbscrews (levelling screws)

Thumbscrews are adjustable screws used to level or position an instrument by turning them with your fingers. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

tilting level

(also known as split-bubble levels or engineer's levels); a surveying instrument used to measure height differences and establish level lines. It has a telescope that can be slightly tilted to center the bubble in the level vial for accurate readings. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

timber hitch

A knot used to secure a rope around logs, poles, or other long objects for lifting or dragging. The knot tightens when tension is applied and loosens easily when the load is removed. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

tirfor jacks

A hand-operated lifting or pulling device that uses a wire rope and gripping jaws to move heavy loads. By operating a lever, the device pulls the rope through the mechanism to lift, lower, or pull materials with controlled force. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

toe-boards

A small board along the edge of a platform that prevents tools or materials from falling off. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

tolerances

The small amount a measurement can vary from the exact value and still be acceptable. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

tool rest

An adjustable support on a grinder that holds the workpiece steady while grinding so the operator can control the tool safely and accurately. (Section B-2.3 (#chapter-b-2-3-describe-stationary-power-tools-used-in-the-pipe-trades))

top screw chain vise

A portable pipe vise with three legs and a chain used to hold pipes firmly at a job site. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

top screw stand chain vise

A portable pipe vise mounted on a stand with legs that support long pieces of pipe during work. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

top-running

A type of overhead travelling crane where the crane bridge runs on rails mounted on top of runway beams, allowing it to carry heavier loads. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

torpedo level

A torpedo level is a small, narrow level used to check whether a surface or pipe is level or plumb in tight spaces. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

torque

A twisting force applied to a fastener or tool. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

Torx head screwdrivers

A tool used to tighten or loosen screws that have a star-shaped pattern with six points in the head. The shape helps the screwdriver grip the screw firmly, reducing slipping and allowing more turning force. Torx screwdrivers are commonly used in electronics, automotive work, and machinery. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

toxic fumes

Harmful gases or airborne particles produced during welding that can cause illness or injury when inhaled. (Section B-6.1 (#chapter-b-6-1-describe-safety-requirements-and-precautions-for-arc-welding))

trammel points

Adjustable points attached to a bar or ruler that are used to draw very large circles or arcs. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

transit level

A surveying instrument used to measure horizontal and vertical angles and to establish level lines in construction and layout work. It has a telescope that can rotate both horizontally and vertically for accurate measurements. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

tri-stand chain vise

A portable pipe vise with three legs and a chain used to hold pipes firmly at a job site. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

tri-stand yoke vise

A portable vise with three legs and metal jaws used to clamp and hold pipes while they are being worked on. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

trucker's knot

A knot system used to tighten a rope when securing loads. It creates a mechanical advantage that allows the rope to be pulled very tight, making it useful for tying down equipment or materials. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

tube-and-clamp system

A type of scaffold built from metal tubes connected with adjustable clamps. The tubes can be arranged in many different ways, allowing the scaffold to be built to fit different shapes and sizes of work areas. (Section B-3.1 (#chapter-b-3-1-describe-ladders-and-elevated-platforms))

tubing

Thin-walled pipe used to transport fluids or gases. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

tubing benders

Tools used to bend metal tubing or pipe into smooth curves without flattening or damaging the tube. They help create accurate angles and shapes when installing plumbing, heating, or mechanical tubing. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

tubing nut wrench

(flare nut); A special wrench used to tighten or loosen nuts on tubing connections. It fits around most sides of the nut, which helps prevent slipping and reduces damage to the corners of the nut. It is commonly used on fuel lines, brake lines, and plumbing tubing. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

tubing spring bender

A tightly wound metal spring that slides over or inside soft tubing to help it bend without kinking or flattening. It supports the tubing while it is being bent so the curve stays smooth and the tube keeps its round shape. (Section B-1.2 (#chapter-b-1-2-use-hand-tools))

tuggers

A powered winch, usually electric or hydraulic, that pulls or lifts heavy loads using a drum and cable or rope. Tuggers are commonly used to move pipes, equipment, or materials into position. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

turnbuckles

A metal device used to adjust the tension or length of ropes, cables, or slings. It has a threaded body with two threaded ends that can be tightened or loosened by rotating the central frame. (Section B-4.5 (#chapter-b-4-5-use-hoisting-lifting-and-rigging-equipment))

turning point

A temporary reference point used when moving a level instrument to a new position. A reading is taken on this point before and after the instrument is moved so measurements stay accurate. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

twist drills (drill bits)

Common drill bits with spiral grooves that remove material as the bit drills into wood, metal, or plastic. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

under-running

A type of overhead travelling crane where the crane bridge is suspended from the underside of runway beams, typically used for lighter loads. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

undercut

A groove or dip along the edge of a weld that makes the joint weaker. (Section B-6.4 (#chapter-b-6-4-use-arc-welding-equipment))

unstable load

A load that shifts, tilts, or moves unexpectedly when lifted. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

variable speed

A feature on a power tool that allows the operator to control how fast the tool runs. The speed can be increased or decreased depending on the task being performed. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

ventilation

The movement of fresh air through a space to remove harmful fumes, gases, or heat. (Section B-6.1 (#chapter-b-6-1-describe-safety-requirements-and-precautions-for-arc-welding))

vertical pipe wrench

A pipe wrench designed for use on vertical pipes or in tight spaces where a long handle cannot be used. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

vise

A mechanical tool used to securely hold a workpiece during cutting, drilling, or assembly operations. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

voltage

The electrical pressure that pushes current through a circuit, measured in volts (V). (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

volts (V)

The unit used to measure voltage, or the electrical pressure that pushes current through a circuit. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

water jetter

A drain-cleaning machine that uses a high-pressure stream of water to break up and wash away grease, debris, and other blockages inside pipes. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

water pump pliers

adjustable pliers used to grip and turn pipes, fittings, and other round objects. The jaws can be moved to different

positions to fit different sizes, and the teeth help hold the object tightly without slipping. They are commonly used in plumbing and mechanical work. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

wavy set

A band-saw tooth pattern where small groups of teeth are bent slightly in alternating directions to make smooth cuts in thin materials. (Section B-2.1 (#chapter-b-2-1-describe-portable-power-tools-used-in-the-pipe-trades))

weld deposit

The metal that is melted and added during welding, forming the final weld as it cools and hardens. (Section B-6.3 (#chapter-b-6-3-describe-the-arc-welding-process-and-equipment))

weld joint

The point or area where two or more pieces of metal are joined together by welding. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

welding position

The orientation of the weld and workpiece during welding, such as flat, horizontal, vertical, or overhead. (Section B-6.2 (#chapter-b-6-2-identify-types-of-welds-positions-joints-and-symbols))

whip line

A secondary hoist line on a crane that is typically lighter and faster than the main hoist line. It is used for lifting smaller loads or for quicker lifting operations. (Section B-4.3 (#chapter-b-4-3-describe-lifting-and-hoisting-communication))

whipline (auxiliary hoist)

A secondary hoist line from the main, usually lighter and faster. (Section B-4.6 (#chapter-b-4-6-rig-load-for-cranes))

whipping

A method of tightly wrapping twine or wire around the end of a rope to prevent it from fraying or unraveling. (Section B-4.4 (#chapter-b-4-4-select-slings-and-tie-knots-bends-and-hitches))

winch

A mechanical device used to pull or lift loads using a rotating drum and cable. (Section B-4.2 (#chapter-b-4-2-describe-hoisting-lifting-and-rigging-equipment))

wonder bar

A small flat metal prying tool with claws on both ends used for light prying and nail removal. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

wood vises

A vise designed to hold pieces of wood securely while cutting, shaping, or sanding. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

working load limit (WLL)

(or *rated capacity*); The maximum weight a piece of lifting equipment can safely carry. (Section B-4.1 (#chapter-b-4-1-describe-the-principles-of-lifting-and-hoisting))

workpiece

The material or object being worked on, such as metal, pipe, or wood. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

wrap-around

A flexible measuring tool, often made of paper, plastic, or metal, that is wrapped around a pipe to mark a straight and even cutting line all the way around it. It helps ensure the pipe is cut square (perfectly straight) across its diameter. (Section B-1.2 (#chapter-b-1-2-use-hand-tools))

wrecking bar

(also called a gooseneck); A heavy metal bar used for prying materials apart and pulling nails during construction or demolition. (Section B-1.1 (#chapter-b-1-1-describe-hand-tools-used-in-the-pipe-trades))

zero datum

The starting reference level from which all elevations or depths are measured. It is considered the “zero” point for height measurements. (Section B-1.3 (#chapter-b-1-3-use-levelling-equipment))

zip disks (cut-off disks)

A thin abrasive cutting disk used with a grinder to cut metal or other hard materials. It cuts quickly along the edge of the disk and should not be used for grinding on the side. (Section B-2.2 (#chapter-b-2-2-use-portable-power-tools))

Version History

This page provides a record of changes made to this learning resource, Plumbing Apprenticeship Level 1, Block B (https://b-handmeasuringtools-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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Version	Date	Change	Details
1.0	May 2026	Plumbing Apprenticeship Level 1 Block B learning resource from STBC content converted to open and freely accessible digital platform and published at TRU.	

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.