POWER ENGINEERING

Fourth Class

Edition 3.5

Energy Plant Maintenance

Part B

Unit B-5

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UNIT B-5

ENERGY PLANT MAINTENANCE

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Unit Introduction

An energy plant maintenance program is a key element to safe and efficient boiler operation. These programs include not only repairs but preventative maintenance as well. The repair and preventative maintenance tasks covered in this unit are designed to achieve a reasonably long, safe, and useful boiler life. These tasks also ensure that boilers operate as intended.

Maintenance schedules are set up based on the manufacturer's specifications. Service intervals are based on the amount of "in service" time and the amount of steam generated.

This unit presents the most common tools and equipment to maintain, repair, and clean boilers. As well, general information on boiler cleaning and boiler maintenance procedures is included. Review questions at the end of each chapter will help to review and learn the materials presented.

Unit Rationale

Power Engineers must be able to safely and correctly perform basic mechanical repairs. These repairs are done with the use of hand and power tools, and equipment such as ladders, scaffolds, slings, and hoists. It is necessary to be familiar with various tools and equipment for cleaning, maintenance, calibration, small repairs of power house equipment, and the boilers themselves.

All buildings and industries require ongoing maintenance to:

- Pumps
- Valves
- Boilers
- Piping
- Associated powerhouse equipment.

Employers will have specific requirements for each facility. The general knowledge in this unit is required for Power Engineering certification.

CHAPTER 1

Energy Plant Maintenance I

Learning Outcome

When you complete this chapter you should be able to:

Describe the safe use of common hand tools in the powerhouse.

Learning Objectives

Here is what you should be able to do when you complete each objective:

1. Describe the types and proper use of hacksaws, files, chisels, hammers, screwdrivers, and wrenches.
2. Describe the types and proper use of hand threading tools.
3. Describe the types and proper use of measuring tools.
4. Describe the proper layout of work and the use of layout tools.
5. Describe the types and proper use of portable and fixed grinders, hand drills, drill presses, and the care of drill bits.

Chapter Introduction

The Power Engineer can expect to perform regular maintenance on equipment such as pumps, air handlers, compressors, and boilers. To do these maintenance tasks, Power Engineers will use various hand tools, including everyday tools such as screwdrivers and wrenches. Sometimes, specialized hand tools may be used, for threading pipe, filing surfaces, or tapping holes.

When hand tools are not adequate for the task, the Power Engineer will need to be able to safely and correctly use power tools. These can include hand-held drills, drill presses, bench grinders, and angle grinders, to name a few.

Throughout this unit, emphasis is put on the safe use of the equipment. Sometimes, the use of hand and power tools require specialized procedures and training, in order to comply with Occupational Health and Safety rules and guidelines. Procedures, where provided in this chapter, are to be used only as general guides for the safe use of that equipment.

Objective 1

Describe the types and proper use of hacksaws, files, chisels, hammers, screwdrivers, and wrenches.

Hand Tools

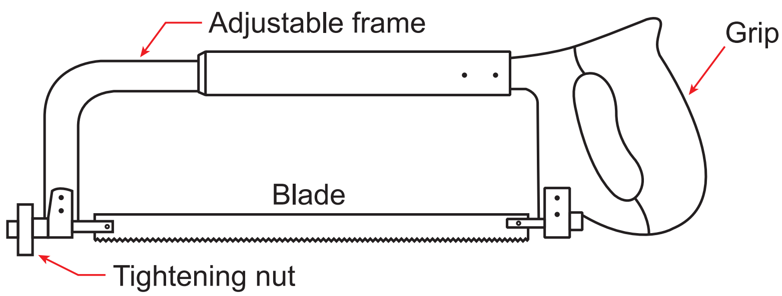
Hand tools are usually small and portable, and are used to perform specific jobs. For example, screwdrivers must not be used as scrapers or pry-bars. Tin snips should not be used to cut wire. Other types of tools classed as hand tools include hacksaws, pliers, and hammers.

Hacksaws

The hand hacksaw will cut all metals with the exception of hardened steels.

The parts of a hand hacksaw are illustrated in Figure 1. The frame keeps the blade in tension, by means of the tightening nut. Most frames are adjustable in length to accommodate different blade lengths, and many have unbreakable plastic grips.

Figure 1 – Hand Hacksaw



Hacksaw blades are made from thin high-grade steel which has been hardened and tempered. There are numerous blades to choose from. In general, blades with fine teeth are used for thin metal stock and coarse teeth for thick stock. The blades are made from a variety of metals and alloys.

Blades made from molybdenum are hard, long wearing, and straight cutting. Tungsten blades cut the toughest materials and are also used on tool and die steel. Standard flexible blades for general purpose cutting have only the teeth hardened. The back of the blade remains flexible, which minimizes breakage. Hand hacksaws are mainly used in cramped areas and where it is not possible to use a vise to support the workpiece.

When putting a new blade in a hacksaw:

1. Point the teeth of the blade away from the handle.
2. Fasten the blade to the hook at each end of the frame.
3. Apply tension to the blade by turning the tightening nut. A loose blade makes a crooked cut and is likely to break.
4. Release the tension on the blade when storing the hacksaw.

When cutting with the hacksaw:

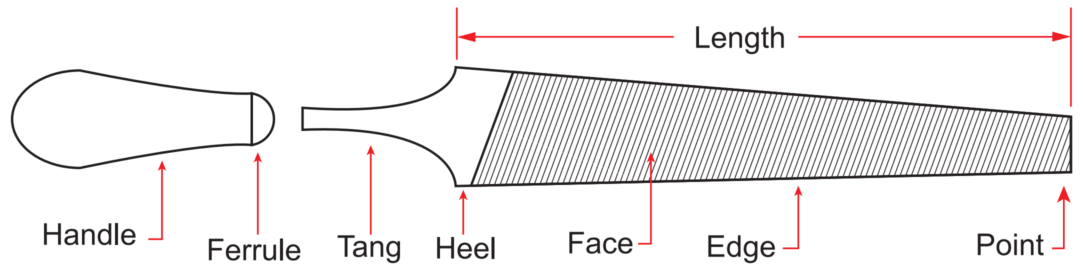
1. The work piece should be held firmly in a vise, a little below the height of the elbows.
2. Hold the saw firmly with one hand on the grip and the other at the top of the frame, near the front.
3. When commencing the cut, use light pressure and slow short strokes. Pressure should be applied only on the forward stroke.
4. When the cut has been started, increase the stroke length to use the full blade. Lift up a little on the return stroke because the blade cuts only on the forward stroke. Maintain about 40 strokes per minute.

Good practice dictates at least three teeth should be cutting at any one time, hence the use of fine teeth blades on thin workpieces. Thinner material must be cut with the blade on a slant, to maintain three teeth contact. An old blade will make a narrower cut than a new blade because the "set" of the teeth becomes worn as the blade is used. Therefore, a new blade may jam and break if it is placed in a cut started by an old blade. If a cut cannot be completed with an old blade, start a new cut with a new blade.

Files

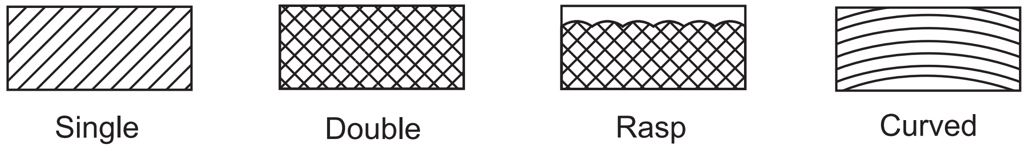
Files are very important tools in mechanical work. They are used to cut and smooth surfaces by removing small amounts of material. The various parts of a file are shown in Figure 2.

Figure 2 – File Parts



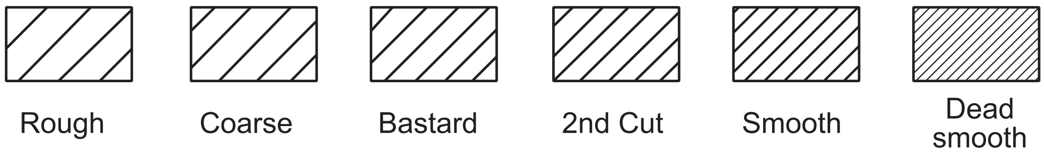
The "cut" of a file refers to the layout of the file's teeth. The four cuts available are shown in Figure 3.

Figure 3 – Cuts



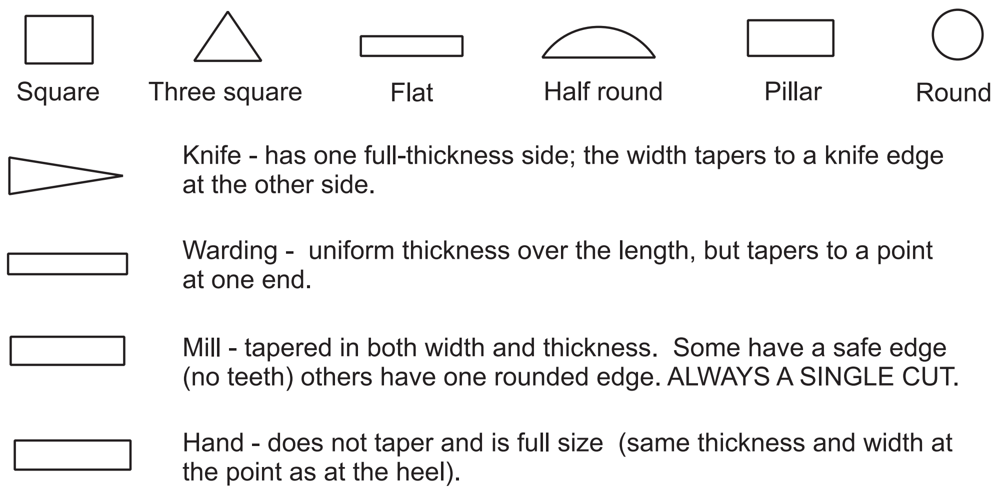
In addition to the cut, there is also the degree of coarseness, which is determined by the row spacing. The degrees of coarseness are shown in Figure 4.

Figure 4 – File Coarseness



Another method of categorizing files is the shape, which is determined by the cross sectional view. The more commonly used shapes are shown in Figure 5.

Figure 5 – File Shapes



The correct file must be selected for the intended job.

a) Generally, for a heavy rough cut, a large, coarse double cut file is best.
b) For finishing cuts, use a second cut or a smooth single cut file.
c) To file cast iron, start with the bastard cut file and finish with a second cut.
d) To file soft steel, start with a second cut file and finish with a smooth cut.
e) To file hard steel, start with a smooth cut file and finish with a dead smooth.
f) To file brass or bronze, start with a bastard cut file and finish with a second cut or smooth cut.

To correctly hold a file:

a) Hold the handle against the palm of your right hand (left handed persons will be opposite), thumb on top.

b) Hold the other end in your left hand with your fingers curled under it. The file must be held straight or the surface of the work will not be flat.

c) Maintain a speed of about 30 to 40 cutting strokes per minute.

Safety Check

Do not use a file without a handle. The handle protects your hand from injury.

Apply pressure on the forward stroke only. The file will quickly become dull unless the file is lifted from the surface on the return stroke. (This rule does not apply when filing soft metals, such as aluminum or lead. On soft work, pressure on the return stroke helps to keep the cuts of the file free of removed metal). Apply only enough pressure to make the file cut cleanly.

When filing round surfaces, the best results are obtained by using a rocking motion. Do not apply pressure to a new file. When the file is new, the teeth are very fine and will break easily under pressure.

Hold the work firmly in the vise, with the surface to be filed projecting slightly above the vise jaws and parallel to them. If the work is loose in the vise, the file will chatter which damages the teeth and produces poor workmanship in the work piece.

Sometimes, small particles of metal become clogged in the teeth of the file and scratch the metal being filed. This condition is called "pinning". It is usually the result of applying too much pressure to the file. If a file is pinning or not cutting properly, it should be cleaned with a file card, pick, or brush.

Like any cutting tool, a file is dulled quickly and made useless by rough or improper usage. It should never be thrown into a toolbox or drawer, but should be hung up or wrapped separately.

Chisels

Chisels are the simplest type of cutting tool. They are made from heat-treated steel and come in several cutting edge shapes. The cutting edge is hardened, but the head is left relatively soft to prevent it from chipping and splintering. The cutting edge is placed against the metal to be cut or chipped and the head is struck with a hammer, usually of the ball peen type.

The types of chisels most commonly used by Power Engineers are known as cold, cape, round nose and diamond point (Figure 6).

Figure 6 – Metal Cutting Chisels

The **cold chisel**, also called a flat chisel, is used to cut metals and other materials, and to shear old bolts and split nuts. It is identified by its flat shaped cutting edge.

The **cape chisel** is used to cut keyways, channels, and slots. It is specified by its cutting edge which ranges from 3 to 21 mm wide.

The **round nose chisel** is used for cutting round shaped channels, such as oil grooves. It is somewhat similar to the cape chisel with one edge ground flat and the other formed into a round cutting edge.

The **diamond point chisel** is used to cut v-shaped grooves, to turn out broken studs and split pipe nipples which have broken off in a fitting. It has a solid diamond shaped point with a variety of cutting edge sizes.

The cutting angle of a chisel is determined by the type of metal to be cut. For general-purpose work, an angle of 60° to 70° is preferred (Figure 7).

To work effectively, chisels must be kept sharp. Grinding is required when the cutting edge becomes rounded or nicked. Grind the cutting edge slightly convex (Figure 8). Care should be exercised in grinding to make sure that the point does not overheat and remove the hardness from the cutting edge. Dip the chisel often in water while grinding. This will preserve the tip's hardness. Grind both bevels, keeping each equal. If a chisel head mushrooms, grind the excess metal off.

Safety Check

Always wear goggles when using or grinding chisels.

Figure 7 – Chisel Work Angle

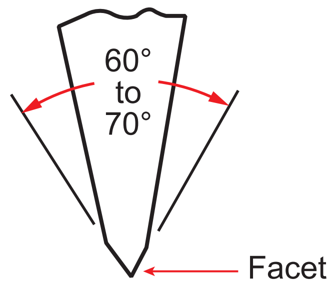
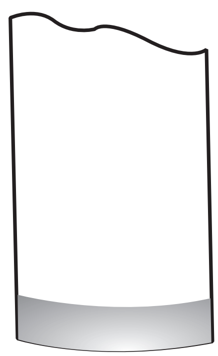


Figure 8 – Convex Cutting Edge



When using a chisel, it is preferable to use a safety handle. If a safety handle is not available, grip the chisel firmly but not too rigidly. All four fingers should encircle the chisel. The first three fingers grasp the chisel and the little finger is used to guide it. When chipping, always work towards the centre of the work. If the work piece is held in a vise, work towards the stationery jaw. A 1 kg hammer is most commonly used when working with metal cutting chisels.

Shear cutting may be accomplished on steel up to 3 mm thick. In this type of cutting, the metal is sheared between the sharpened edge of the chisel and the edge of the back jaw of the vise. The chisel must be held correctly; otherwise, a rough or badly twisted job will result. The bottom facet of the chisel should be flat against the jaw of the vise. To achieve a smooth scissor like action, the chisel must be angled across the work. Never try to cut from the end of the metal.

Hammers

The ball peen or machinist's hammer (Figure 9), as it is commonly called, is the hammer Power Engineers will use most often.

The end of the handle should fit the eye of the hammer, which is smaller at the middle, as shown in Figure 10. A wedge is driven in the middle of the handle end, which will make the hammer head tight from both sides. Hammers also are available with fibre handles, with the head locked onto the handle with epoxy.

Safety Check

Never use a hammer with a loose handle! A serious accident can result if the hammer head goes flying when swung.

Figure 9 – Ball Peen Hammer

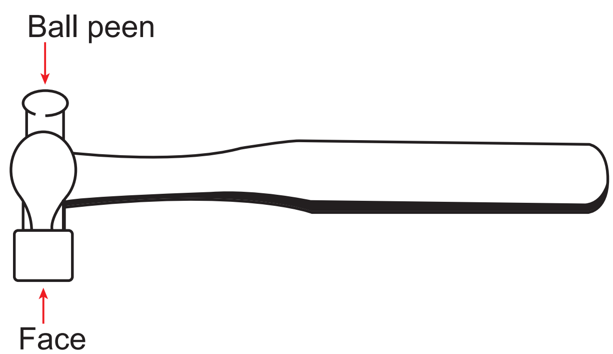
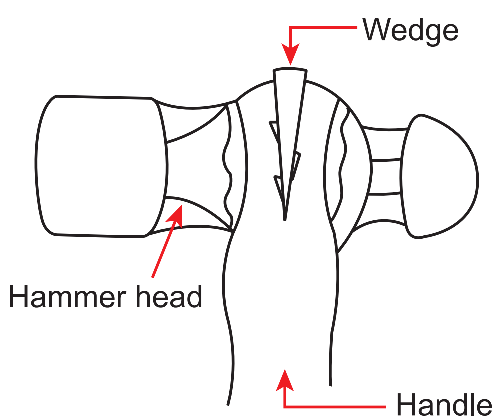


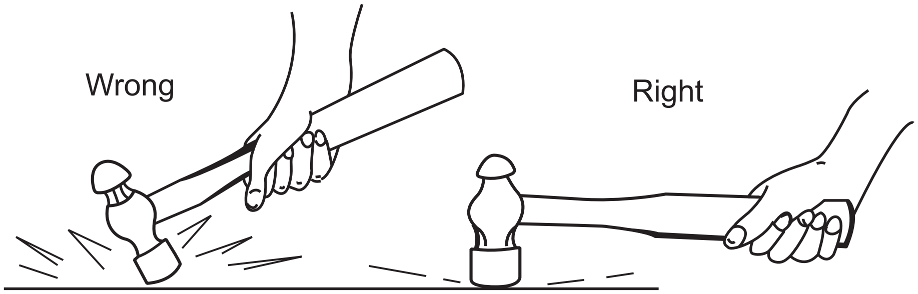
Figure 10 – Ball Peen Hammer Assembly



The face and the peen of the hammer are hardened, but the centre is left soft to reduce the possibility of breakage. The face is rounded a little so the force of the blow is concentrated in the centre and it will not leave marks on the work; for this reason, it is very difficult (and not advisable) to use a machinist's hammer to drive nails.

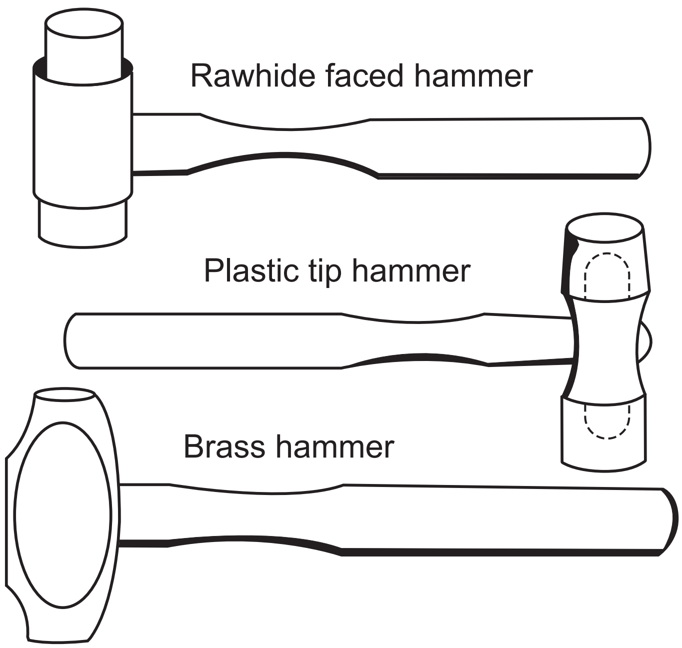
It is important to hold the hammer properly, as shown in Figure 11, which illustrates the right and the wrong way to grip and use the hammer. Gripping too tightly will cause fatigue and some loss of control. Hammers are designated by mass, which varies from 250 grams to 1 kilogram. Hammers larger than a kilogram are referred to as sledges. The peen side of the hammer is used for peening (rounding over) and heading rivets.

Figure 11 – Proper Hammer Grip



Soft faced hammers are used for work where the hard faced hammer would not be suitable; for example, when it is necessary to hammer finished surfaces. These hammers are made from lead, copper, rubber, wood, plastic, leather, and other materials. Some of these are shown in Figure 12.

Figure 12 – Soft Faced Hammers

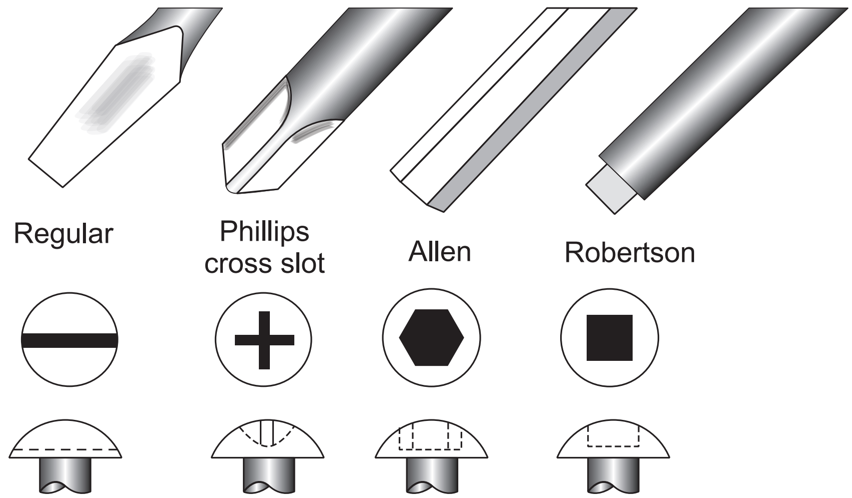


Some of these hammers have interchangeable heads and others have renewable heads.

Screwdrivers

Screwdrivers are tools for driving and removing screws or slot headed bolts. Their names come from their tip style. Some of those commonly used by Power Engineers are shown in Figure 13.

Figure 13 – Common Screwdriver Tips



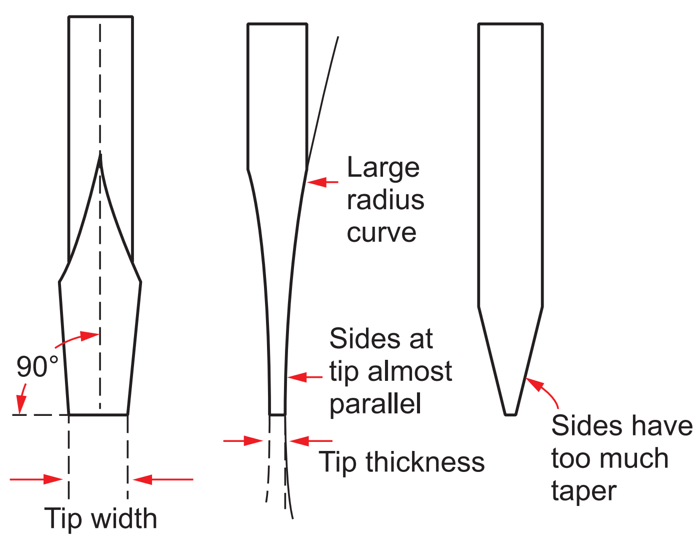
Screwdrivers can be damaged quickly by prying, scraping, or hammering on the handle. Using the driver to scrape paint or mortar from brickwork will round the sharp corners of the tip and make it unsatisfactory and dangerous for use.

Safety Check

Never try to tighten or loosen a screw while holding the workpiece. The screwdriver can slip, and produce a puncture wound.

When driver tips are worn out, chipped, or nicked, they should be reground to the correct size and shape, which can be done by grinding and dressing the tip. It should be straight and at the correct angle to the axis of the blade, as shown in Figure 14. Generally, very little maintenance can be done on Phillips, Allen, and Robertson screwdrivers. When these become worn or damaged, they should be discarded and replaced with new ones.

Figure 14 – Slotted Screwdriver Tips



Wrenches

Wrenches are tools used to tighten or loosen bolts, nuts, and pipe plugs. Special wrenches are made to grip round stock or pipe. **Torque wrenches** are made to indicate the degree of torque being applied to the nut or bolt. **Spanner wrenches** are made to turn special or specific devices, such as cover plates, rings, shafts, and couplings. A number of other special purpose wrenches are available to perform specialized tasks.

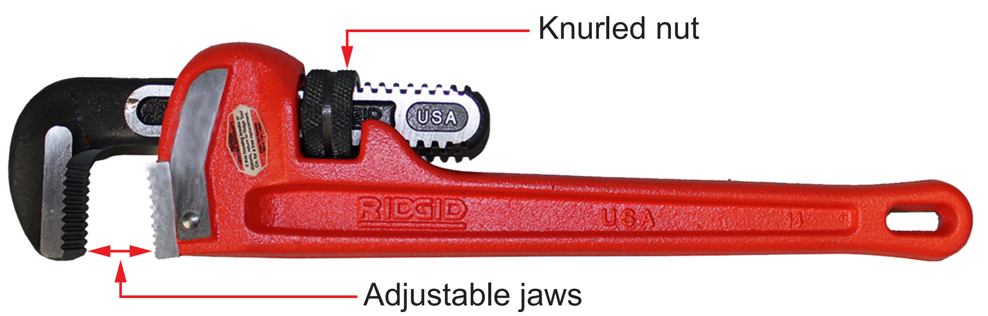
This section will describe the wrenches most commonly used by Power Engineers in routine maintenance work. These include:

- Pipe wrenches
- Combination wrenches
- Adjustable (Crescent®) wrenches
- Open end wrenches
- Socket wrenches
- Torque wrenches, and
- Spanners

A pipe wrench (Figure 15) is used to turn pieces that are round, such as pipe and pipe fittings. It may also be used to turn nuts or bolts with worn off corners.

The pipe wrench has two hardened jaws with milled teeth. It should never be used to turn good nuts and bolts, as it will cut into the metal and prevent the correct wrench from fitting properly. It also should not be used on finished surfaces.

Figure 15 – Pipe Wrench



The outer jaw is adjustable by means of a knurled nut. This jaw has a small amount of play, which will provide a tight grip on the pipe when the wrench is turned in the correct direction, towards the opening of the jaws. Force is applied to the back of the handle, which increases the grip on the work.

The **combination wrench** (Figure 16) is open at one end and has a 6 or 12-point box end at the other (A). Normally, openings at both ends are the same size. The open end is usually angled at 15° from the handle axis. The box end is offset 15° from the plane of the handle (B).

Figure 16 – Combination Wrenches

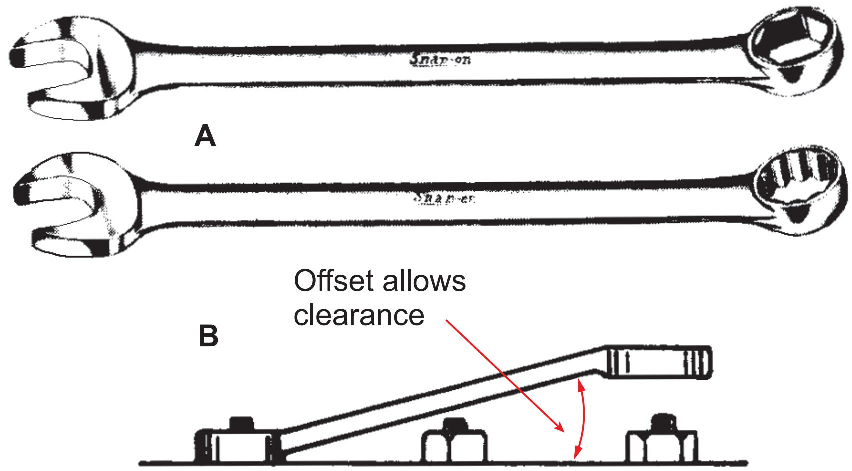


Figure 17 – Adjustable Wrench

An adjustable open end wrench (or **Crescent® wrench**) (Figure 17) is used to tighten or loosen any size of nut, bolt, or pipe plug. The wrench has one fixed jaw and one movable jaw, shaped so that the jaws form four sides for gripping hexagonal nuts and bolts.

Always use the adjustable wrench so that the turning force is applied to the fixed jaw. When the wrench is placed in position, tighten the knurled nut until the jaws make a snug fit on the nut or bolt.

Safety Check

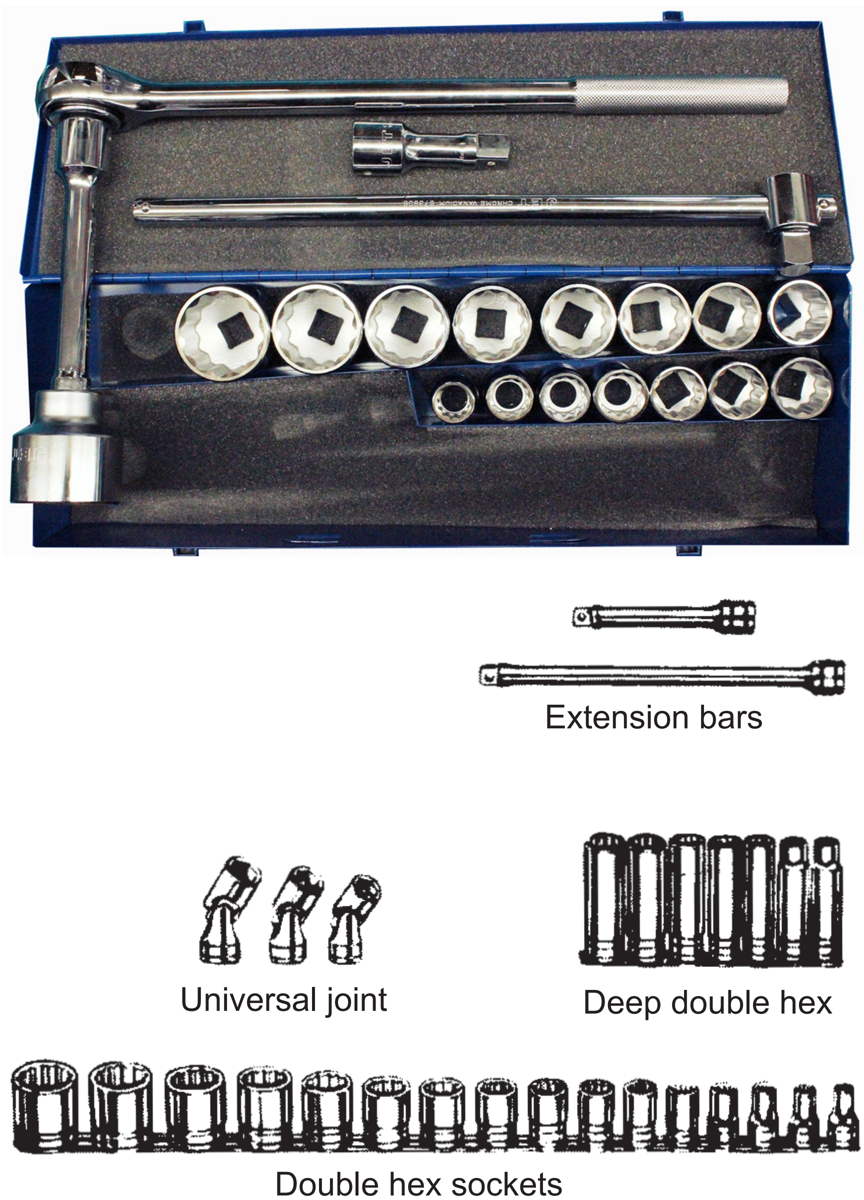
Loose fitting jaws will slip and round the corners of the nut or bolt, potentially causing damage or injury. It is preferable to pull a wrench towards you when tightening. If it is necessary to push, do so with the palm, keeping the knuckles out of the way. This reduces the chance of injury if the wrench slips.

A **socket wrench** consists of a drive handle and a socket to fit a particular nut, bolt, or headed screw. A basic socket wrench set usually consists of various sizes of 12-point sockets and several drive handles. The drive handles are available in a variety of sizes. The small size drives are used to apply smaller amounts of torque to smaller nuts and bolts. The large drive sizes permit more torque to be applied to larger fasteners.

The **ratchet drive** speeds up the work because the socket does not need to be removed from the nut or bolt after each turn when working in a confined space. Sockets have two openings: a square hole that fits the driver and a circular hole with notched sides to fit the nut or bolt head.

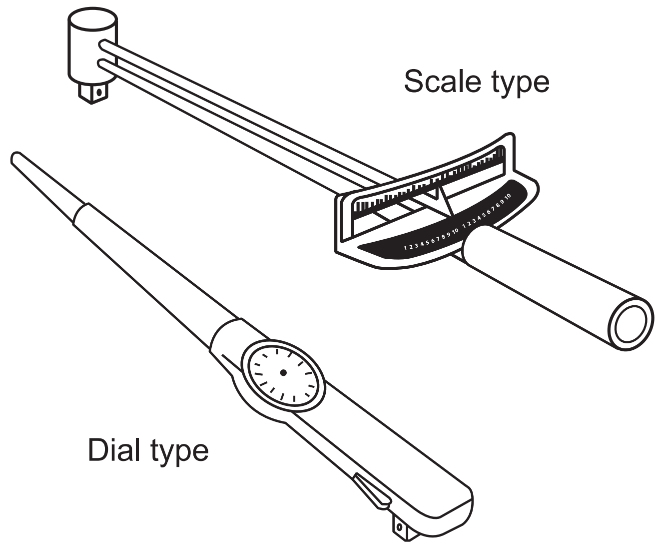
A few socket accessories are shown in Figure 18. The extension increases the length of the socket wrench drive to get into spaces that are difficult to reach. The universal joint makes it possible to turn nuts or bolts where a straight wrench cannot be used due to insufficient space for turning.

Figure 18 – Socket Wrench Set and Accessories



A **torque wrench** (Figure 19) is used to tighten fasteners to a specified turning force. It is used on machines, engines, flanges and bearings, where application of a specified force is required to ensure alignment and evenly distributed clamping force.

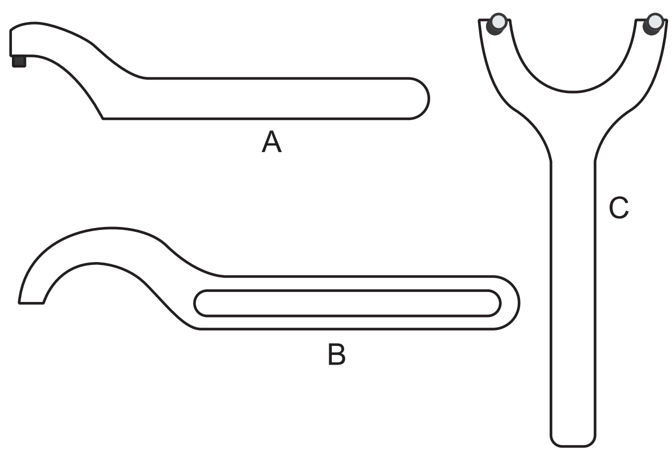
Figure 19 – Torque Wrenches



Torque wrenches are available in torque limiting, deflecting beam, and preset value.

Spanner wrenches (Figure 20) are of three types: pin (A), hook (B), and face (C). These special purpose wrenches are used to work on burners, adjust seal plates, and turn equipment shafts.

Figure 20 – Spanner Wrenches



Objective 2

Describe the types and proper use of hand threading tools.

Hand Threading Tools

Hand threading tools are used to cut connection threads in pipe and fittings, both internally and externally.

Taps

Taps are cutting tools which are designed to cut internal (female) threads. The threaded end has channels or flutes, which are cut lengthwise across the threads to form cutting edges, provide space for removal of chips and admit cutting fluid to the cutting edges. The opposite end of the tap is usually square for receiving the tap wrench (Figure 21), which can be used to turn the tap into the hole.

Hand taps are usually made in sets of three (Figure 22), called the plug, taper, and bottoming taps.

Figure 21 – Tap Handle Wrenches

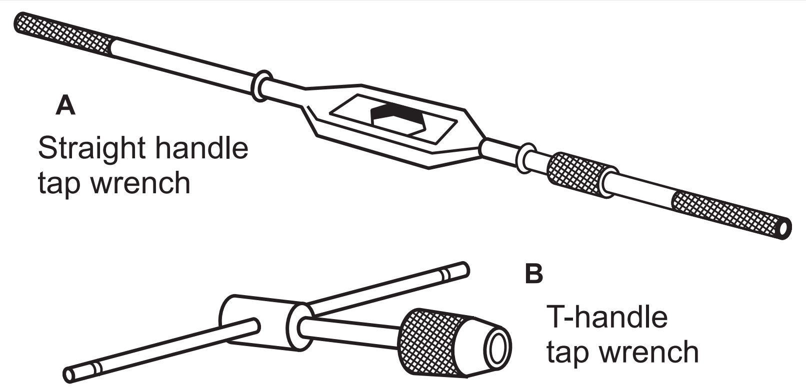
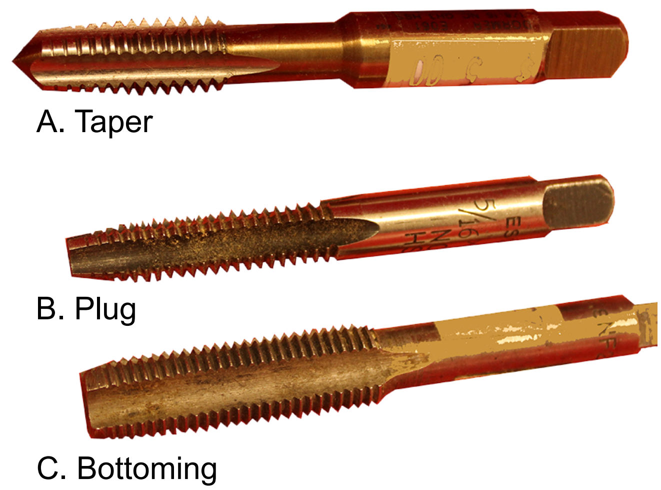


Figure 22 – A Tap Set



A **plug tap** is used for tapping through a workpiece and for general use.

The **taper tap** is used to start a thread easily, for tapping a hole which goes through the workpiece, or for starting a blind hole.

The **bottoming tap** is used to finish threads to full size after they have been started with a taper or plug tap. Blind holes are finished with this tap so that full threads go to the bottom of the hole.

The International Standards Organization (ISO) has adopted a Standard Metric Thread. This series has 25 thread sizes ranging from 1.6 mm to 100 mm diameter. The taps are identified with the letter M followed by the nominal diameter of the thread in millimetres times the pitch in millimetres.

A tap with the markings M4 × 0.7 would indicate:

M- a metric thread

4- the nominal diameter of the thread in millimetres

0.7- the pitch of the thread in millimetres

Tap Drill Size

Before a tap is used, the hole must be drilled to the correct size using a tap drill. The correct drill bit will leave the correct amount of material in the hole so the tap can cut a thread. The tap drill is always smaller than the tap to leave sufficient material for the tap to produce 75% of a full thread depth.

Side Track

Tests have shown that more than 60% thread engagement provides no significant increase in clamping strength. Most taps create threads that are 75% of a full thread. This makes the threads easier to cut, and protects the taps from breaking during threading.

Tap drills are selected by referring to a chart. When a chart is not available, the tap drill size can be calculated quickly by subtracting the pitch of the thread from the nominal diameter of the thread.

Example 1

Find the tap drill size (TDS) for an M22 × 2.5 tap.

Solution 1

$$\begin{aligned} TDS &= \text{Diameter - Pitch} \\ &= 22 \text{ mm} - 2.5 \text{ mm} \\ TDS &= \mathbf{19.5\ mm\ (Ans.)} \end{aligned}$$

Tapping Holes by Hand

1. Select the correct tap and tap wrench for the job.
2. Apply a suitable cutting fluid to the tap. No cutting fluid is required on brass or cast iron.
3. The tap should be started square with the hole as judged by eye. Press down on the wrench equally to both sides. Turn clockwise (right hand thread) for approximately two turns.
4. Remove the tap wrench and, using a set square, check the tap at two positions to ensure it is perpendicular to the work surface.
5. If the tap is not square, it should be backed out and started again.
6. When it has been started squarely, turn the tap clockwise one-quarter turn and then turn backward to break the chip which will allow cutting fluid to cover the cutting edges.

Threading Dies

Threading dies are used to cut external male threads on round work pieces. The three types are:

- Solid
- Round split
- Adjustable

The **solid die** (Figure 23(a)) is used primarily to recut battered thread and clean rusted or otherwise clogged threads. It is driven by a suitable wrench and is not adjustable.

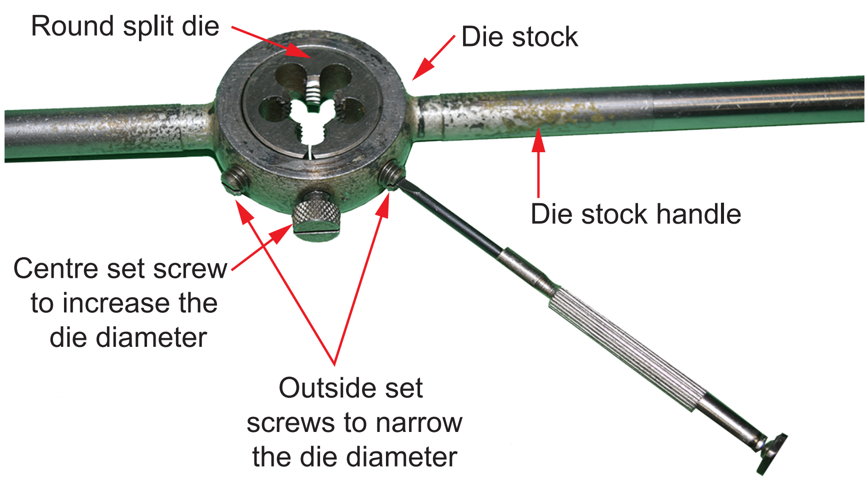
The **round split die** (Figure 23(b)) has a set screw which permits a certain amount of adjustment. The set screw spreads the jaws when tightened and allows them to spring back when loosened. This type of die fits into a **die stock** (Figure 24).

The **adjustable die** (Figure 23(c)) is the most efficient because it provides a relatively wide range of thread fits. Two die halves are held securely in a collet by means of a threaded plate, which also acts as a guide when threading. Adjustment is accomplished by means of two adjusting screws, which push against each half of the dies. One side of each die half is tapered in the thread, to permit easy starting of the die. The other side of the die is stamped with the manufacturer's name. Care should be taken when assembling the dies that they are matched up to avoid damage to the dies. The dies are typically placed in a die stock for use. A two handled example is shown in Figure 24.

Figure 23 – Threading Dies

(a) (b) (c)

Figure 24 – Die Stock



Objective 3

Describe the types and proper use of measuring tools.

Measuring Tools

Measuring tools are devices used to determine the dimensions of an object. If coarse, less accurate measurements are required, a steel scale or tape may be used. If fine, accurate measurements are to be made, a micrometer or vernier caliper is often used.

Scales and Tapes

A steel scale is a flat metal ruler. One edge may be calibrated in millimetres and the other edge in sixteenths of an inch.

When measuring, look perpendicular to the surface of the scale. If observed from an angle, the reading will be inaccurate.

Steel scales should be stored so other tools will not damage them. They should be wiped with light oil to remove fingerprints which cause corrosion.

Most steel tapes have a power rewind mechanism built into them. Damage to tapes occurs when they are rewound too quickly. To prevent damage the rate of rewinding can be controlled by guiding the tape with your free hand as it is being rewound.

Micrometers

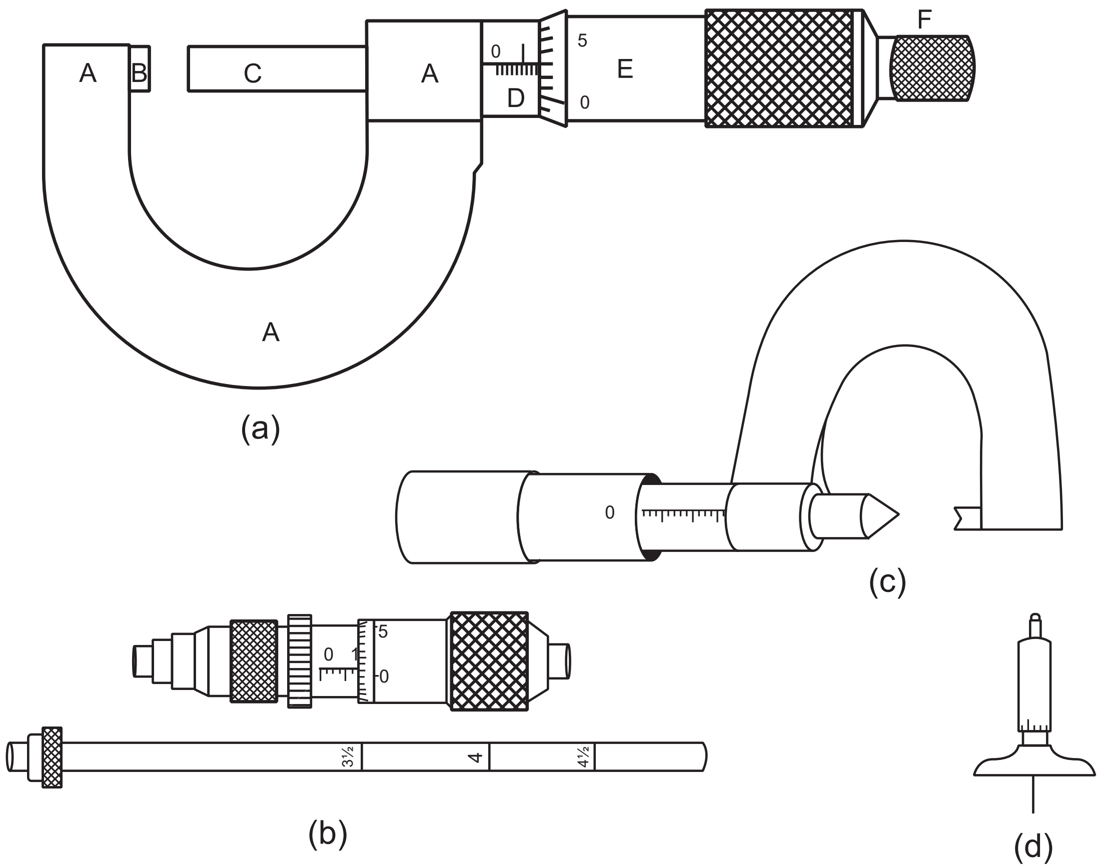
Micrometers or "mikes" are used to make measurements with a fine degree of precision, quickly, and with little chance of error.

Micrometers are made in a variety of sizes ranging from 25 mm up to 300 mm. Whatever the size of a micrometer, the working parts can only move a distance of 25 mm. Therefore, a 25 mm mike will measure from 0 to 25 mm, a 200 mm mike will measure 175 to 200 mm, and so on.

Micrometers are also made in a variety of types (Figure 25), such as the outside micrometer (a), the inside micrometer (b), the screw thread micrometer (c), and the depth micrometer (d).

The main parts of a micrometer are illustrated in Figure 25(a). These are the frame (A), anvil (B), spindle (C), sleeve or barrel (D), thimble (E), and ratchet stop (F).

Figure 25 – Micrometers

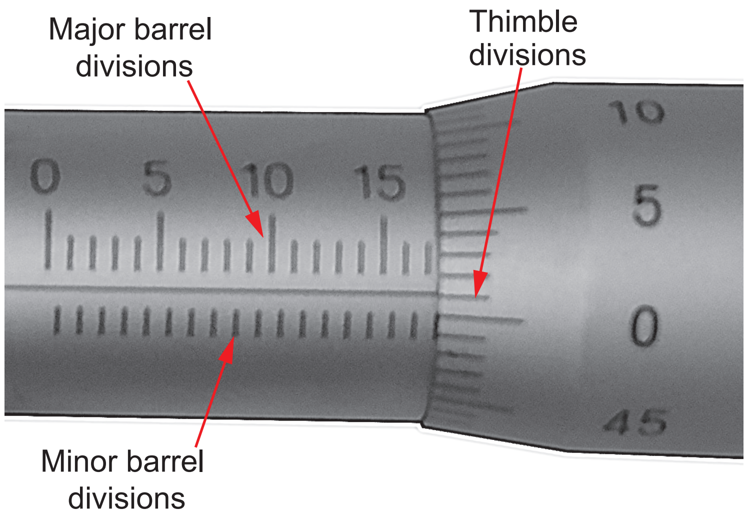


Refer to Figure 26 and read the micrometer distance measured to the nearest one-hundredth of a millimetre.

1. The major barrel divisions are read first.
2. Minor divisions are read next and added to the major divisions reading.
3. The thimble division most closely aligned with the longitudinal line is then read and added to the first two.

Major barrel divisions:	17×1.00 =	17.0 mm
Minor barrel divisions:	1×0.50 =	0.50 mm
Thimble divisions:	1×0.01 =	0.01 mm
	Total =	17.51 mm

Figure 26 – Reading a Micrometer



A micrometer is a precision instrument and must be handled with care to avoid damage. Dropping it on the floor or bench may damage its fine parts and make it useless. It should be kept away from dirt, grit, grease, and moisture. A micrometer should always be stored in its proper case and it needs to be protected from corrosion.

Feeler Gauges

Thickness gauges, usually called feeler gauges, are used to check bearing clearances, gear play, and measure narrow slots and gaps. They are also used to check spark plug gaps and tappet valve clearances.

Thickness gauges should be kept clean from dirt and rust. A thin coat of oil should be occasionally applied to the leaves.

Objective 4

Describe the proper layout of work and the use of layout tools.

Layout Tools and Materials

Layout involves scribing (scratching) the required dimensions onto the surface of the work piece with a sharp instrument, prior to machining or performing a hand tool operation. These lines show boundaries, centres, and other locations, to guide the worker. The accuracy of the finished job depends largely on the care taken during layout.

Marking Materials

When scribing lines on metal surfaces, it is necessary to prepare the surface with a marking material before scribing, so the scribed lines will be legible. Different materials are used for this purpose:

a) Chalk or soapstone may be rubbed on rough surfaces of castings or steel.

b) Layout ink or dye may be applied to the surface.

c) Blue vitriol (copper sulfate) may be applied to a clean surface. The surface must be free of dirt and grease so the blue vitriol solution will stick.

Layout Tools

The basic tools required for layout work are described in the following sections.

Ruler

The steel ruler (or scale) was described previously. It is used for measuring and as a straight edge for scribing lines.

Steel Square

The steel square (or try square) consists of a beam and blade at right angles to each other. It is made from high-grade tool steel and ground to be highly accurate.

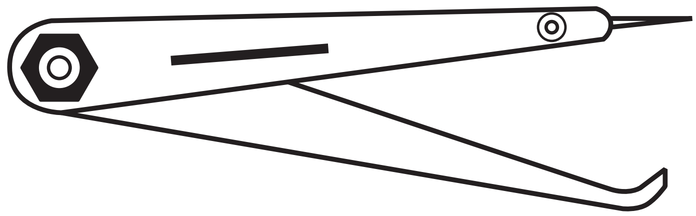
Scriber

A scriber (or scratch awl) essentially consists of a steel rod, 3 to 4 mm in diameter, with a sharp, hardened point and a handle. It is used for scribing the layout lines. It must be kept very sharp, since a very thin scribe line is required in good layout work.

Hermaphrodite Calipers

Hermaphrodite calipers (Figure 27) have one leg blunt and bent at the end while the other leg has a scriber point, which is usually adjustable. These are used to scribe lines parallel to an edge.

Figure 27 – Hermaphrodite Calipers



Prick Punches and Centre Punches

Punches are made from tool steel which has been hardened and tempered. One end is tapered and ground to a point. The point angles are 60° for a prick punch and 90° for a centre punch. The prick punch is used to make light indentations on layout lines and provide starting points for dividers. The centre punch is used to make heavier indentations to locate centres for holes to be drilled.

Dividers

Dividers have two straight legs tapered to a needle point, used for measuring distances. They are adjusted with a screw and knurled nut. The divider must always be kept sharp.

Surface Plate

A surface plate is a flat topped, close grained, cast-iron plate heavily ribbed and reinforced at the bottom. It is machined on the top, bottom, and usually the ends and sides. The top is scraped to form an extremely true and flat surface. It may be used to test for flat surfaces or various layout operations in combination with other tools and devices.

Characteristics of a Good Layout

a) The surface of the work should be evenly covered with a suitable layout material.

b) Scribed lines should be single, clear, and sharp.

c) Layout lines should be prick punched lightly. The marks should be spaced evenly and punched to a uniform depth.

d) Layout lines should be accurate.

Objective 5

Describe the types and proper use of portable and fixed grinders, hand drills, drill presses, and the care of drill bits.

Power Tools

Power tools operate entirely or partially by power, such as electricity or compressed air. They help to complete the work easier, faster, or more accurately. Electric drills, grinders, and air hammers are in this class.

Portable Grinders

Hand grinders power tools are used to remove material from a work piece in the field, by abrasive means. They can be used for tasks such as:

a) Wire brushing rust and paint
b) Grinding surfaces flat
c) Removing welding or other protrusions
d) Buffing or polishing to finish a work piece

Safety Check

Wear appropriate PPE when using a grinder. Minimum protection includes:

a) Safety glasses with side shields and a face shield
b) Respiratory protection
c) Hearing protection

Clear the area nearby of combustibles. A hot-work permit may be required, depending on the job location.

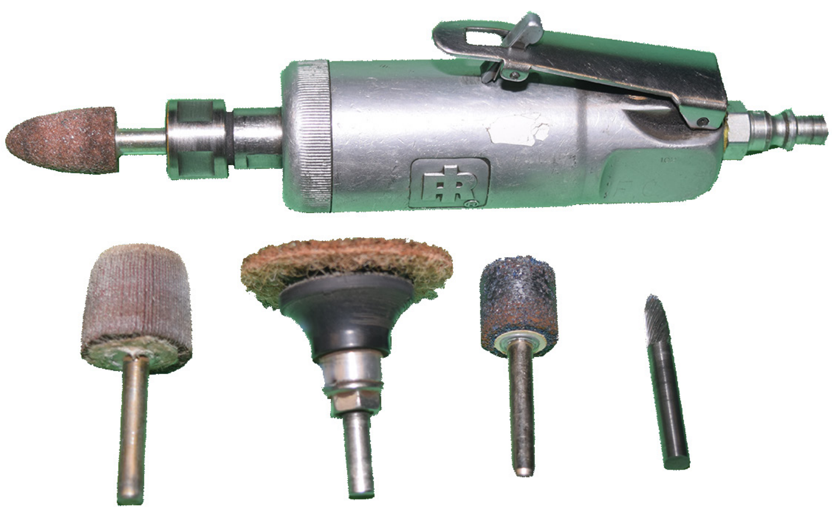
In addition:

a) Long hair must be tied back and concealed so that it cannot come into contact with the grinding wheel.
b) Long sleeves must not be allowed to interfere with the grinding wheel. It may be necessary to roll-up long sleeves when grinding.
c) Jewelry should not be worn while grinding.

Two common hand grinders are shown in Figure 28. The angle grinder is often used to grind off high spots or welding from flat plate. The die grinder is shown with several different attachments that are available.

Figure 28 – Portable Grinders

(a) Electric angle grinder



(b) Pneumatic die grinder with attachments

Grinders are normally equipped with wheel guards and a spindle friction clamping assembly for safety purposes. The guard usually covers approximately one half the wheel or brush.

Safety Check

Never remove the guard from a power grinder. It protects the user from grinding or wire particles and, more rarely, from the shattering of a grinding wheel.

The friction clamping assembly applies pressure to the grinding wheel to hold it tightly against the flanged end of the spindle. If the grinding wheel or brush should jam, the shaft will continue to turn when the friction clamp slips, and protects the user from the sudden twisting force of the grinder.

Safety Check

Select grinding wheels for the RPM of the grinder in use. A wheel with an inadequate RPM rating may shatter and cause serious injury.

When starting a grinder make sure the wheel is not in contact with the work. This could cause the grinder to jump, which can damage the wheel and the work, as well as, cause personal injury.

Fixed Grinders

Bench and floor mounted grinders are used for a wide variety of jobs around a plant. Sharpening tools, shaping work pieces, and removing material are examples of its versatility. Some grinders may be mounted on a bench (Figure 29) or on a pedestal on the floor.

Figure 29 – Bench Grinder

Generally, these grinders consist of a double-ended sealed motor. A threaded mounting shaft is provided at each end for grinding wheels. The grinding wheel is clamped with a friction clamp similar to the ones used on a hand grinder. Wheel guards are attached to the motor and surround most of the wheel to protect the user, or anyone in the area, from flying grinding particles.

Most grinders have a movable safety glass shield to cover the opening in the guard for further protection of the user. A notched metal plate is attached in front of each wheel. The plate can be adjusted in towards the wheel and tipped to form a range of angles with the grinding wheel. The purpose of this plate is to support the work during a grinding operation.

Safety Check

The gap between the wheel and the plate must be as small as possible. A gap which is too large will allow small pieces to slip and jam the rotating wheel. This could cause shattering of the wheel and personal injury.

The usual arrangement of grinding wheels on grinders is to have a roughing wheel and a finishing wheel. The roughing wheel is used to remove a large amount of material quickly. The finishing wheel is then used to give a smoother finish; this is the wheel used to sharpen tools.

Safety Check

Whenever using grinders, wear a full-face shield for protection from flying grinding particles. Dip the workpiece in water frequently to prevent overheating the workpiece and operator burns.

Wheels must be examined closely prior to each use. Chipped or nicked wheels should be dressed with a dressing tool to remove the nick, if possible. Wheels that have cracks anywhere should be discarded immediately. Cracked wheels will explode at speed and cause personal injury.

Do not use the side of the wheel to grind a job. This practice can weaken the wheel, which causes breakage and personal injury.

Practice using the whole face of the wheel when grinding. The preferred method is to move the work piece back and forth slowly across the wheel. When the wheel becomes worn, rounded, grooved, or the grit filled with material, it must be reshaped or dressed.

Abrasive Wheels

Abrasive or grinding wheels are tools which use hard abrasive particles to remove or finish materials. The grits are bonded together in various shapes and sizes.

Abrasive wheels are classified and marked using six different categories.

1. Abrasive type
2. Grain size
3. Grade
4. Structure
5. Bond type
6. Manufacturer's record

The two types of abrasive in common usage are aluminum oxide and silicon carbide. Aluminum oxide is mostly used for general grinding. Silicon carbide is used on very hard metals and tool bits.

Grain sizes are grouped into coarse, medium, fine, and very fine. Large grain sizes are used for fast removal of metal. Finer grains are used to produce smoother finishes.

Grade refers to the grit bond strength. Grinding wheels range from very soft to very hard.

The structure refers to a range of grains from dense to open type. A dense wheel will have the grains tightly packed, so it appears smooth. The open type wheel appears rough with pockets between the grains.

The bond type identifies the method used to hold the grains together. Four general bond types are used:

1. Vitrified (V)
2. Resinoid (B)
3. Rubber (R)
4. Shellac (E)

The most common type is the vitrified wheel which uses a ceramic type material to bond the wheel together. These wheels are not affected by water, oil, acids, or wide temperature changes.

Wheel Speed

Manufacturers also list the maximum speed for a particular grinding wheel. It is very important that the wheel is never operated beyond this speed, as it may disintegrate, causing very serious injury to the user and people in the surrounding area.

Drilling Machines

Hand Drills

The hand drill is used to do a variety of jobs, such as:

- Drilling
- Buffing
- Grinding
- Driving
- Removing screws

The standard hand grip style is the most common. It consists of four basic components (Figure 30):

1. An air cooled motor
2. A gear reducer
3. A chuck
4. Trigger switch

Figure 30 – Hand Drill

Hand drill size refers to the maximum diameter drill bit which will fit into the drill chuck. This size is selected by the manufacturer. Any attempt to use a larger size drill for heavy drilling will result in overloading, with possible damage to the drill.

Hand drills are usually available with several output speeds, namely fixed, two-speed, and variable speed. Some drills are also available with a reversible rotation, as well as other options.

When drilling with a hand drill, make sure the drill bit is held tightly in the chuck. If the bit slips, its shank will become burred and it will erase the size that is stamped on the bit. This will make it difficult to know the size of the bit for future use. Any burrs formed should be ground off before the bit is put away.

Safety Check

It is extremely important to maintain a firm grip on the drill and to maintain a good footing. Many injuries have resulted from a jammed drill. It can twist the users arm or cause a loss of balance.

Drill Press

Drill presses are available in a wide range of sizes and types, ranging from a small, high speed, precision bench type to a large, radial arm, floor mounted type. The most common types found in an average plant are the general **shop bench** type and the **floor or pedestal mounted** type. These are all very much alike except for the height and mounting. Other than drilling, drill presses are also used for:

- Counter boring
- Spot facing
- Reaming
- Grinding
- Tapping

A typical drill press is shown in Figure 31. Drill presses of this type vary in size from 300 to 760 mm. The size is determined by the distance from the edge of the column to the centre of the spindle. A 380 mm drill press could drill to the centre of a 760 mm diameter work piece.

The main part of the drill press is the drill head, mounted close to the top of the column. It contains the mechanism used to revolve the cutting tool and advance it into the work. The spindle, a round shaft that drives the cutting tool, is housed in the spindle sleeve or quill. The sleeve does not revolve, but slides up and down inside the head to provide a feed for the cutting tool. The end of the spindle may have a tapered hole to hold the tapered shank tools, or it may be threaded to hold a drill chuck.

The hand feed wheel is used to move the spindle sleeve and cutting tool vertically. A depth stop can be set to control the depth a cutting tool will enter the work piece.

Twist Drill Bits

Twist drill bits (Figure 32) are end cutting tools used to produce holes in most types of materials. They are made from carbon steel or high-speed steel. High-speed drill bits are considered better than the carbon steel type because they can be operated at much higher cutting speeds and the cutting edge lasts longer.

Figure 31 – Drill Press

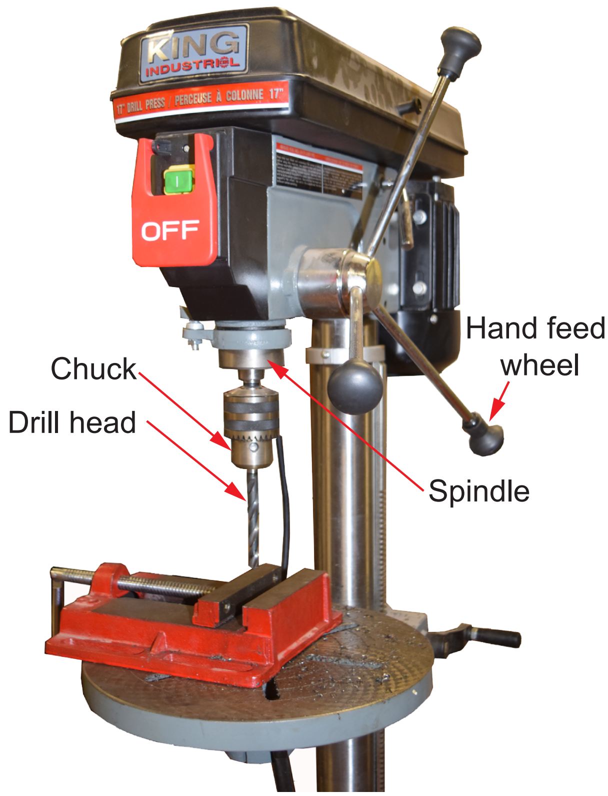
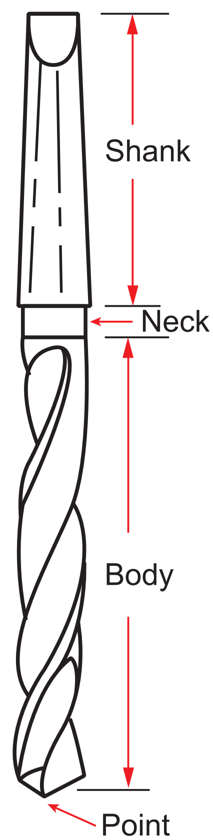


Figure 32 – Twist Drill Bit



A drill bit may be divided into three main parts:

1. Shank
2. Body
3. Point

Generally, bits up to 12 mm in diameter have straight shanks, while those that are larger have tapered shanks. Straight shank bits are held in a drill chuck; tapered shank bits fit into the internal taper of the drill press spindle. The tapered shank has a tang on the end to prevent the bit from slipping, thus the bit can be removed from the spindle socket without damaging the shank.

The body is made up of the following:

Flutes: special grooves that provide a passage for cutting oil and debris to come out.

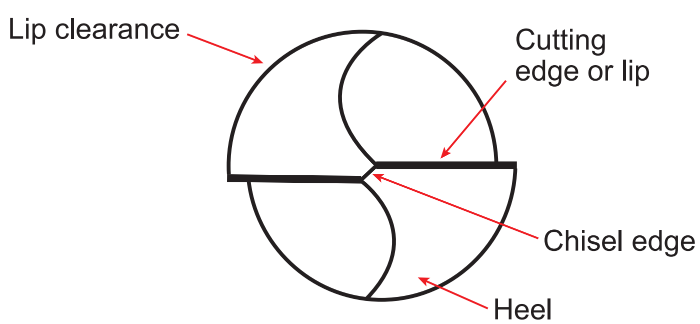
Margin: the narrow bright strip that runs along the side of the flute. It is the actual diameter of the bit.

Body Clearance: the portion of the body undercut between the margin and the flutes. This undercutting reduces friction between the bit and the walls of the hole so less power is needed to turn the bit. It also keeps the bit from overheating.

Web: the metal in the center running lengthwise between the flutes. The web thickness gradually increases towards the shank to give the bit strength.

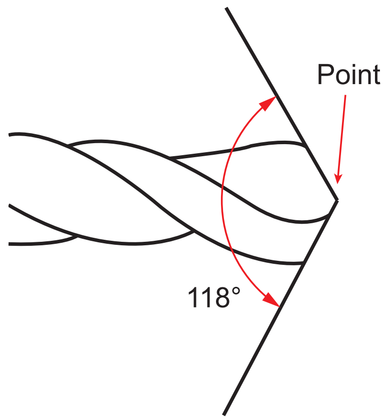
The point of a twist drill bit (Figure 33) consists of the chisel edge, lips, lip clearance, and heel. The **chisel edge** is the chisel shaped portion of the bit point. The **lips or cutting edges** are formed by the intersection of the flutes. The lips must be of equal length and have the same angle, so the bit will run true and not drill an oversized hole. The **lip clearance** is the relief which is ground on the point of the bit, and extends from the cutting edge to the **heel**. Lip clearance varies from 8° to 12°, depending upon the hardness of the material to be drilled.

Figure 33 – Twist Drill Point



The point must be properly ground in order for the bit to cut accurately. The point angle normally used for general drilling is 118° (Figure 34).

Figure 34 – Twist Drill Point Angle



When sharpening a bit, four points must be considered:

1. Lip clearance
2. Length of lips
3. Lip angle
4. Location of the dead center

If the first three are correct, the last one must be correct. Dip the bit frequently in a coolant such as water to prevent it from overheating while grinding it.

In the SI system, bit sizes are designated by their diameter in millimetres.

Miniature metric bits range from 0.04 to 0.09 mm, in steps of 0.01 mm.

Straight shank standard metric bits are available in sizes from 0.5 to 20 mm.

Taper shank metric bits are made in sizes from 8 mm to 80 mm.

Drilling Procedures

All holes to be drilled should be laid out properly before starting. The centre of the hole should be centre punched. This makes it easier for the drill bit to enter the metal to be cut. If the hole to be drilled is over 10 mm, a pilot hole, approximately 3 mm, should be drilled first to prevent bit wander. Sometimes the circumference of the hole to be drilled is scribed and prick punched, to ensure that the bit has not wandered.

It is very important for a bit to operate at the correct speed and rate of feed. If the speed is too high, the cutting edges will dull rapidly; if the speed is too slow, the bit may break. Consult a drilling chart to determine the correct speed and then set the drill press for this rate. As a rule, the larger the bit the slower the speed.

Drilling generates considerable heat at the bit point, which must be dissipated as quickly as possible. The purpose of a cutting fluid is to provide cooling and lubrication.

Safety Check

A work piece should never be held by hand when drilling. A variety of clamps and work holding devices are available and should always be used to avoid injury. Also, always wear eye protection and never handle the metal chips or filings.

Chapter Summary

The use of hand and power tools is a daily part of the Power Engineer's work activities. This chapter covered the types of tools most commonly used, including:

a) Hand tools, such as:
   i. Saws
   ii. Screwdrivers
   iii. Hammers
   iv. Wrenches
   v. Chisels

b) Hand threading tools

c) Measuring tools, such as:
   i. Tapes
   ii. Micrometers
   iii. Feeler gauges

d) Layout tools and materials

e) Power tools, such as:
   i. Drills
   ii. Grinders

This chapter also provided general information on the use of tools. Key safety information was given with reference to the use of particular tools.

Employers and tool manufacturers provide more detailed information on the use and maintenance of tools. As well, local jurisdictions and employers may require specialized training before particular tools may be used.

CHAPTER 2

Energy Plant Maintenance II

Learning Outcome

When you complete this chapter you should be able to:

Discuss and describe the safe and proper setup of equipment for hoisting and working above ground.

Learning Objectives

Here is what you should be able to do when you complete each objective:

1. *Describe the requirements for setting up work platforms in general and ladders and scaffolding in particular.*
2. *Describe the general safety precautions and calculations used when rigging equipment.*
3. *Describe the general safety precautions used when hoisting equipment.*
4. *Discuss the correct use and limitations of wire cable and rope, including cable attachments and rope knots.*
5. *List and describe common types of metal fasteners, such as screws, bolts, studs, nuts, and washers.*

Chapter Introduction

Potential energy may be a hazardous energy source. Those working at heights expose themselves and others to great danger. To ensure their safety and the safety of those nearby, people working at elevated workplaces must use specialized equipment, training, and work procedures.

Serious injuries occur when unrestrained workers fall from ladders, scaffolds, or any other elevated work platforms. Unsecured tools or equipment can fall and injure persons below elevated work platforms. Work platforms themselves, if improperly secured or constructed, may collapse and injure those on or below the platform. These are real hazards that are nearly always present in a power plant.

Power Engineers use elevated work platforms daily, and must understand how to use them safely. This chapter introduces ladders and scaffolds, and emphasizes their safe use.

There are times when Power Engineers need to remove and reinstall heavy equipment, such as pumps or safety valves. To move such heavy items, it is necessary to use cranes, hoists, chains, ropes, and other rigging equipment. This creates additional safety concerns.

Are the ropes, slings, and cables strong enough for the lift? Is the load greater than the capacity of the hoist? Is the load correctly secured and balanced? Will the load swing into workers or equipment? Have the components of the lift equipment been correctly assembled and maintained? Are those performing the lift trained on how to properly conduct the lift?

Poorly planned lifts are very dangerous, leading to expensive equipment damage and, more importantly, human injury or death. This chapter introduces the types of equipment used for moving heavy equipment. Also covered are:

a) Calculations for rigging,
b) The proper use of slings, and
c) The safety precautions that must be followed when rigging and hoisting equipment.

Mechanical fasteners come in various sizes, shapes, and grades, for specific applications. These include bolts, screws, and studs. Improper fastener selection and installation can lead to costly equipment failure and possible injury. Therefore, Power Engineers must be able to properly identify, select, and install a variety of fasteners used in power plants. The various symbols and designations for sizes and classes of fasteners are included in this chapter.

Objective 1

Describe the requirements for setting up work platforms in general and ladders and scaffolding in particular.

Work Platforms

A platform of some type may be required to work above floor level. This can take the form of a ladder, scaffolding, or even a stool. A safe platform must be sufficiently strong and stable. For stability, a work platform requires a good solid base. Depending on its height, a platform may also require additional attachments to a more stable structure. Chairs, pails, hastily concocted contraptions, and improper use of work platforms can cause serious accidents.

The **Occupational Health and Safety Acts and Regulations** of each province or territory typically contain sections on work platforms. Learn and follow these regulations, as well as any other plant-specific safety rules and policies.

When work is carried out above the floor, falling objects can injure workers below. Platforms must be surrounded with a raised edge or **toe plate** to prevent objects from rolling off. Heavy objects and parts being dismantled should be secured with a rope or chain before dismantling. Wrenches and other tools should also be secured when not in use.

Finally, provisions should be made to warn people below of the hazard. A safety person posted below, warning signs, lights, or complete isolation of the area are some of the ways to accomplish this. Typically, areas are "caution flagged" with tape or rope to prevent unauthorized access to areas where overhead work is being done.

Safety Check

NEVER enter an area that is flagged or roped off for overhead work.

Ladders

Ladders are the most common way of accessing elevated work locations. All ladders should meet **Workers' Compensation Board regulations**, and be **CSA approved**.

There are two main types of ladders: step and rung. Step ladders include regular **step ladders** and platform ladders. Portable **rung ladders** may be straight one-piece ladders, or **extension ladders**. Permanent rung ladders are often built onto the sides of tanks or buildings.

Safety Check

ALWAYS ascend or descend ladders FACING THE LADDER.

ALWAYS maintain three points of contact when ascending or descending ladders. Either two hands and one foot, or two feet and one hand.

Ladders must NEVER carry more than one person at a time.

NEVER stand on the top two steps of a step ladder.

NEVER stand any higher than three steps from the top of an extension ladder.

NEVER climb a closed step ladder.

NEVER climb, stand, or sit on spreaders, rear braces, the paint tray, or the top step of a step ladder.

NEVER carry tools up or down ladders.

NEVER reach away from the ladder or apply excessive force on wrenches while working on a ladder.

NEVER overload a ladder.

NEVER try to repair a ladder. Few ladder parts are repairable. Only a factory-authorized agent can repair a ladder.

Step Ladders

Step ladders have a series of flat step-like surfaces that are arranged like stairs for stepping on: hence the name "step" ladder. Step ladders are self-supporting, and made of wood, aluminum, or fibreglass. They come in a variety of heights, up to 6 metres tall (Figure 1). They are highly maneuverable and are used to quickly reach overhead work locations.

Step ladders are easily damaged, so care must be exercised in their use. Always inspect a ladder before using it. Look for:

a) Manufacturer's nameplate with load rating, to ensure the ladder can be used appropriately for the job.
b) Missing or loose steps or rungs (they are loose if you can move them by hand).
c) Non-slip feet that are damaged or worn.
d) Loose nails, screws, **bolts**, or **nuts**.
e) Spreaders (the parts that hold the legs apart) that are loose or faulty.
f) Wooden ladders with rot, cracked, or warped steps.
g) Fibreglass ladders that have cracks and exposed fibreglass strands.
h) Rails or braces that are twisted, cracked, distorted, split, worn, or broken.
i) Corrosion, rust, oxidization, and excessive wear, especially on the treads.
j) A valid inspection tag. Most plants require regular inspection of all ladders, and prohibit the use of ladders that have not passed recent inspection.

If a ladder is found to be defective, it must be removed from service. Ensure that a safety tag is affixed to it, to indicate that the ladder is unsafe to use. A work order must be generated to repair or dispose of the defective ladder.

The step ladder is never very stable, and will easily tip. The legs must always be fully separated when in use, for maximum stability.

Always place step ladders on a flat surface. An assistant should help support the step ladder when it is in use.

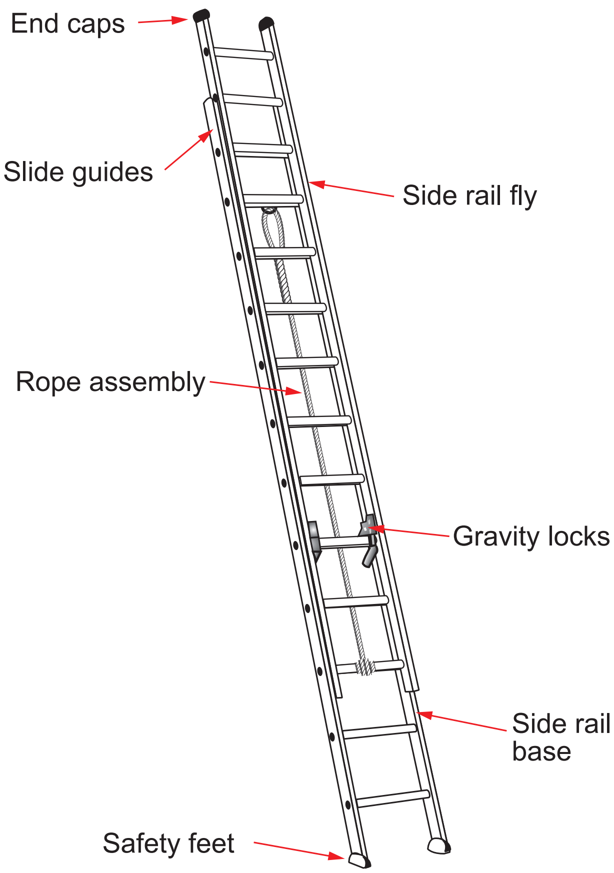
Figure 1 – Step Ladder

Rung Ladders

Rung ladders are appropriately named, because the climbing surfaces are cylindrical "rungs." Rung ladders are not self-supporting like step ladders. They must rest against a support structure, such as a wall.

Rung ladders come in a variety of types and sizes. Some are portable while others are permanently fixed in position on the sides of vessels or buildings. Some ladders have a fixed length while others (extension ladders) can be varied in length. Whatever the type, rung ladders must meet Workers' Compensation Board regulations and be CSA approved. Figure 2 shows a sample of a free standing rung ladder.

Figure 2 – Rung Ladder



The most easily portable rung ladders are made of aluminum or fibreglass.

Aluminum ladders are lightweight, which makes them easy to move and set up. They are unlikely to warp and are corrosion resistant. Since aluminum is soft, this type of ladder is easy to damage, if handled roughly. DO NOT use it near electrical sources, because aluminum is an excellent conductor of electricity. Fibreglass ladders are heavier than aluminum, but do not conduct electricity. This is why electricians will usually use fibreglass ladders.

Inspect extension ladders before using them. Look for the same types of problems as during a step ladder inspection. In addition, look for:

a) Gravity locks that are loose, broken, or missing.
b) Gravity locks that are defective and do not engage when the ladder is extended.
c) Properly lubricated working parts, including extension locks and pulleys.
d) Cords, chains, and ropes that are defective.
e) Pads or sleeves that are missing or defective.

The ladder must have safety feet braced against a weight or cleat on the floor, or lashed to a fixed, solid object.

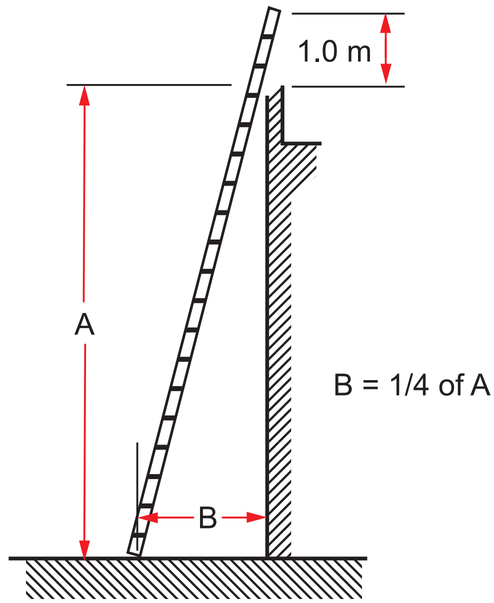
The top of the rung ladder must rest against a strong, solid surface with both rails touching. It should extend approximately one metre above the level of the upper landing to which it provides access (Figure 3).

The ladder should be inclined. The horizontal distance from the base of the ladder to the vertical wall or structure should be no further than 1/4 of the distance from the base to where the ladder contacts the wall or structure (Figure 3).

If the ladder cannot be secured, then someone must hold the ladder in place to prevent it from moving.

Never leave a ladder leaning against a wall unattended if it is not secured.

Figure 3 – Placing a Rung Ladder



Fixed rung ladders should be inspected regularly for weakening from corrosion and broken or loose rungs. Bolts, nails, or other fastenings should be checked to make sure that they properly anchor the ladder.

SCAFFOLDING

Scaffolds are temporary structures made of posts, planks, and boards. Workers stand on scaffolds to perform work from an otherwise inaccessible height. Jurisdictions have similar health and safety requirements concerning the erection, inspection, and use of scaffolds. Typically, jurisdictions require scaffolds to be designed and erected to meet **CSA Standard CAN/CSA S269.2**. Company rules may be more stringent than jurisdictional requirements. Always follow the more stringent requirements.

Scaffolds come in various styles, including:

Single pole scaffolding (carpenter's bracket scaffolds) – has a bracketed frame that supports a work platform, which is bolted to a supporting wall.

Double pole scaffolding (mason's square scaffolds) – is made of framed squares that support a work platform.

Tube and coupler scaffolding – has work platforms supported by separate tubing and couplings.

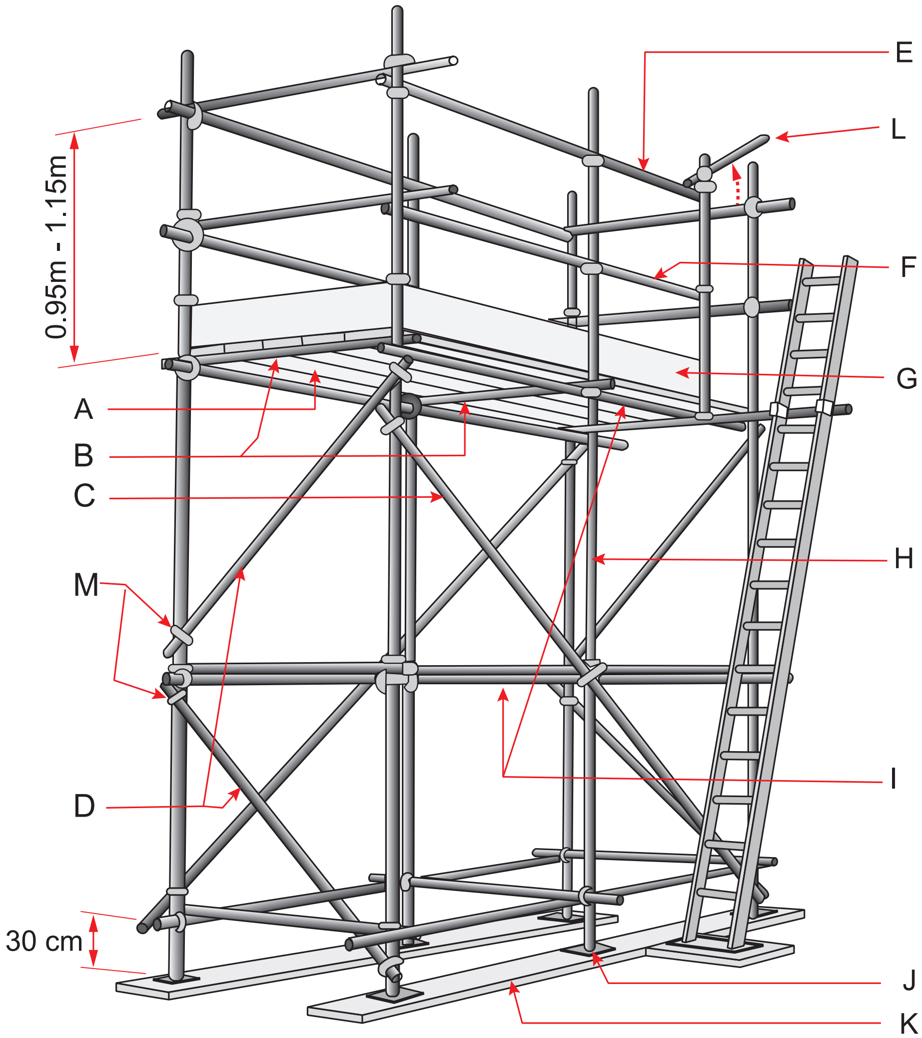
Fabricated frame scaffolding – is constructed from welded tubular end-frames that support work platforms.

Mobile scaffolding – is mounted on castors, or may be truck-mounted or self-powered lifts.

Of these, fabricated frame scaffolds and tube and coupler scaffolds are most commonly found in power plants.

All scaffolds must be erected and dismantled by (or under the supervision of) workers experienced in this type of work. Damaged or weakened scaffolds must be repaired or strengthened before use. Keep only materials that are for current use on any scaffold. Scaffolds must never be overloaded.

Figure 4 – Scaffold Construction

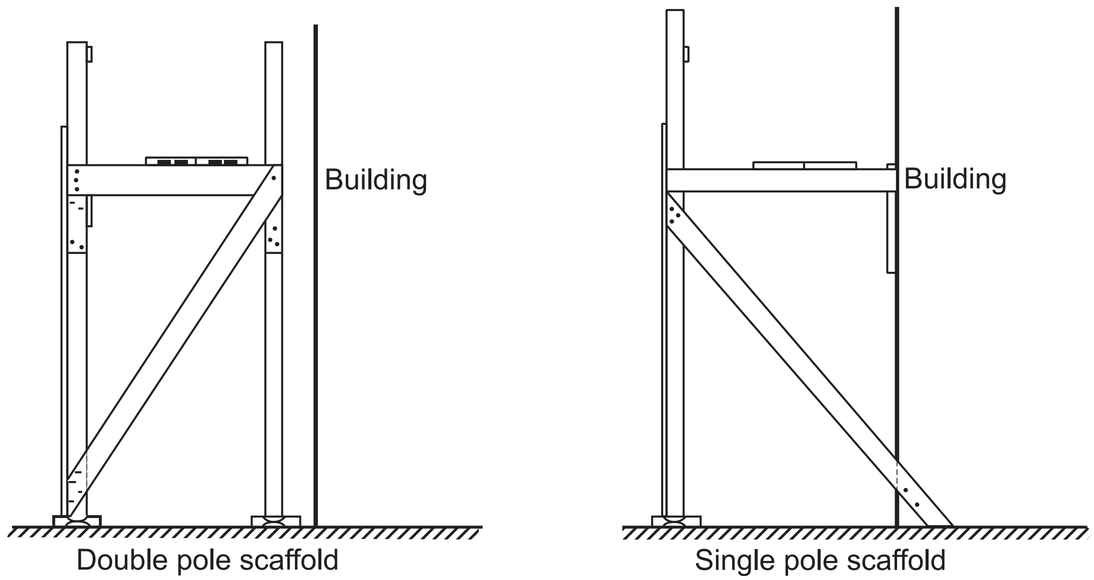


Scaffold Terminology			
A	Scaffold Planks (Boards)	H	Post (Standard)
B	Bearer (Transom)	I	Runner (Ledger)
C	Longitudinal (Façade) Bracing	J	Base Plate
D	Transverse (Sectional) Bracing	K	Sill (Sole Board)
E	Toprail	L	Self-Closing Drop Bar (Inside Posts)
F	Midrail	M	Coupler
G	Toeboard		

Scaffolding must be erected plumb and level on stable ground, with all connections securely fastened.

The single pole and double pole methods of constructing scaffolds are shown in Figure 5. The double pole scaffold is free standing from the building or structure and, therefore, places no load upon the building. The single pole scaffold is partially supported by the building.

Figure 5 – Double Pole and Single Pole Scaffolds

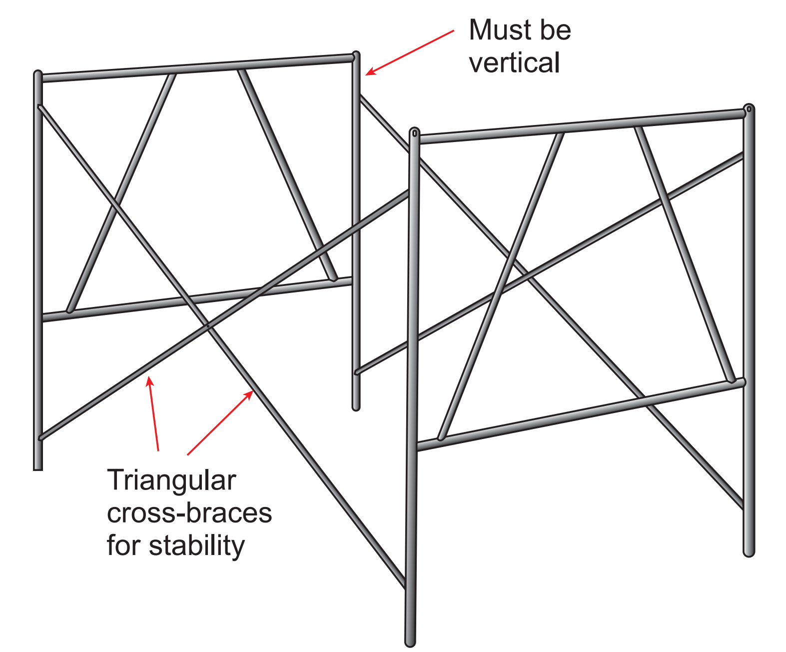


Metal scaffolds (including the tube and coupler scaffold, and the fabricated frame scaffold) are:

- Light
- Portable
- Easily assembled
- Taken down with a minimum of tools

A typical fabricated frame metal scaffold is shown in Figure 6.

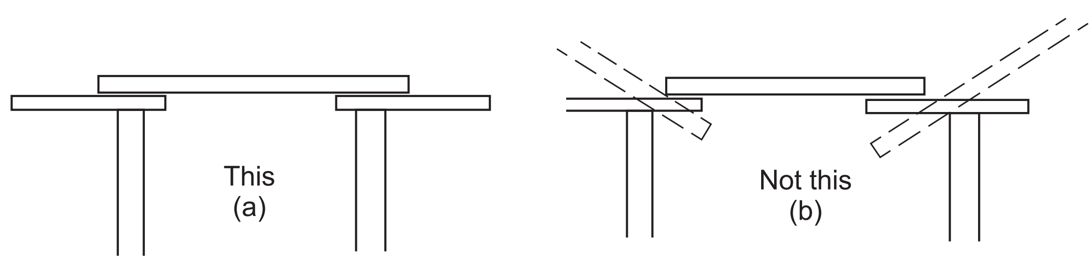
Figure 6 – Fabricated Frame Metal Scaffold



Scaffold work surfaces may be manufactured metal or composite planks with built-in cleats, or wooden planks. Wooden scaffold planks are carefully selected high quality boards, made to specific dimensions, and stamped "scaffold grade." Ordinary wooden boards must never be used for scaffold planks. Wooden planks often have "cleats" located 15 cm from the ends of the planks, to prevent the planks from slipping off the scaffold frame.

Care should be exercised in placing adjoining planks on scaffolds. Planks should be overlapped by 30 cm, in such a way that there is no danger of tipping (see Figure 7). The support must always be directly beneath the overlap.

Figure 7 – Scaffold Planking



Tube and coupler scaffolds, and many other kinds of scaffolds, must be inspected upon erection and before use. Only authorized and specially trained individuals can inspect scaffolds. After inspection, scaffolds must be tagged as:

- Safe for use,
- Safe for use with additional safety precautions required, or
- Unsafe for use.

Become familiar with local jurisdictional requirements. If unsure, ASK!

Scaffold inspection tags are coloured green, yellow, or red, and have statements like those in Table 1.

Table 1 – Scaffold Inspection Tag Information

Colour of Inspection Tag	Wording on the inspection tag
Green	“Safe for Use”
Yellow	“Caution: Potential or Unusual Hazard”
Red	“Unsafe for Use”

Inspection tags let workers know that a particular scaffold is:

- Safe for use
- That a potential or unusual hazard is present, or
- The scaffold is unsafe for use.

A scaffold being modified requires a yellow tag. The tag alerts workers of the modification work and any special precautions that might affect them. A yellow tag must describe any precautions that need to be taken while working on the scaffold.

Scaffolds that require inspection also require re-inspection at regular intervals. By definition, scaffolds are temporary structures. If in use for long periods of time, their condition may change as components loosen, wear, or shift. Some jurisdictions require re-inspection every three weeks.

Safety Check

NEVER use a scaffold that is un-inspected, needs re-inspection, or is red-tagged.

ALWAYS use a hoist or rope to move materials to upper levels of a scaffold.

NEVER carry materials when climbing scaffolding.

NEVER allow tools, materials, or debris (grease, dirt, snow, ice) to accumulate on the work platform.

NEVER overload the scaffolding with too many people or materials in any one area.

ALWAYS make sure there is a safe entrance to all working levels.

ALWAYS barricade areas below if there is a chance of items falling from the scaffolding.

NEVER work on scaffolding located outdoors during storms or high winds.

Objective 2

Describe the general safety precautions and calculations used when rigging equipment.

Rigging

Rigging is the process of moving heavy objects, like equipment and machines, with the use of ropes, cables, rollers, **hoists**, and other lifting devices.

On Track

Poor rigging practices result in dangerous conditions. Rigging must be done by trained and experienced tradespersons. The content in this objective is introductory. It is designed so that newer Power Engineers can work effectively alongside experienced tradespersons.

All of the following knowledge is required to perform rigging operations safely.

a) How the object is constructed: what the object is it made of, how heavy it is, and how large it is.

b) The path of the move.

c) The rigging equipment that is available.

d) Safety requirements.

The construction of the object will determine the method and degree of care in handling. A large steel casting, such as a pump base, will require much less care in handling than a computer control panel with delicate parts. The mass of the object will determine the choice and size of moving equipment required. As the mass increases, so does the stress on rigging and the potential for a serious accident.

It is very important to determine the mass of an object before making any attempt to move it. Size can often be quite deceiving. For example, hollow objects, such as pressure vessels, can appear quite massive, but are lighter than they appear to be. Similarly, small objects (such as anvils) can be heavier than they appear to be, because they are solid and made of a dense material.

To determine the mass of an object:

- Use manufacturer's specification sheets
- Calculate the mass, based on the object's physical dimensions, or
- Estimate the mass

Manufacturers often show the mass of various equipment in catalogues, brochures, or manuals. Sometimes the mass is included in the shipping papers or stamped on the shipping crate. Equipment mass should be recorded and filed for future reference.

Often, when moving older pieces of equipment, the record of the mass is not available. Therefore, the mass needs to be calculated. The following information is needed to calculate mass:

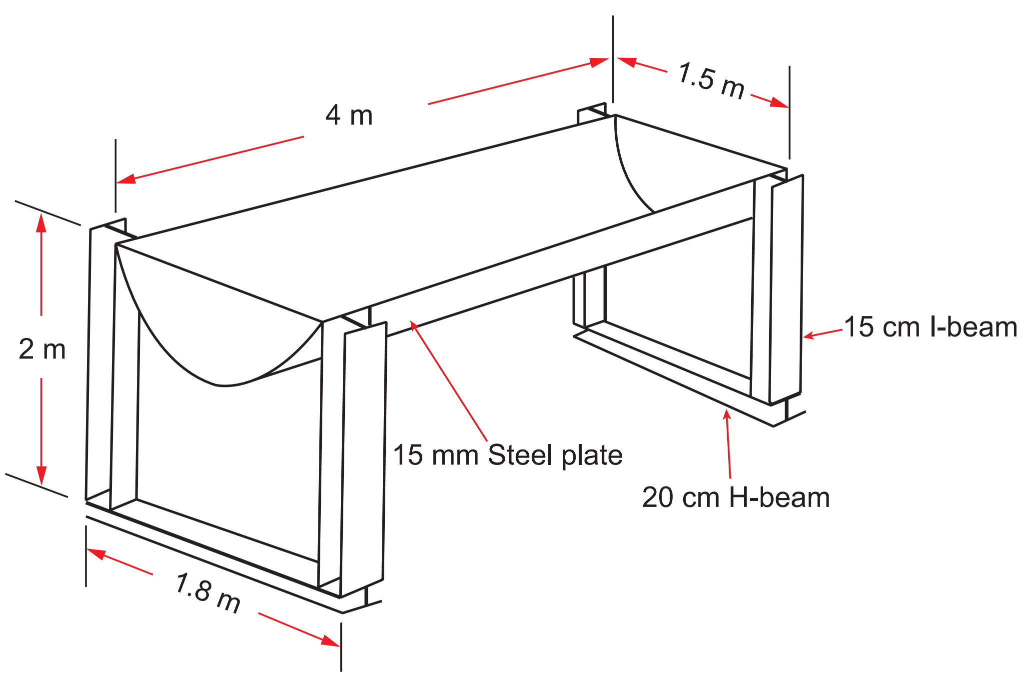
a) Formulas to calculate the volume of the various geometric shapes, such as:
    i. Cubes
    ii. Prisms
    iii. Pyramids
    iv. Solid cylinders
    v. Hollow cylinders
b) The density of the material used in constructing the object. Most heavy objects that need to be moved in a plant will be made from iron or steel. Both of these materials have an approximate density of 8×10^3 kg/m^3.

Volume calculations for simple shapes were covered in previous chapters. Complex structures can be thought of as collections of simple shapes. The volume of a complex shape can be determined by following these steps:

1. Divide the complex shape into several simple shapes.
2. Calculate the volumes of the simple shapes.
3. Add the volumes of the shapes together.

To determine the mass in kilograms, multiply the volume in cubic metres by the density in kilograms per cubic metre. Sometimes, mass tables are available for metal bars, sheets, pipes, and structural shapes. These tables list the weight by area and by linear measurement. In this case, it is only necessary to determine an area or length and multiply by the factor given in the tables.

Figure 8 – Steel Tank and Base



Example 1

The tank in Figure 8 is being relocated. To do so, it is necessary to determine its mass. 15 cm I beams form the vertical legs at each end, and 20 cm H-beams form the horizontal braces between the legs.

Given that densities of:

15 mm Steel Plate = 7.7×10^3 kg/m^3

15 cm I-beam = 26 kg per running metre

20 cm H-beam = 60 kg per running metre

Total length of 15 cm I-beam = 2 m × 4

= 8 m

Mass = 8 m × 26 kg/m = 208 kg

Total length of 20 cm H-beam = 1.8 m + 1.8 m

= 3.6 m

Mass = 3.6 m × 60 kg/m = 216 kg

Volume of steel plate used to form the tank:

$$\text{Volume of both ends} = \frac{1}{2} \times \frac{\pi}{4} d^2 \times 2 \text{ ends} \times t$$

$$= 0.7854 \times (1.5 \text{ m})^2 \times 0.015 \text{ m}$$

$$= 0.7854 \times 2.25 \text{ m}^2 \times 0.015 \text{ m}$$

$$= 0.0265 \text{ m}^3$$

$$\text{Volume of shell} = \frac{\pi d}{2} \times L \times t$$

$$= \frac{3.14 \times 1.5 \text{ m}}{2} \times 4 \text{ m} \times 0.015 \text{ m}$$

$$= \frac{4.71 \text{ m}}{2} \times 0.06 \text{ m}^2$$

$$= 0.1413 \text{ m}^3$$

$$\text{Total volume of metal for the tank} = 0.0265 \text{ m}^3 + 0.1413 \text{ m}^3$$

$$= 0.1678 \text{ m}^3$$

$$\text{Mass of tank} = 7.7 \times 10^3 \text{kg/m}^3 \times 0.1678 \text{ m}^3$$

$$= 1292 \text{ kg}$$

$$\text{Total mass of structure} = 208 \text{ kg} + 216 \text{ kg} + 1292 \text{ kg}$$

= **1716 kg (Ans.)**

It is usually impractical to calculate the exact mass of an object. Safe rigging practice should be accurate to within 20% for light objects. For heavier objects, the accuracy must increase.

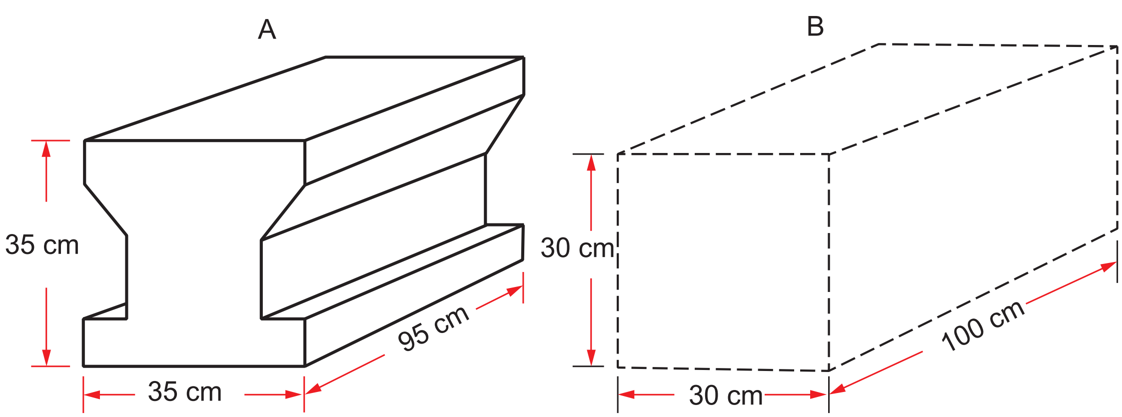
It is common to estimate an object's mass when specifications are unavailable. An estimate is not a guess; it is a carefully made calculation that makes a reasonable approximation. Estimates within safe limits can be calculated easily and quickly.

For safety reasons, it is preferable that the estimated mass is on the heavy side. For example, estimating a 200 kg turbine casing to be 300 kg is far better than estimating it to be 175 kg.

The mass of an irregular object may be reasonably estimated by visualizing the object as a regular shape or group of regular shapes. The object in Figure 9(A) may be visualized as a solid rectangle with proportionally adjusted dimensions, as shown in Figure 9(B).

The volume estimation is now a simple calculation of the volume of a rectangular object.

Figure 9 – Estimation



Self-Test 1

Refer to the PanGlobal Academic Supplement. For Figure 9, estimate the mass of the shape if it is constructed of:

a) Aluminum

b) Steel

a) 230.4kg (Ans.)
b) 708.3kg (Ans.)

Objective 3

Describe the general safety precautions used when hoisting equipment.

Hoisting

A hoist is a device used for raising or lowering heavy or bulky objects, such as machines and equipment. Hoisting involves the use of the following:

a) A rope, cable, **sling**, or chain strong enough to support the load.

b) A method of connecting the ropes, cables, or chains to the load such as knots, **eye bolts**, and rigging hooks.

c) A hoisting device, such as a crane, a come-along, a block and tackle, or a chain hoist.

On Track

Hoisting is a hazardous operation, and must be done by trained and experienced tradespersons. The content in this objective is introductory. It is designed so that newer Power Engineers can work effectively alongside experienced tradespersons.

Before hoisting a piece of equipment:

a) Determine the number and locations of slings needed to balance the load. A load with uniform shape and density can be lifted with only one sling. However, a non-uniform load will require a minimum of two slings (Figure 10). Long loads, which may bend and become damaged, or become unstable during the lift, require a minimum of two separate lifting devices (Figure 11).

b) Determine whether the lifting devices are strong enough to handle the load. The load rating must be clearly marked on all hoisting devices. Plants may not have hoisting devices for loads greater than 2000 to 3000 kg. It is extremely unsafe to try and lift equipment which has a mass greater than the rating of the hoisting device.

Figure 10 – Weight Distribution

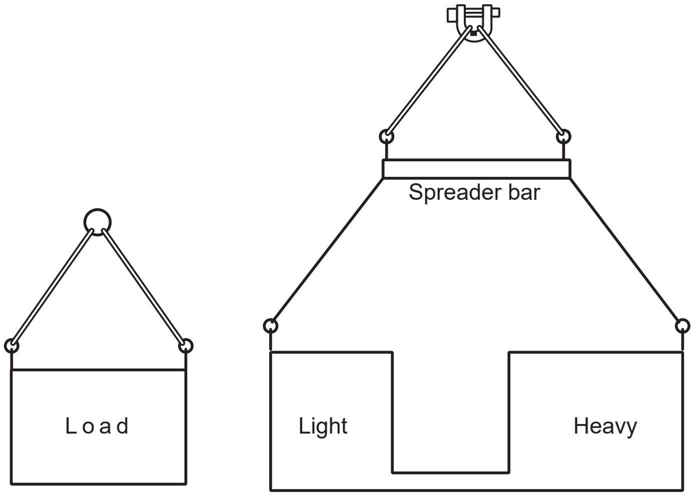
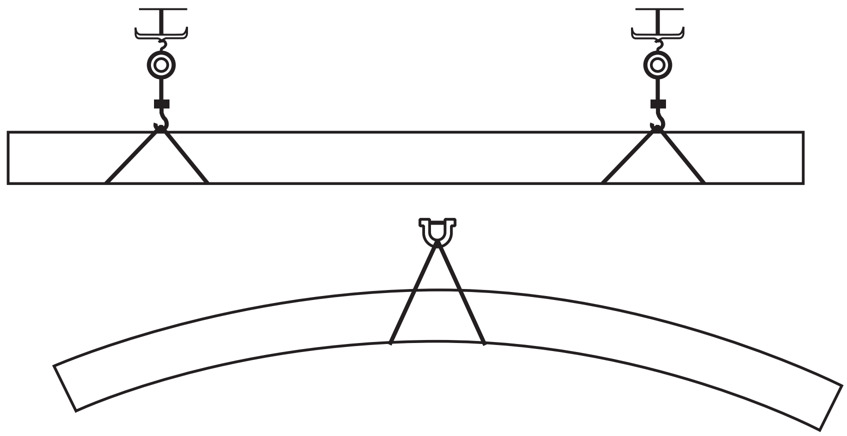
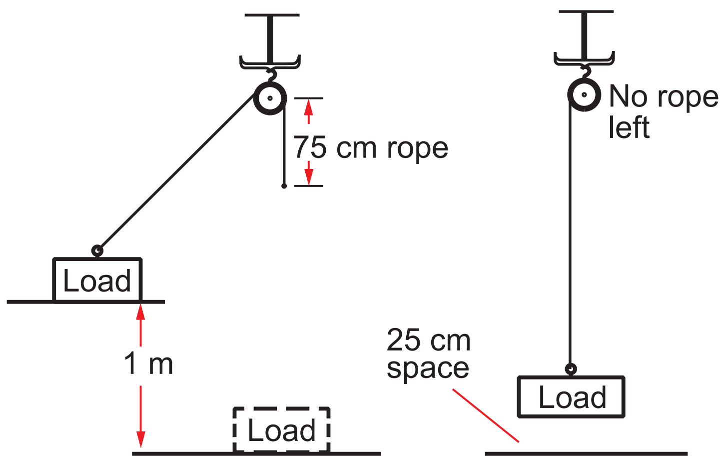


Figure 11 – Separate Lifting Devices



c) Determine whether the lifting device can raise or lower the load to the required elevation. Perhaps the job requires an extra-long length of rope (Figure 12). This problem may arise when hoisting the load to an elevated mounting.

Figure 12 – Rope Lengths



d) Determine whether the beams or overhead supports are strong enough for the load. Are they suitably located to attach the lifting devices?

e) Determine what hazards will be encountered during the lifting and moving operation. Are there electrical, steam, water, or air lines in the way? Are there tripping hazards that may not be noticed while focusing on the load? Is it necessary to shut equipment down or move personnel out of the area while conducting the lift? Are there special work permits or procedures to follow?

Block and Tackle

A block and tackle, which is a combination of ropes and pulleys (Figure 13), was a common lifting device in many plants. Today, chain hoists and come-alongs are preferred, in part because these devices have ratcheting mechanisms or clutches that prevent loads from falling when no lifting effort is applied.

The block consists of a shell, pulleys, and a hook or eye. Usually, two blocks are used with a connecting rope. The principle of operation and the mechanical advantage derived from various arrangements are explained in the chapter "Simple Machines."

When not in use, a block and tackle should be stored properly so the pulleys and rope do not become damaged. The method of coiling and wrapping shown in Figure 14 should always be followed. Standard methods of coiling ropes reduce aggravation for the next user. Ropes should be stored in a dry vermin-proof shed and hung from a proper support.

Always inspect the rope prior to each use. Never stand below the load when it is supported by the rope.

Figure 13 – Block and Tackle

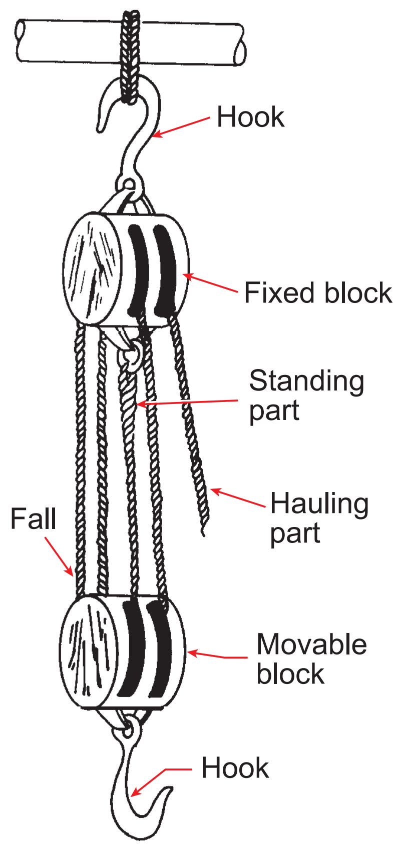
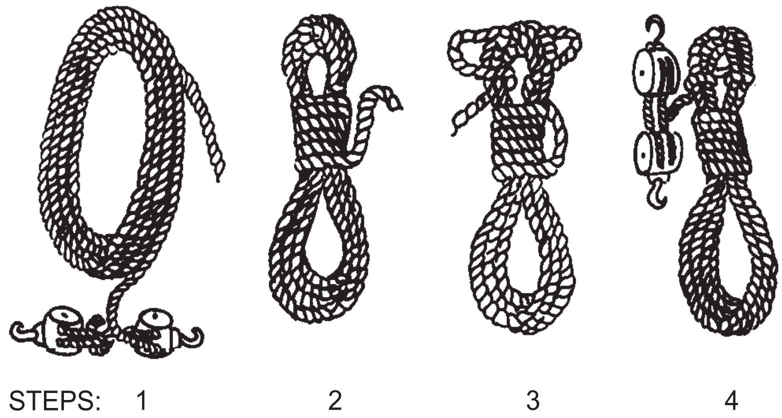


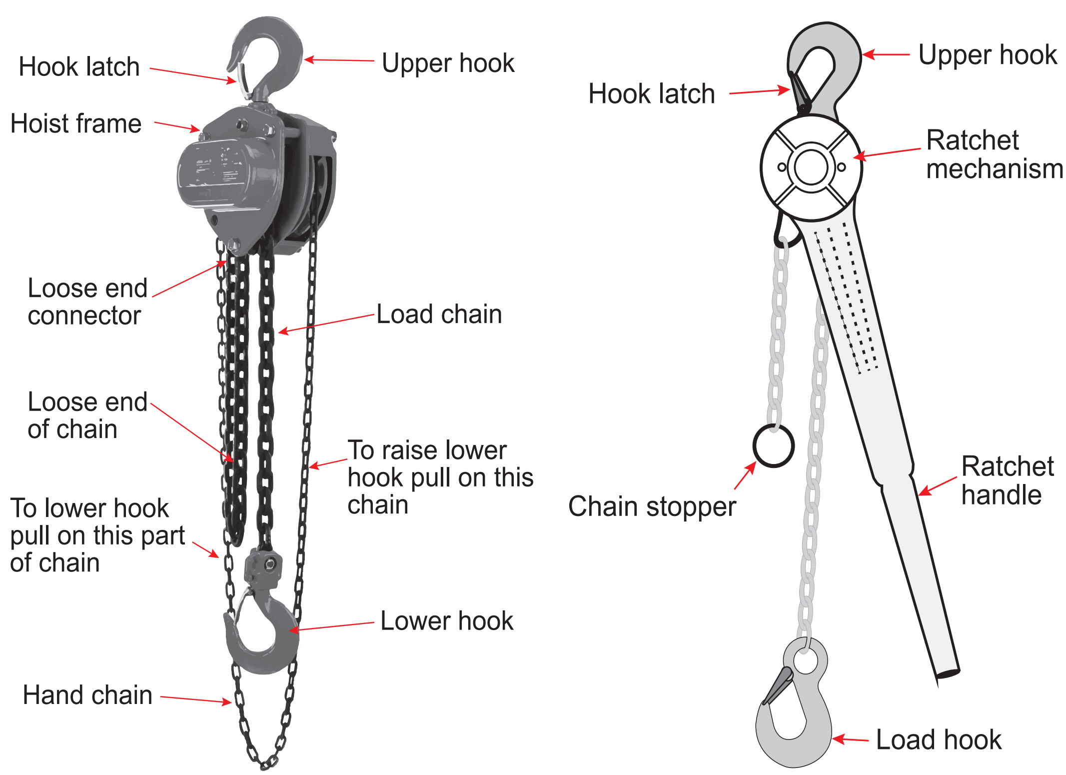
Figure 14 – Storing Block and Tackle



Chain Hoists (Chain Falls) and Come-Alongs

Chain hoists and Come-alongs are used where a load must be lifted and held suspended for an extended period of time, or where a very small amount of movement is required. Chain hoists are used mostly for vertical lifting, however, any deviations to the vertical lift make the pull chain difficult to handle. On the other hand, come-alongs can be used in any position from the vertical to the horizontal, or they can be inverted. This versatility makes the come-along an extremely useful tool for many jobs other than straight lifting. A chain hoist and a come-along are illustrated in Figure 15.

Figure 15 – Chain Hoist and Come-Along



Chain hoist
(a)

Come along
(b)

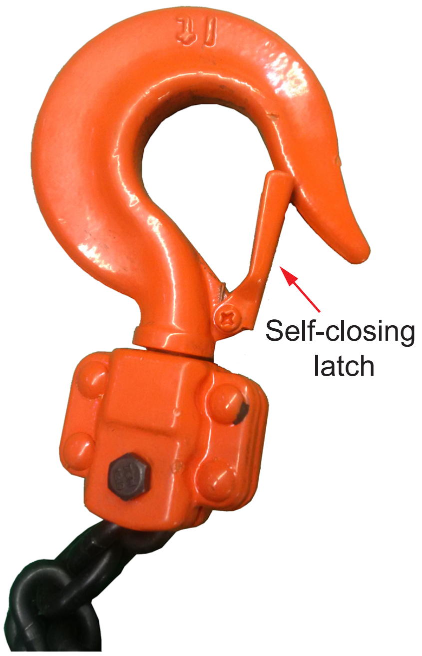
Chain hoists are designed with the lower hook weaker than the top hook. Overloading will first show by distortion of the bottom hook. A hook distorted by overloading should be discarded and replaced with a new one.

When using a chain hoist or come-along, make sure the load is always less than the rated capacity of the block. The mechanical advantage of these units is quite high, so it may be difficult to tell when the device is overloaded by "feel." Overloading can cause serious damage to the lifting device or it may result in injury if the device fails.

Safety Check

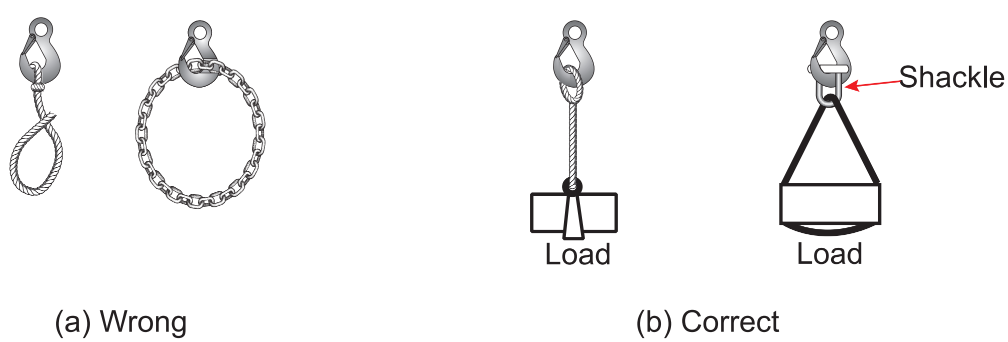
Most Jurisdictions require hoisting devices to have "safety hooks with a self-closing latch" (Figure 16), or some other means, to prevent a load from accidentally slipping off a hook.

Figure 16 – Safety Hook



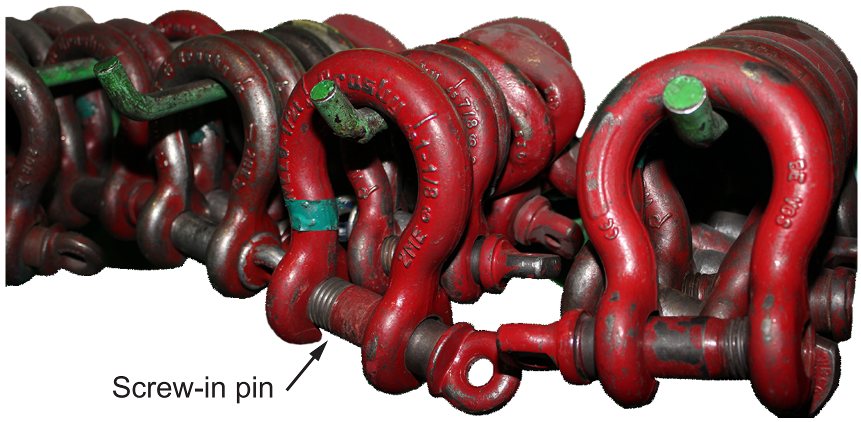
When using a chain hoist, never "choke" the load with the lift chain or strap, as in Figure 17(a). Instead, use a sling or grab chain, as in Figure 17(b).

Figure 17 – Use of Sling or Grab Chain



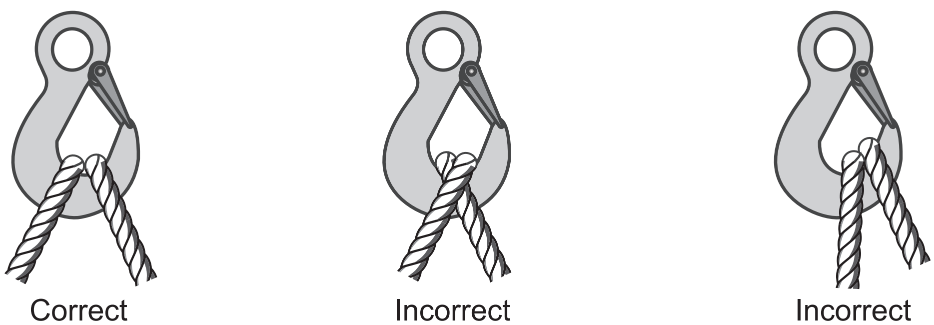
Two sling eyes should not be placed on the lift hook at the same time unless they are both in a vertical lift. If the sling legs are spread, shackle them together and place the shackle on the lift hook. Good safety practice dictates that whenever two or more eyes are used in lifting, they should be held in a shackle with screw-in pin (Figure 18).

Figure 18 – Shackles Used for Rigging and Hoisting



When placing two sling eyes in a hook or shackle, make sure that one eye does not lie on top of the other. Both eyes must be at the bottom of the hook (Figure 19).

Figure 19 – Placement of Sling Eyes



Workers should keep away from the load or the ropes and slings when heavy stress is applied to them. If the line separates from the load, it may snap back and whip around, with the potential to cause a serious accident.

Safety Check

Never stand beneath a load during a hoisting operation!

Objective 4

Discuss the correct use and limitations of wire cable and rope, including cable attachments and rope knots.

Ropes

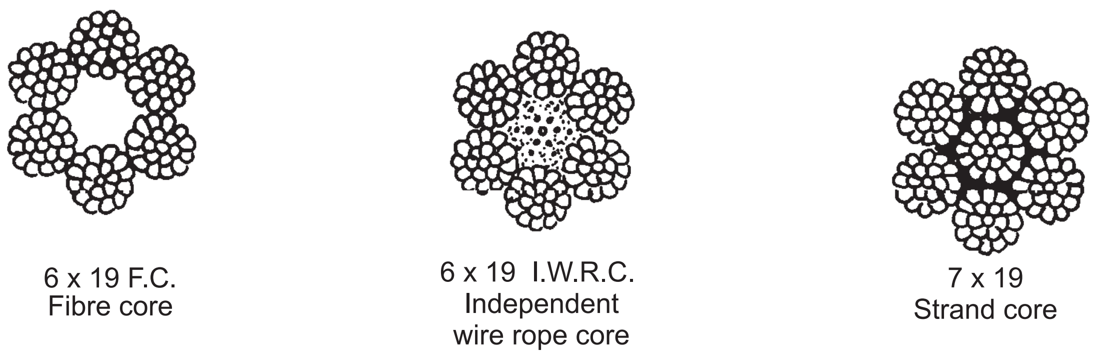
Ropes used for rigging, hoisting, and general use for securing loads may be made of natural fibres, synthetic fibres, or metal wires. **Manila**, **hemp**, and cotton are commonly used in the manufacture of natural fibre ropes. Synthetic ropes are made from **nylon**, **Dacron**, **saran**, and **polyethylene** fibres. Wire ropes are made of steel, or a combination of steel and natural fibre.

Wire Rope

The most common type of wire rope used for hoisting is made using a number of wires, laid left handed around a central wire, to form a strand. Several strands are then laid right-handed around a central hemp rope. Wire rope is classified by the number of strands and the number of wires per strand. For example, 6 × 19 refers to a rope having 6 strands with 19 wires per strand. Rope with more wires is more flexible, but has less resistance to abrasion.

Most wires are laid with a hemp rope, as a core, to act as a cushion and storage space for lubrication. Sometimes the hemp rope is replaced by a wire rope centre (Figure 20).

Figure 20 – Wire Rope Cores



The size of a wire rope refers to its greatest diameter.

Wire rope should be stored in a dry place away from extremes of heat and moisture.

A length of wire should be removed from a spool by rotating the spool on a spindle or turntable, or rolling the spool along the floor or ground. To prevent kinks, the wire rope should never be unwrapped from the side of a spool. Before cutting off a length of wire, first wrap it or **seize** it on each side of the proposed cut (Figure 21). If the end is to be welded, use friction tape, light wire, or cord.

Lubricate a wire rope used for hoisting to increase the life of the wire. The lubrication will reduce friction and prevent rust. The lubricant may be applied with a brush or poured on and worked in with a cloth (Figure 22).

Figure 21 – Cutting Wire Rope

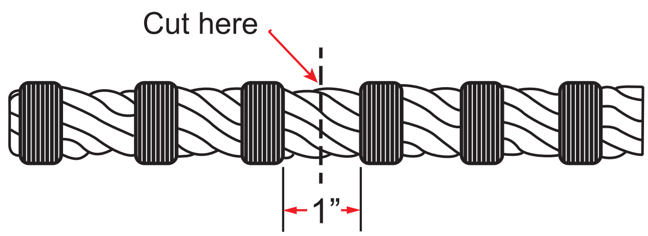
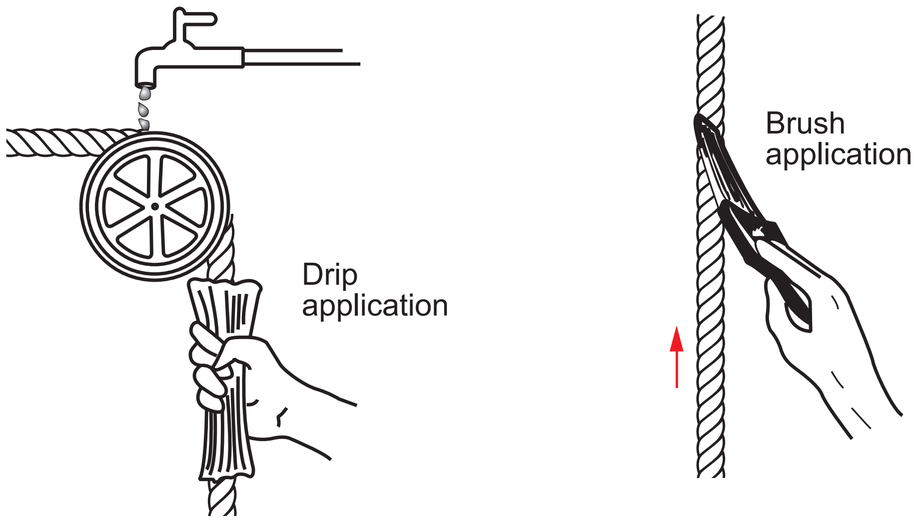
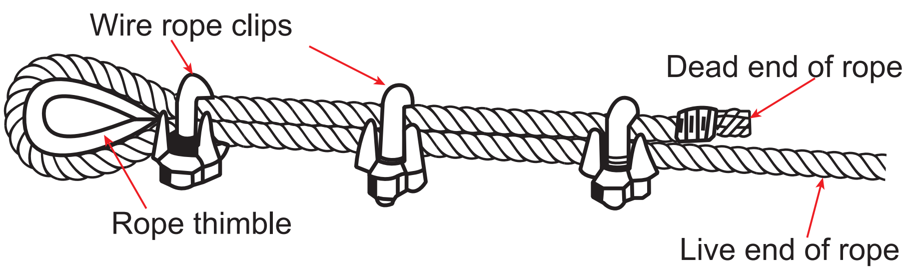


Figure 22 – Lubricating Wire Rope



The most common method of attaching wire rope to a piece of equipment is by using a wire **rope clip** (**Crosby® clip** Figure 23). Eyes made in a wire rope should always have a **thimble** installed to reduce the strain and wear on the wire rope. Clip manufacturers provide instruction on how many clips to install for a given rope. This varies from two clips for a 13 mm rope up to six clips for 30 mm rope. An eye made by using clips is 80% as strong as the rope.

Figure 23 – Clip Attachment (a) and Wire Rope Clip (b)



Clip attachment
(a)

Wire rope clip
(b)

Galvanized wire rope clips may be used repeatedly. Some clips are made from high strength bronze designed for use where electrolysis or corrosion makes the use of steel clips impractical.

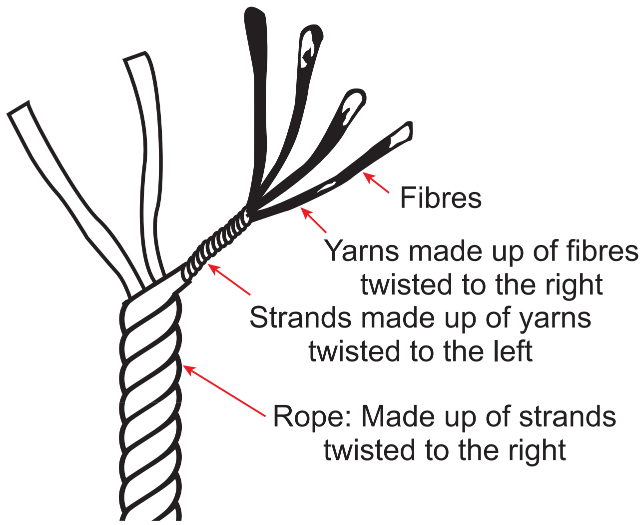
The clips should be attached to the rope end with the base of the clip (the saddle) against the live or long end. The U-bolt must only press against the dead or short end, of the rope (Figure 23). The lock nuts are fastened from the live end of the rope to secure the U-bolts. This is the only correct method of attaching wire rope clips. To help remember this fact, consider the following: "Never put a saddle on a dead horse."

Slings are constructed by splicing a rope to form an endless loop, or a length of rope with an eye spliced in each end. Splicing should be done by a qualified person and always protected against kinking or coiling. Slings should be removed from service when they show signs of wire breaks or sharp kinks.

Fibre Rope

Fibre ropes are made by combining fibres 2 to 6 metres into parallel lengths. A given number of fibres are twisted right-handed to form a yarn. A number of yarns are twisted left-handed into a strand. Three or four strands are then twisted right-handed to form the rope (Figure 24). This method of reverse twisting gives the rope stability and keeps it from untwisting when under load.

Figure 24 – Fibre Rope



In making rope, the yarns can be made into strands of varying tightness. This results in hard laid, standard laid, or soft laid rope. Soft laid rope has greater **tensile strength**, but does not withstand abrasion very well.

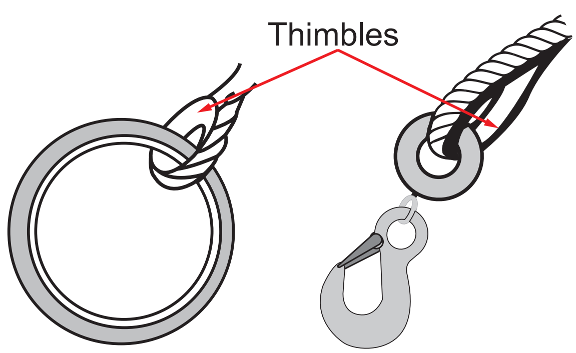
Rope is measured in two ways: by diameter or circumference. Small ropes up to 2.5 cm are usually measured by diameter. Larger ropes are measured by circumference.

Store rope in a dry vermin proof room away from extremes of heat and moisture. It is preferable to hang up rope to ensure air circulation. Wet rope should be thoroughly dried before storage. Keep the rope away from oils, grease, paint, solvents, and washing compounds which will cause deterioration. Avoid letting a rope freeze; this will reduce its life. If used frozen, its strength is considerably lower.

Overloading a rope is dangerous. Use a **factor of safety** of 5 to determine the safe load for a new rope. Increase the factor of safety as the rope ages and wears. Rope should not be dragged over concrete, sand, sharp corners, or angles. Use a chain in these conditions!

When a rope is spliced to a hook or a ring (Figure 25), a thimble should be placed in the eye. The thimble will reduce wear and stress that develops when the rope is bent around a small diameter.

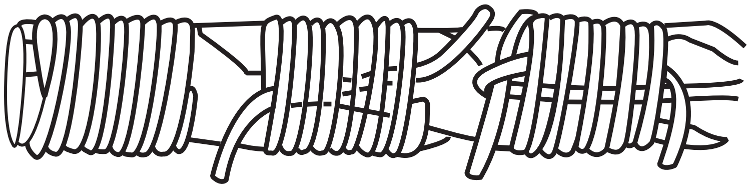
Figure 25 – Use of Thimble



When a rope becomes tangled, do not take the loose ends and pull the tangle into a tight mess. Keep the tangle loose and work the slack line out one twist or wrap at a time.

Remove the rope from the inside of a coil. Before cutting the rope to the required length, the ends of the rope should be seized or whipped to prevent untwisting. **Whipping** consists of binding the end of a rope with twine or string (Figure 26), so that the twine is fastened.

Figure 26 – Whipping Rope Ends



Synthetic Ropes

Nylon rope is very strong and elastic. It is used where shock loading is common, or when a rope smaller than natural fibre, but of equal strength, is needed. It is resistant to mineral oils and greases, but is affected by paint, linseed oil, and acids. It becomes slippery when wet, but will not rot or develop mildew.

Dacron rope has less elasticity than nylon, but is more resistant to acid and water. It has a greater tensile strength and is resistant to abrasives, rot, and mildew.

Saran rope is highly resistant to acids, alkalis, and organic solvents. It is almost unaffected by water. It has high resistance to abrasions and the effects of weather, but it cannot be used at temperatures greater than 50°C (120°F) due to its low melting point.

Polyethylene rope is highly resistant to acids, alkalis, and common solvents. It is unaffected by mildew, rot, or fungi. It has high elasticity, but poor resistance to abrasion. It absorbs practically no water, and therefore remains buoyant in water indefinitely.

The ends of synthetic rope should be taped, seized, or whipped like fibre ropes. Nylon rope ends can be fused with heat to prevent unravelling of the fibres.

Knots

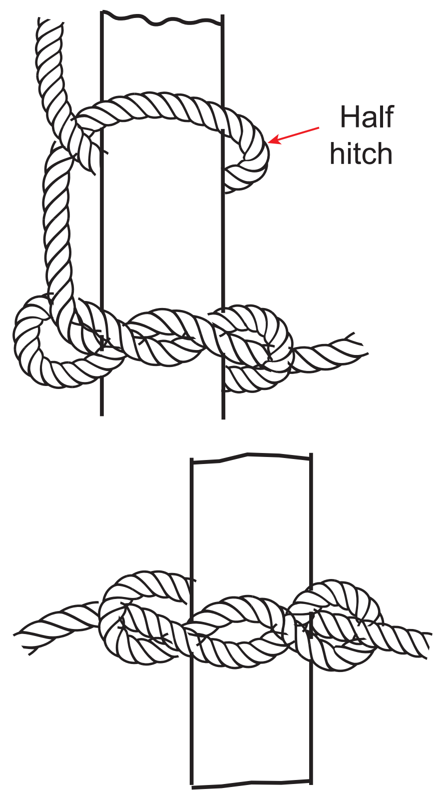
Many jobs require ropes to temporarily secure or fasten objects. These connections must be secure, yet capable of easily being taken apart when the job is complete. In the following sections, a few safe, easily tied and untied knots and hitches are described.

Timber Hitch

The **timber hitch** (Figure 27) forms a secure connection which stays tight under a load, yet is easily undone when the line is slack. It is a **half hitch** with the running end wrapped at least two full turns to increase the area of friction contact between the load and the rope itself.

When a plank or pipe is lifted in a near vertical position, a half hitch is added above the timber hitch as an extra choke to keep the line from slipping.

Figure 27 – Timber Hitch



Clove Hitch

The **clove hitch** (Figure 28) is used for attaching a rope to pull at right angles to the pipe or pole. It will hold its position with the line tight or slack. There are two ways of tying the clove hitch. The first (Figure 28) is used when tying the knot to a pole or pipe, which is closed at both ends. The second (Figure 29) is used when the hitch can be passed over the load, or when the rope ends are inaccessible.

Figure 28 – Hitch (Around the Load)

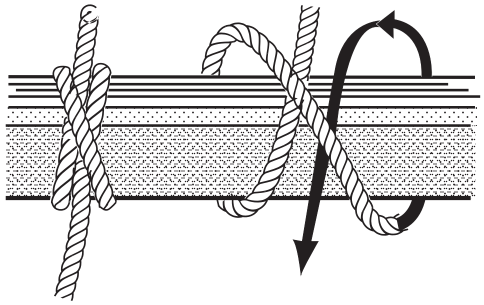


Figure 29 – Hitch (Over the Load)

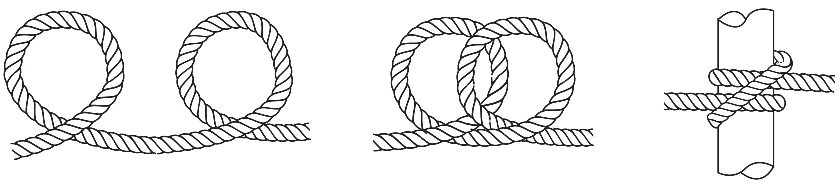
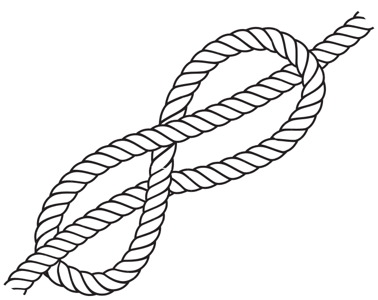


Figure Eight Knot

The **figure eight knot** (Figure 30) is used to prevent the end of a rope from slipping through a ring or pulley, and will not damage the rope fibres.

Figure 30 – Figure Eight Knot



Square or Reef Knot

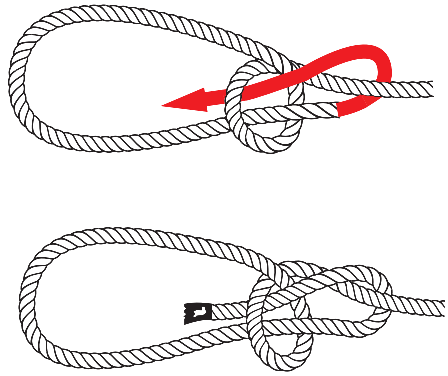
The square or **reef knot** (Figure 31) is used for tying two ropes of the same size together, or for tying together the ends of a short rope to make a temporary endless sling. Properly tied, a reef knot will not slip when the rope is dry. It has about 50% of the rope strength.

Figure 31 – Reef Knot

Bowline

The **bowline** (Figure 32) forms a loop that will not slip or jam. It can be easily untied when the rope is slack. Used as a running bowline, it makes a quick temporary sling. A bowline on a bight is used to make a loop any place in the rope.

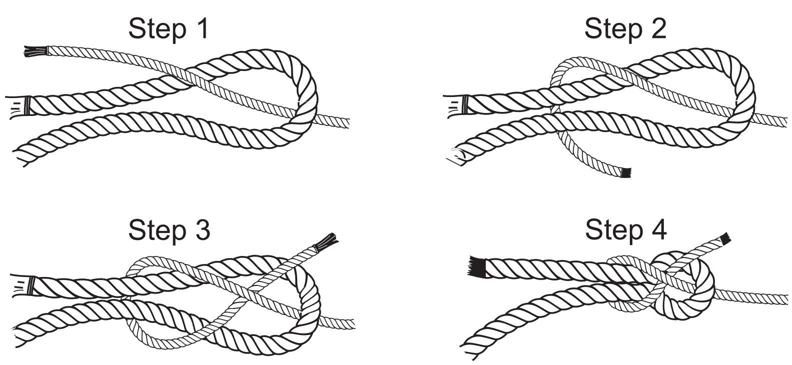
Figure 32 – Bowline



Sheet Bend

The **sheet bend** (Figure 33) is used to join together two ropes of equal or of unequal thickness. Notice how the thin rope jams against the loop of the thick rope to prevent it from slipping.

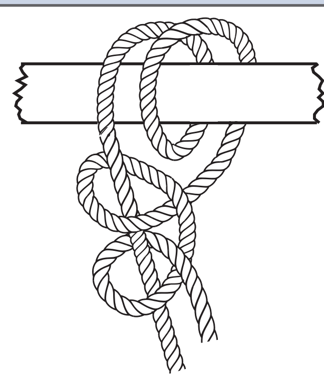
Figure 33 – Sheet Bend



Round Turn and Half Hitches

The **round turn and two half hitches** (Figure 34) is a simple method of attaching a rope to a pole, ring, or another rope. It is especially useful for towing purposes.

Figure 34 – Round Turn with Half Hitches



Eye Bolts

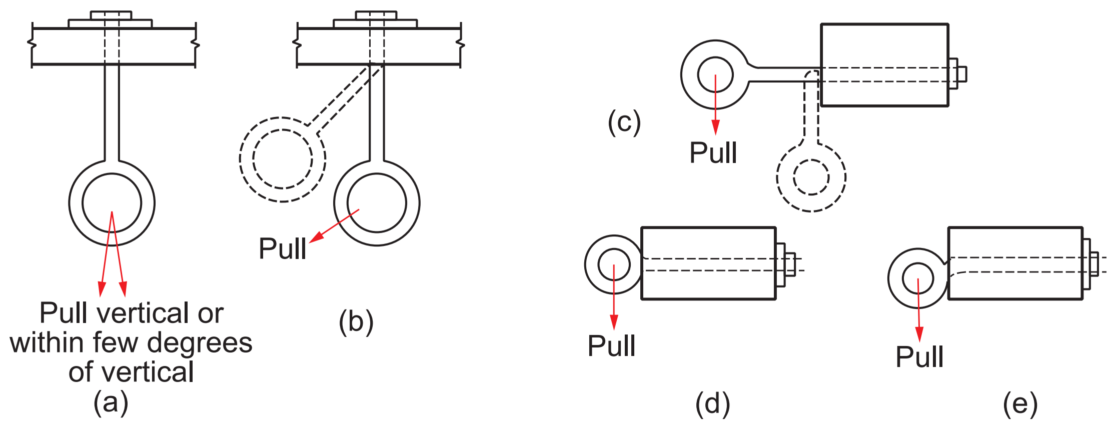
In addition to the lifting device and the rope, eye bolts are often used to make the lifting work safer, faster, and more efficient. Eye bolts are devices used as substitutes for chains or slings to suspend lifting equipment, such as chain hoists or come-alongs. They also serve as a means of connecting the lifting device to the load.

The suspending type (Figure 36) eye bolts are used in areas where there is no possibility of using a sling. The size of the eye bolt will vary to suit the job, but must always be rated appropriately to carry the load.

When an eye bolt is set up for heavy lifting, there should be some way of hoisting the chain hoist so the hook can engage the eye bolt. A hand line or rope blocks supported separately but close to the eye bolt is the preferred method of raising the chain falls.

Eye bolts are meant to be used with the pull in the same direction as the bolt. If the load pulls at an angle, the eye bolt may bend and break (Figure 35).

Figure 35 – Loading Eye Bolts



(a) Is acceptable, the load is vertical

(b) Is unacceptable due to the horizontal loading

(c) Unacceptable due to vertical load at 90 degrees

(d) Unacceptable. A shoulder eye bolt should have been used.

(e) The result of (d): bending of the eye bolt

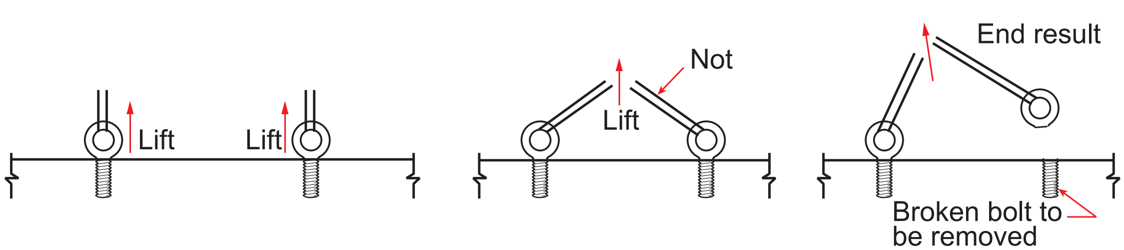
When a piece of heavy machinery, such as a heavy pump cover, is built with tapped holes for installing eye bolts, the strain can be loaded at an angle up to 45 degrees, if **shoulder eye bolts** are used (Figure 36).

A shoulder eye bolt has additional material at the base of the eye, called the shoulder. This material is machined flush so that when the eye bolt is secured, the shoulder bears against the surface of the object being lifted. The extra material strengthens the bolt where it attaches to the load.

Figure 36 – Shoulder Eye Bolts

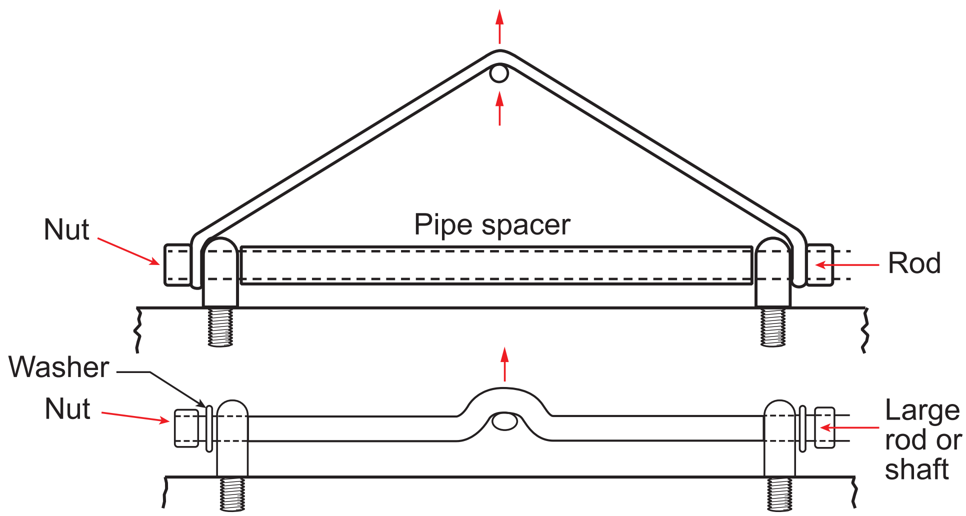
When non-shoulder eye bolts are used, the strain must be applied to the bolts in a vertical direction (Figure 37).

Figure 37 – Loading Two Eye Bolts



Whenever possible, it is preferable to use some form of **bridle** which allows lifting with one lifting device (Figure 38). To allow for slight bending in the rod, the nuts should not be tightened against the eye bolts.

Figure 38 – Lifting Bridle



Objective 5

List and describe common types of metal fasteners, such as screws, bolts, studs, nuts, and washers.

Mechanical Fasteners

Mechanical fasteners are devices used to fasten two or more parts of an object together.

Generally, fasteners may be divided into three classes: threaded, fixed, and aligning. Joints on any piece of equipment can be readily assembled and disassembled with threaded fasteners, such as bolts, screws, and **studs**. Fixed fasteners, such as **rivets**, are used to permanently secure two pieces together. Aligning fasteners, like the common **dowel** or tapered pin, are used where it is important that two pieces go together in an exact relationship to each other (for example, pump and turbine parts).

Threaded fasteners are available in a variety of types. Descriptions of some of those in general use follow.

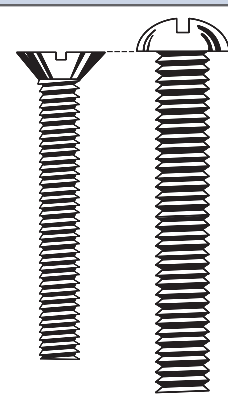
Stove Bolts

Stove bolts (Figure 39) are used in either tapped holes or through holes with nuts on the end. They are most commonly used in electrical equipment, household goods, and toys. They are normally available with the following type heads:

- Flat
- Round
- Oval
- Truss

They most commonly come with slotted heads, but may also be found with **Phillips** (cross-shape) or **Robertson** (square recessed) heads. When nuts are supplied, they are usually of the square type.

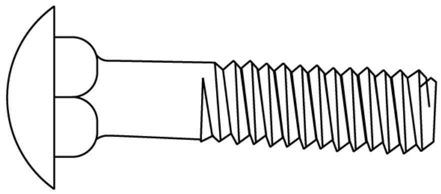
Figure 39 – Stove Bolts



Carriage Bolts

This type of bolt (Figure 40 is generally used to fasten castings, forgings, and wooden parts to metal parts. **Carriage bolts** are normally available with truss type heads while some may have square heads. These bolts have a square neck immediately below the head, so they will not turn in wood or in a square hole.

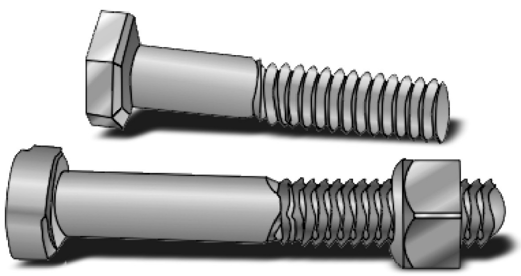
Figure 40 – Carriage Bolt



Machine Bolts

Machine bolts (Figure 41) are used where a snug fit is required in a drilled or tapped hole, such as in automotive parts and various plant machinery. They are most commonly supplied with hexagonal heads.

Figure 41 – Machine Bolts

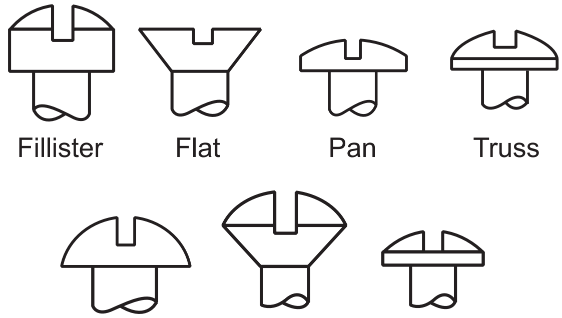


Machine Screws

These are similar to stove bolts and are available in a variety of head styles (Figure 42). The screws usually have the threads running along their full length. They are hand driven by four basic tools:

- Standard slot screwdriver
- Phillips screwdriver
- Robertson screwdriver
- **Allen wrench** (**hex key**)

Figure 42 – Machine Screw Heads



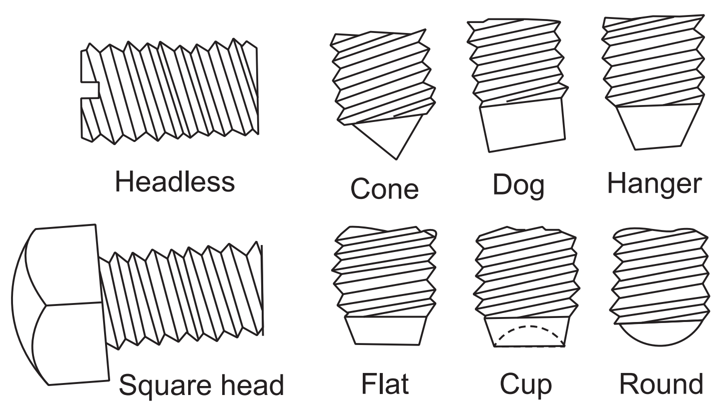
Cap Screws

Cap screws resemble machine screws, but are used where a screw is required to have a finer tolerance and finish than machine screws. Hex cap screws feature a **washer** face under the head and a chamfered point. A normal hex bolt does not have a washer face or chamfered threads. Cap screws are made of low-carbon steel and are very common in the construction of machinery such as of pumps and compressors.

Set Screws

Set screws are used for assembling shafts to parts such as pulleys and flywheels or to hold parts in a fixed relative position to each other. They are available with many styles of heads and points (Figure 43). Set screws are case hardened, so they will be able to withstand severe use. Headless set screws may have a slot for turning, but more common is the hex key recessed head type. The headless set screw is preferred for safety reasons on rotating shafts. Set screws with heads are potentially dangerous because clothing may get caught on the head.

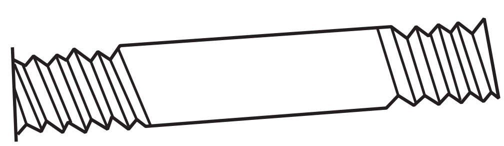
Figure 43 – Set Screw Types



Studs

Another metal fastener used extensively in equipment assembly is the stud. Whereas the other fasteners described previously are all removed whenever the equipment is dismantled, the stud (Figure 44) remains in place and the nut that is screwed on one end of it is removed. The stud is made from cylindrical stock threaded at both ends. It is installed and removed with a special stud removal tool. The type of material used and the torque loading are very important considerations when working with studs. Studs are also used for fastening pipe flanges together. Studs used for flanges may have a different thread pitch compared to a standard coarse thread bolt.

Figure 44 – Stud



Bolts

The most common type of threaded fastener is the **bolt**. It may have square or hexagonal heads and is torqued by open end, box, combination, or adjustable wrenches.

Bolt Sizes

The sizes of bolts recommended for general engineering use are shown in Table 2. There are 17 sizes available. Bolts 8 mm in diameter and larger are available in coarse and fine thread. Some sizes are preferred because they have a better diameter/thread combination. The square head bolt is commercially available in one grade, while the hexagonal head bolt is available in three grades: regular, semi-finished, and finished.

Table 2 – ISO Metric Threads for Screws, Bolts, and Nuts
(Recommended Sizes for General Engineering Use)

Nominal Diameters		Pitch	
Preferred Size	2nd Choice	Coarse mm	Fine mm
M 1		0.25	
	M 1.1	0.25	
M 1.2		0.25	
	M1.4	0.3	
M 1.6		0.35	
	M 1.8	0.35	
M 2		0.4	
	M 2.2	0.45	
M 2.5		0.45	
M 3		0.5	
	M 3.5	0.6	
M 4		0.7	
	M 4.5	0.75	
M 5		0.8	
M 6		1	
	M 7	1	
M 8		1.25	1
M 10		1.5	1.25
M 12		1.75	1.25
	M 14	2	1.5
M 16		2	1.5
	M 18	2.5	1.5
M 20		2.5	1.5
	M 22	2.5	1.5
M 24		3	2
	M 27	3	2
M 30		3.5	2
	M 33	3.5	2
M 36		4	3
	M 39	4	3

Thread Length

The threads on bolts, unlike machine screws, are available in a variety of lengths. The lengths of thread recommended by the International Standardization Organization (ISO) are shown in Table 3.

Table 3 – Formulae for ISO Thread Length for General Purpose Bolts

Bolt Nominal Length (mm)		Formulae for Thread Length
Over	To	
---	125	2 x Diameter, plus 6 mm
125	200	2 x Diameter, plus 6 mm
200	---	2 x Diameter, plus 6 mm

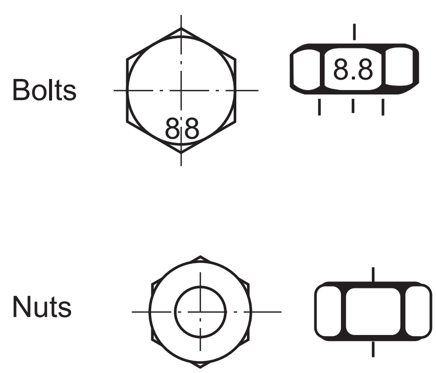
Mechanical Properties

In order to identify and select appropriate fasteners by strength, the ISO developed a system of identification markings (Table 4). In addition, the ISO recommends clearance holes for metric bolts, as shown in Table 5.

Table 4 – Mechanical Properties of Fasteners

Mechanical Properties of Fasteners Conforming to ISO Standards													
Property Class		3.6	4.6	4.8	5.6	5.8	6.6	6.8	6.9	8.8	10.9	12.9	14.9
Marking Symbols	Preferable	3.6	4.6	4.8	5.6	5.8	6.6	6.8	6.9	8.8	10.9	12.9	14.9
	Permissible	36	46	48	56	58	66	68	69	88	109	129	149
Old-Style DIN Marking		4A	4D	4S	5D	5S	6D	6S	6G	8G	10K	12K	
US Grade (Approximate)		1		2			3			5	8		

Identification



Designation

The ISO designation system for property classes of fasteners consists of two digits separated by a decimal (such as 8.8, 10.9, or 12.9). For example, consider a bolt stamped "12.9." The value "12" indicates the minimum tensile strength of the bolt multiplied by 100, in MPa. Therefore, the bolt's minimum tensile strength is 1200 MPa. The second digit "9" shows that the **yield strength** is 90% that of the tensile strength.

The product of the number before the decimal and the number after the decimal gives the minimum yield strength, in MPa. Using the same example, the bolt stamped "12.9" would have a minimum yield strength of 1200 × 0.9 = 1080 MPa.

Table 5 – Clearance Holes for ISO Metric Bolts

Thread Diameter mm	Clearance Holes mm		
	Fine	Medium	Coarse
M 1.6	1.7	1.8	2
M 2	2.2	2.4	2.6
M 2.5	2.7	2.9	3.1
M 3	3.2	3.4	3.6
M 4	4.3	4.5	4.8
M 5	5.3	5.5	5.8
M 6	6.4	6.6	7
M 7	7.4	7.6	8
M 8	8.4	9	10
M 10	10.5	11	12
M 12	13	14	15
M 14	15	16	17
M 16	17	18	19
M 18	19	20	21
M 20	21	22	24
M 22	23	24	26
M 24	25	26	28
M 27	28	30	32
M 30	31	33	35
M 33	34	36	38
M 36	37	39	42
M39	40	42	45

Nuts

Nuts are threaded metal pieces that are used on screws, bolts, or other threaded products to tighten and clamp parts together. Rough and semi-finished nuts are pressed, hammered, or punched out of cold or hot metal. Finished nuts are machine cut from steel bars. Machine bolt nuts are cut out of a square or hexagonal bar of steel.

Jam nuts, sometimes called lock or check nuts, are thinner than the standard nut. They are used as a lock to keep another nut from loosening by vibration.

Castle nuts have slots across the top. A split pin is placed in a slot in the nut and through a hole in the bolt to lock the nut in place. These nuts are commonly used to hold wheel bearings and wheels in place.

The property classes of nuts are designated by the numbers 4, 5, 6, 8, 10, 12, and 14.

Washers

Washers are metal rings or discs which are used between a nut or bolt head and the work surface. They are either of the flat or lock type.

Flat Washers

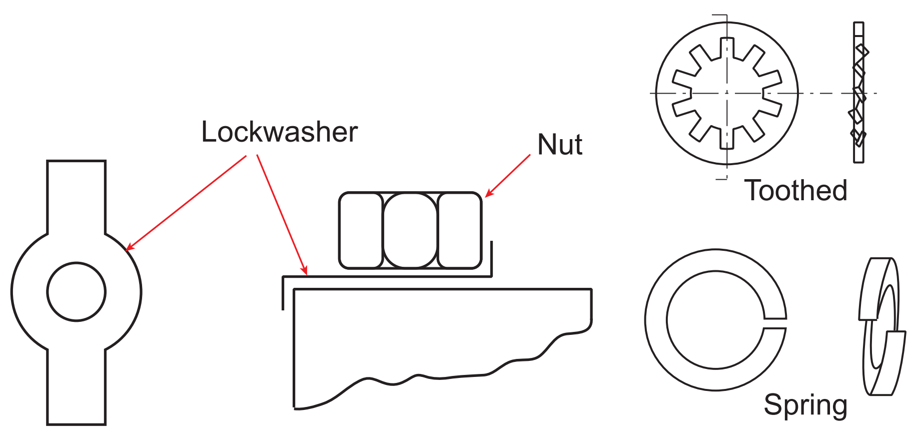
Flat washers are used for the purposes of:

a) Allowing the bolt or nut to be used in an oversized clearance hole.
b) Preventing marring of the work surface.
c) Distributing the compressive loading of the nut more evenly.

Lock Washers

Lock washers are metal discs or rings which are used to prevent unwanted turning of a nut or bolt head. Some available types of lock washers are shown in Figure 45.

Figure 45 – Lock Washer Types



Chapter Summary

This chapter described the various types of ladders and scaffolding used in power plants. The most common types of ladders used in a power plant are the step ladder and the rung ladder. Key safety considerations were introduced so the Power Engineer can select, erect, and use ladders safely.

Scaffolding can vary in style, erection method, and material. All scaffolds must be erected plumb and level on stable ground. Scaffolding must be inspected before use and at regular intervals by a qualified scaffolder or qualified safety person. Safety tags were discussed, so that workers on scaffolds are not exposed to unusual hazards.

Maintenance and repair work may require equipment to be removed and reinstalled. To move equipment, workers use rigging techniques and hoisting equipment. Workers must be able to accurately determine or estimate the mass being lifted, to avert potential disaster. To do this, the worker needs to know all of the following:

a) Equipment dimensions of the load being moved.

b) Material composition and density of the equipment being moved.

c) The direction in which the load will be moved.

d) The limitations of the devices selected to perform the move.

Knowledge of ropes and knots is fundamental for rigging and hoisting. Various rope materials (natural fibre, synthetic fibre, and wire), and their suitability for certain conditions, were covered. Again, safety was discussed, including topics such as:

a) Proper selection and inspection of ropes

b) Rope maintenance and storage

c) Installation of thimbles and clips

d) Cutting and whipping rope ends

Tying knots and knot application were introduced. Various knots were discussed and illustrations for each were provided.

Finally, several threaded fasteners were described, including:

- Stove bolts
- Carriage bolts
- Set screws
- Machine screws
- Studs
- Nuts
- Washers

Information about bolt sizes, threads, and lengths were available in tables. Identification marks were illustrated.

CHAPTER 3

Boiler Maintenance

Learning Outcome

When you complete this chapter you should be able to:

Describe the service and maintenance required for boilers.

Learning Objectives

Here is what you should be able to do when you complete each objective:

1. *Describe the general maintenance and service of packaged firetube and cast iron sectional boilers.*
2. *Identify the operational procedures for wet and dry boiler layups.*
3. *Describe ways of detecting firetube and tubesheet leaks.*
4. *Describe the general procedure for the removal and replacement of defective firetubes.*

Chapter Introduction

Boilers, like other kinds of equipment, require regular maintenance to perform safely and efficiently. This chapter deals with the maintenance of packaged firetube and cast iron sectional boilers. This is not meant to replace the specific maintenance requirements of boiler manufacturers; rather, it covers general boiler maintenance practices.

Power Engineers must be able to inspect boilers for signs of adverse conditions, especially leaks. Boilers with leaks have damaged pressure boundaries; therefore, they require immediate response and serious attention. When boilers require repairs, the Power Engineer must be well versed in repair procedures to supervise tradespersons, and ensure repairs are carried out in accordance with applicable codes. These procedures include performing temporary repairs of tube leaks, and removing and replacing defective tubes.

Preparing a boiler for inspection is one of the most important tasks Power Engineers perform. Inspection and repair cannot proceed unless a boiler is properly prepared.

Another important maintenance task is the proper storage of boilers that are temporarily out of service. Boilers can sustain expensive and possibly irreparable damage if stored incorrectly. These "layup" procedures are also covered in this chapter.

Objective 1

Describe the general maintenance and service of packaged firetube and cast iron sectional boilers.

Many of the following maintenance activities are performed only after the boiler is cooled, locked out, and drained. Plants often require safe work permits before proceeding with these activities. Ensure site specific and jurisdictional lockout and work procedure requirements are followed.

Some of these procedures may involve confined space entry. Be familiar with confined space rules, regulations, and procedures prior to entering a confined space.

General Maintenance

Boiler operators should always watch for leaks in steam and water connections. If a leak is allowed to continue for any length of time, the force of escaping water or steam may cause erosion of the sealing surfaces. This is particularly noticeable when handhole and manhole gaskets leak. Leaks in gauge glass packing will erode and weaken the glass. This will lead to gauge glass failure and possible injury. All leaks should be repaired as soon as they are noticed. To prevent leaks, periodically check and adjust the tightness of packing glands, flange bolts, handhole and manhole yokes, and unions.

Pumps with packing glands require more maintenance than those with mechanical seals. Inspect the boiler feed pump or hot water circulating pump packing glands weekly. The gland nuts should only be tightened enough to prevent excessive leakage. Leakage of a few drops a minute is desirable to prevent drying out of packing and scoring of the shaft.

Washing Out the Boiler

After the first three months of operation, new boilers should be:

1. Shut down
2. Drained
3. Opened up
4. Flushed out with a high-pressure hose
5. Inspected

Thereafter, this procedure should be repeated as often as conditions warrant. Tubes and tube sheets should be inspected for scale formation and pitting. This inspection will show the effectiveness of the water treatment.

Cleaning the Firetubes

1. Open the front and rear doors of the reversing chambers. If the tubes are coated with soot, they must be cleaned by brushing.
2. Remove the **flame retarders** if they are used. The tubes and tubesheets can now be brushed at both ends.
3. Remove all soot deposits in the furnace and reversing chambers.
4. After cleaning, re-install the flame retarders.
5. Close the front and rear doors, unless refractory repair is necessary. Always cover the door gaskets with graphite and oil, or an anti-seize compound, before closing the doors. This will make future opening easier.

If a boiler has fireside soot accumulation, have a licensed burner technician perform a combustion analysis, and adjust the fuel-air ratio of the burner across its entire firing range.

Lubrication

The burner and fan motor may have either standard ball bearings or pre-lubricated sealed bearings. Standard bearings normally require lubrication once a year. Sealed bearings only require lubrication every three years. Follow the manufacturer's recommendation as to the frequency of lubrication, and type of lubricant required.

Refractory Maintenance

Inspect the refractory each time the boiler is opened up for cleaning. To prolong its life, regularly washcoat the refractory with a diluted heat resistant cement. Cover joints and cracks with this cement, or else extensive damage may occur.

Replace burned out or broken refractory segments with the same kind of material. Complete renewal will be necessary if there is a general deterioration of the refractory.

Do not fill refractory cracks with solid refractory material. Small cracks will usually close up when heated. If a solid material is used to repair the crack, when the refractory heats up, it will cause more cracking when the material expands. In these situations, use gunnable refractory materials that dry soft and pliable. Consult a refractory contractor for further information.

Burner Maintenance

In addition to maintaining the proper fuel-air ratio for complete combustion, the boiler operator should observe the burner flame regularly during operation. A symmetrical flame is a good indication of a clean burner. A distorted flame indicates a dirty burner.

Gas burners will seldom give trouble and should not require cleaning and inspection more than once a year, but oil burners should be cleaned periodically. Follow the procedure in the boiler manual. The procedure below varies for different types of burners and boilers.

The following general directions apply to the cleaning of oil burners:

1. Make sure the power supply to the boiler and fuel pump is disconnected. Before removing the oil burner, ensure that the fuel line manual stop valves are locked closed. Follow proper lockout/tagout procedures.
2. Disconnect the fuel lines and remove the burner assembly from the front of the boiler.
3. Dismantle the burner assembly. Handle the nozzle and component parts carefully, as they are precision-made pieces of equipment.
4. Use a monarch brass wire brush to remove carbon build-up from the nozzle. Do not clean the orifice with an ordinary wire brush or any other metal object; the abrasion may distort the spray angle, and alter the burner capacity.

5. Soak all parts in a good carbon solvent. Rinse them thoroughly with hot water afterwards.
6. Dry the components with a lint-free cloth. With a round, sharpened toothpick, polish the front and rear of the orifice lightly.
7. Make sure hands and tools are clean before reassembling the nozzle.
8. Clean the diffuser, pilot tube, and igniter. Run a cloth through the scanner tube to keep it clean and shiny. Wipe the rotary damper and check that it moves freely.
9. After reassembling, replace the burner in the burner head on the furnace. Make sure the nozzle is properly centered, and extends the correct amount into the nozzle tube.
10. If removal of the burner nozzle requires the removal of the igniter as well, reinstall the igniter, and adjust it to the exact position recommended in the boiler manual.
11. Connect the fuel lines and make sure that they are properly tightened.

Heating Boiler Annual Maintenance – Hot Water Service

Hot water heating boilers are commonly made of copper tubing, cast iron, or steel. Cast iron and steel hot water boilers (firetube or watertube) have similar requirements for annual shutdown and maintenance. This section discusses the annual shutdown and maintenance of steel and cast iron heating boilers.

Conduct a complete check of the system at the end of the heating season, while the system is in operation. Ensure all repairs are done immediately. Do not leave any repairs until the start of the heating season.

The following procedures are general in nature. Always follow the manufacturer's recommendations when maintaining a boiler.

1. Briefly open the boiler drain cocks one at a time, to remove impurities. It may be necessary to drain several gallons of water until all traces of sediment are gone. Then, blow sediment and debris from the base of the low water cut-off float assembly.
2. Test all safety limit controls, so that repairs can be made to defective controls during the off-season.
3. Shut down the boiler following manufacturer instructions. Turn off and lock out all power supplies to the boiler and its components.
4. Close and lock out all fuel valves.
5. Boilers with atmospheric burners should have their burner tubes covered to protect them from dust.
6. If soot and ashes are left in the boiler while it is idle, then boiler surfaces, ductwork, and breeching will rapidly corrode. Using a wire brush and a vacuum cleaner, clean all carbon, dust, and debris from the boiler fireside heating surfaces to protect the boiler from the corrosive action of combustion deposits. Follow the manufacturer's instructions for accessing the fireside flue gas passages. Clean the vent connector all the way to the chimney base tee.
7. Apply a light coating of oil to the fireside surfaces. This protects the fireside from corrosion during extended non-operating periods.
8. Check ductwork, breeching, piping, and pipe fittings for cracks, corrosion, and signs of leakage. Replace all defective parts.
9. Do not drain hot water boilers and heating systems at the end of the heating season.
10. Examine and service all controls and fittings, such as high temperature cut-offs and temperature controllers.

Cast Iron Sectional Heating Boiler Annual Maintenance – Steam Service

Like steel steam boilers, cast iron steam boilers require regular care and maintenance. Steam boilers require more annual maintenance than those in hot water service.

To prepare a cast iron steam boiler for annual shutdown and maintenance, use the procedure for steel steam boiler maintenance. However, after re assembly, fill the boiler up to the base of the main steam outlet with treated water (**wet layup**). Then, before placing the boiler back in service, drain the water down to normal operating water level.

Cast iron steam boilers should only be left empty (**dry layup**) if the shutdown period is expected to be long term (beyond the next heating season), or if freezing conditions are expected while the boiler is not in use. In this case, fasten a large sign to the boiler to warn against firing until it has been filled with water and prepared for service. The firing circuit should remain disabled and locked out as an added precaution.

Power Boiler Annual Maintenance

Both watertube and firetube power boilers are constructed of steel, and primarily used in high-pressure steam service. Hot water power boilers should be taken out of service and maintained like hot water heating boilers.

The following are general maintenance procedures. Always refer to a boiler manufacturer's specific instructions.

1. While the boiler is in operation and under pressure, open the bottom blowoff connections one at a time, and blow sediment from the base of the boiler. Then, blow sediment and debris from the base of the water column, feeder control, gauge glass, and low water cut-off float assembly. Refill the boiler to the proper water level.
2. While the boiler is under pressure, operate the safety valve try-lever to ensure the safety valve is free to operate. Then, ensure the safety valve reseats firmly.

On Track

Do not open power boiler safety valves with the try-lever when the steam pressure is less than 75% of the set pressure of the safety valve. Adequate pressure under the valve seat will prevent safety valve damage.

3. Test all safety limit controls, so that repairs can be made to defective controls during the off-season.
4. Shut down the boiler following manufacturer instructions. Turn off and lock out all power supplies to the boiler and its components.
5. Close and lock out all fuel valves.
6. Boilers with atmospheric burners should have their burner tubes covered to protect them from dust.
7. Using a wire brush and a vacuum cleaner, clean all carbon, dust, and debris from the boiler fireside heating surfaces. Follow the manufacturer's instructions for accessing the fireside flue gas passages. Clean the vent connector all the way to the chimney base tee.
8. Apply a light coating of oil to the fireside surfaces. This protects the fireside from corrosion during extended non-operating periods.
9. To clean the boiler waterside, open the blowdown valve and drain the boiler after it cools. If the boiler is hot when drained, remaining sediment will bake on the metal surfaces, making it harder to remove.

10. After the boiler is drained, remove cleanout openings, washout plugs, handholes, and manholes.
11. Hose the inside of the boiler with high-pressure water to remove remaining sludge and sediment. If hard scale is baked on the internal surfaces, the boiler must be cleaned chemically. Consult with a reputable water treatment representative.
12. Open the low water cut-off, the feeder, and the water column float cages, and flush out remaining sediment. Remove all related inspection plugs. With a metal rod and brush, ensure steam and water connections to the boiler are clean and unobstructed. Examine the low water cutoff float and switches to ensure they are in good condition.
13. Check the gauge glass connections for obstructions, and clean out if necessary. Replace the gauge glass, gauge glass packing, and gauge glass washers.
14. Examine and service all controls and fittings, such as high-pressure cut-offs and pressure controls, if necessary. Clean the pressure control piping. It is advisable to replace pressure control pigtails on an annual basis, because they are susceptible to plugging.
15. Dry the boiler waterside thoroughly prior to inspection. This can be done with an air mover.
16. Check ductwork, breeching, piping, and pipe fittings for cracks, corrosion, and signs of leakage. Condensate return piping is particularly susceptible to corrosion. Replace all defective items.
17. Power boilers in steam service should be left in dry layup if out of service for long periods of time. If the boiler is to be on standby, it should be laid-up wet, after firing it long enough to ensure the layup chemicals are circulated throughout the boiler and dissolved gases are driven from the boiler water.

Objective 2

Identify the operational procedures for wet and dry boiler layups.

Laying Up Boilers

To place a boiler out of service for a considerable length of time, it must be protected against corrosion. Wet and dry layup methods are used to prevent waterside corrosion.

Dry Method

This procedure is preferable for boilers:

a) That will be out of service for extended periods of time.

b) In locations where freezing temperatures may be expected during the time the boiler is not in use.

Use the following procedure for the dry method of storage:

1. After the boiler is shut down, drained and safely locked out, clean the water and firesides thoroughly.
2. Inspect the boiler and make the necessary repairs.
3. Dry the boiler out completely. Then, place trays with moisture absorbing materials (slaked lime, silica gel, or activated alumina) in the shell.
4. Close the manhole and handhole doors. Install blank flanges or blinds in all boiler connections to ensure no moisture from steam lines or feed lines will be able to enter the boiler.
5. Coat the fireside of heating surfaces (furnace and tubes) with mineral oil using a rag swab.
6. Close all dampers and keep the furnace as dry as possible.
7. Leave the boiler and surroundings clean and tidy.
8. Inspect and renew the moisture absorbing material at regular intervals.

Wet Method

Use the wet layup method to place a boiler in a stand-by condition. Wet storage is particularly useful if:

a) The stand-by boiler is required for service at short notice.

b) It is impractical to employ a dry storage procedure.

Do not use the wet method for boilers that may be subjected to freezing temperatures.

To perform a wet layup:

1. Make sure the boiler is off-line. Then, cool it, drain it, and lock it out.
2. Clean the boiler fireside and waterside.
3. Fill the boiler to the top with deaerated water, conditioned chemically to minimize corrosion while in storage. Consult the manufacturer's manual, or ask a water treatment consultant for the correct chemical concentrations to use.

4. The boiler water pressure during the layup period must be kept greater than atmospheric pressure to prevent air from getting into the water. To do this, connect a head tank to the top vent of the boiler to maintain pressure.

5. Coat the heating surfaces on the fireside with mineral oil.

6. Check the boiler water at least monthly. Maintain the chemicals at the correct strength.

Capping Steam Boilers

Wet layup exposes boilers to a greater possibility of corrosion; especially if the boiler water is untreated and contains dissolved gases, such as oxygen and carbon dioxide. As an extra measure, it is advisable to "cap" boilers that are laid-up wet with inert gas or steam. The most common inert gas used is nitrogen.

Nitrogen Capping

A nitrogen cap uses nitrogen from compressed gas cylinders, regulated in pressure to a few kPa, and piped to the boiler steam space. The boiler fires are extinguished and its steam outlet is shut. After the boiler cools and drops in pressure to around 40 kPa, the nitrogen is turned on to the steam space. When the boiler pressure drops below the regulated nitrogen pressure, nitrogen automatically enters the steam space. Because nitrogen fills the steam space, the drum vent does not need to be opened to prevent a vacuum from forming in the drum.

When the boiler is drained for annual maintenance, the nitrogen is left on. Nitrogen continues to fill the waterside spaces as the boiler drains, preventing oxygen from reaching metal surfaces. Prior to opening the boiler for maintenance, the nitrogen is turned off and locked out. The boiler is then dried and THOROUGHLY ventilated with fresh air prior to any confined space entry.

When the boiler maintenance is complete, the re-assembled boiler is filled with deaerated and treated water, and fired to remove dissolved gases, and to circulate the water treatment chemicals. During this period, the boiler is fired until it develops several kPa steam pressure with the drum vent open. This allows dissolved gases to escape the steam drum. After the fires are extinguished, the drum vent is shut, and the nitrogen cap is restored. Now, the wet layup can be maintained for longer periods of time with less concern about waterside corrosion.

Steam Capping

Some boilers are placed on hot standby, and therefore need to be laid-up for short periods of time. For these boilers, steam is often the choice for capping. The steam pressure prevents oxygen from entering the steam space during wet layup.

Steam may be provided by a live steam header, or a small steam heating boiler. This steam pressurizes the steam space and heats the boiler water. In this way, the boiler can be brought back to normal operating pressure in a shorter period of time. Some boilers admit capping steam by first circulating it through a heat exchanger located in the mud drum. In this way, the mud drum receives heat, and water circulation is maintained during the layup period.

With steam-capped boilers, it is important to pay attention to the boiler water level, and to drain the boiler on occasion as condensed steam accumulates in the drum.

Objective 3

Describe ways of detecting firetube and tubesheet leaks.

Detection of Cracks in Tube Ends and Tube Sheets

Cracks in tube ends and tube sheets weaken boiler structures, and create hazardous operating conditions. Tube sheet cracks and tube leaks should be repaired as soon as they are noticed.

In serious cases, cracks may become so large that boiler water escapes. The first indication of a larger crack is an increase in make-up water to the boiler. Water meters installed on the make-up system are helpful in this regard. Depending on the boiler and the power plant, it may be possible to hear steam hissing from the boiler when it cycles off. For large leaks, water may be noticed dripping on the floor by the boiler. For firetube boilers, larger leaks result in drips at the front and rear doors. These drips may only occur when the boiler cycles off.

Whenever there are signs of a tube leak during operation, shut down the boiler immediately. On a steam boiler, close the stop valve on the steam outlet. On a hot water boiler, close the stop valves in the supply and return lines. Maintain the normal water level in the boiler until it has cooled down. Then open the front and rear doors on the reversing chambers and check for the location of the leak.

Operators may find smaller leaks unnoticeable when the boiler is in operation. However, when the boiler is opened up for annual maintenance, the presence of a leak, and its source, can be seen as a white mineral deposit. This deposit results from leaking boiler water evaporating and leaving behind dissolved solids that were in the boiler water.

Usually, cracks develop over a long period of time, without any outwardly visible signs, such as leakage. Careful inspection of tube ends and tube sheets is required during boiler shutdown to detect cracks. In many cases, these cracks are very hard to detect with the naked eye and can be easily overlooked. Several methods have been developed to detect cracks, two of which are described. These techniques are covered in detail in the welding chapter.

Dye-Penetrant Method

The surfaces of tube ends and tube sheets must be thoroughly cleaned. A special penetrating dye is then applied by brushing or spraying. This penetrant works itself into the tiniest cracks. After a suitable period of time, excess penetrant is removed from the surfaces. Next, a thin coating of developer is sprayed on. Any penetrant trapped in cracks is brought to the surface by the wicking action of the developer. The crack shows as a red indication on the white developer background.

Portable spray-on dye-penetrant kits are widely used since they are easily applied, relatively inexpensive, and readily available.

Fluorescent Dye Penetrant

Black light is the common name for invisible light in the ultraviolet range of wavelengths. Black light is not directly visible, but it causes many materials to visibly fluoresce (glow), which makes them easier to see with the naked eye. Black light is used in combination with a fluorescent penetrant to detect tiny cracks, which are difficult to find with the unaided eye.

After the area to be checked is cleaned, penetrant is sprayed or brushed on, and allowed to penetrate into the cracks. The excess penetrant is removed and developer is applied. When the black light is aimed at the area, the penetrant in the cracks will fluoresce and make the cracks clearly visible.

Objective 4

Describe the general procedure for the removal and replacement of defective firetubes.

Defective Firetubes

Tube failure is not an unusual occurrence, considering the conditions under which boiler tubes operate: external pressure, buckling stress, tensile stress, corrosive and scale-forming waterborne constituents, and high temperatures. Tube failures occur for the following reasons:

1. Overheating of the tube caused by:
   a) Over firing
   b) Poor water circulation
   c) Heavy scale formation on the tubes due to poor water treatment
   d) Failure of the low water fuel cut-off, resulting in a low water condition

   Slight overheating may cause the tubes to droop mid-length. This can be detected during inspection by holding a light at one end of the tube and looking into the other end. If the tube is bent, the light will be partially obstructed, or may not even be visible. More severe overheating can cause the tubes to collapse completely, and will cause a serious pressure vessel explosion.
2. Corrosion weakens tube walls, causing leakage or total collapse. Corrosion may take place on the waterside due to lack of proper water treatment, and on the fireside due to the combination of corrosive combustion products and moisture.
3. Tube ends may crack due to uneven expansion, **thermal shock**, or **caustic embrittlement**.

Boiler Repairs

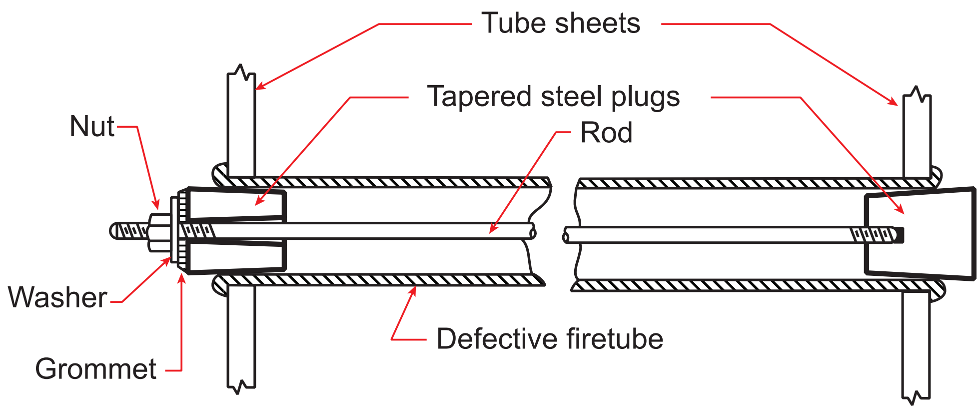
A **repair** is defined as the work necessary to restore a boiler or pressure vessel to a safe and satisfactory operating condition, provided there is no deviation from the original design. In other words, repairs must restore a boiler or its parts to the original design. Any repair that deviates from the original design is called an **alteration**. Both repairs and alterations are subject to the approval of the authority with jurisdiction.

Plugging a Defective Firetube

If a tube wall is perforated or ruptured and leaking badly, the tube must be replaced. This means that the boiler must be out of service until the repair is complete. If, however, a boilermaker is not immediately available and the boiler is desperately needed, the tube can be temporarily plugged so that boiler operation can resume until the repair can be done.

An arrangement to temporarily plug a leaking firetube is shown in Figure 1.

Figure 1 – How to Plug a Firetube



To plug a firetube for temporary operation, two steel plugs are needed, each about 75 mm long with a 20 to 1 taper. The smaller diameter of the plugs should be less than the inside diameter of the tube. One plug should have a 25 mm deep hole in the small end with 16 mm internally threaded hole. The other plug should have a 19 mm hole through its centre. A 16 mm diameter steel rod will also be needed. It should be about 125 mm longer than the length of the firetubes. The rod should be threaded for about 25 mm at one end and 75 mm at the other.

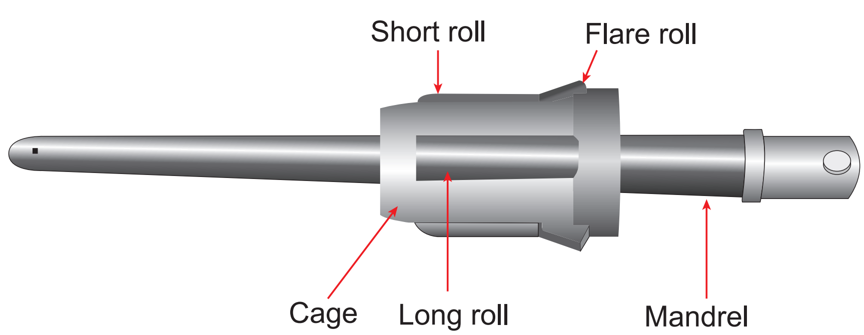
To install the plug:

1. First, clean the inside of the ends of the defective tube.
2. Then thread the plug with the threaded hole onto the short thread of the rod.
3. Insert the rod into the tube until the plug is seated firmly inside one tube end.
4. At the other end of the boiler, slip the second plug onto the rod, and drive it firmly into the other tube end.
5. Make a grommet of high-temperature rope, and slip it over the rod against the plug.
6. Place a washer against the grommet.
7. Put the nut on the rod and tighten it firmly. The plugs should now seal the tube ends watertight.

Repairing a Weeping Firetube

A firetube with minor leakage at its seat is said to **weep**. A weeping firetube can often be repaired by re-expanding the tube end, provided the tube end is not cracked. The tool used for this procedure is called a **three-roller expander** (Figure 2).

Figure 2 – Three-Roller Tube Expander



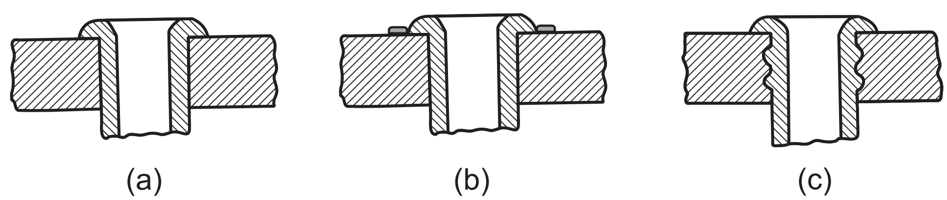
This tool is used to attach tubes to tube sheets in firetube boilers, and to drums of watertube boilers.

The expander consists of three rollers mounted in a cage, which fits inside the tube end. A tapered **tube expander mandrel** (or spindle) fits between the rollers. When the mandrel turns, the rollers rotate and apply outward force against the tube wall. This presses the tube wall against the tube sheet. With some types of expanders, a part of one roller is set at an angle in order to flare the tube end. This type of expander is shown in Figure 2.

In firetube boiler construction, the tube ends are expanded and flared. The flared portion is then **beaded** over against the tube sheet. This prevents the tube from overheating when the boiler is in service. Figure 3(a) shows an expanded and beaded firetube. Figure 3(b) shows a firetube which has been expanded, beaded, and seal-welded. Seal welding is done in addition to expanding if the tubes are subjected to bending loads or sudden temperature changes. Often, boiler manufacturers will seal weld the tube ends at the factory.

For very high-pressure service, both watertube and firetube boilers may have the tube ends expanded into grooved tube holes, as shown in Figure 3(c).

Figure 3 – Methods of Attaching Firetubes to Tube Sheets



The procedure for re-expanding tubes is as follows:

1. Clean out the inside of the tube ends where the rolls of the tube expander will touch. Clean the tube seat and the tubesheet around the tube hole.
2. Coat the tube expander with special paste-style lubricant, such as vegetable-based shortening.
3. Insert the tube expander with parallel rolls of the proper size into the tube, so the guides on the expander come up against the tube sheet squarely.
4. Insert the tapered mandrel and drive it in firmly.
5. Attach a handle to the mandrel and turn it until the mandrel loosens up. Then reset and repeat the procedure as required. Do not expand more than absolutely necessary. Over-expansion weakens the tube end.
6. If necessary, re-bead the tube end with a **beading tool**. Seal weld the tube end if required.
7. Apply a hydrostatic test to check the effectiveness of the repair.

Again, such repairs are best left to qualified tradespeople and certified repair agencies, after approval of the local boiler inspector.

Removal and Replacement of Defective Firetubes

If re-expanding the tubes does not stop them from leaking, they will need to be replaced. An experienced boilermaker should replace the tubes. Operators should be familiar with the methods used for the most common repairs, to ensure the tradespeople do the work correctly.

When it becomes necessary to replace one or more defective tubes, the boiler should be taken out of service, cooled, drained, and opened up. Repairs affecting the pressure part of a boiler may only be made after consultation with and the approval of an authorized inspector. All Canadian jurisdictions require prior approval for boiler pressure vessel repairs. This may involve the submission and approval of a jurisdictional "Repair and Alteration" approval form, which details the procedure for the repair. After the local inspector has been consulted and the repair procedure is approved, the repair can begin.

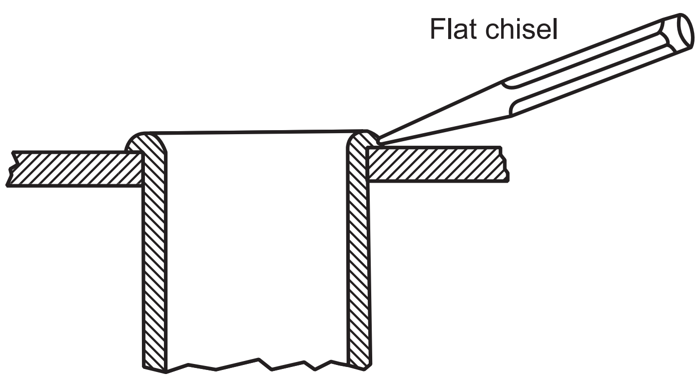
On Track

Some jurisdictions only permit agencies with approved Quality Assurance programs to replace boiler tubes. Other jurisdictions require repair shops to be ASME certified. **DO NOT** attempt a repair to a boiler's pressure parts without the necessary training, certification, experience, specialized tools, and jurisdictional approval.

The following is a common tube replacement procedure. Power chisels, angle grinders, and cutting torches are often used, depending on the experience and qualifications of the person doing the repairs, and jurisdictional approval.

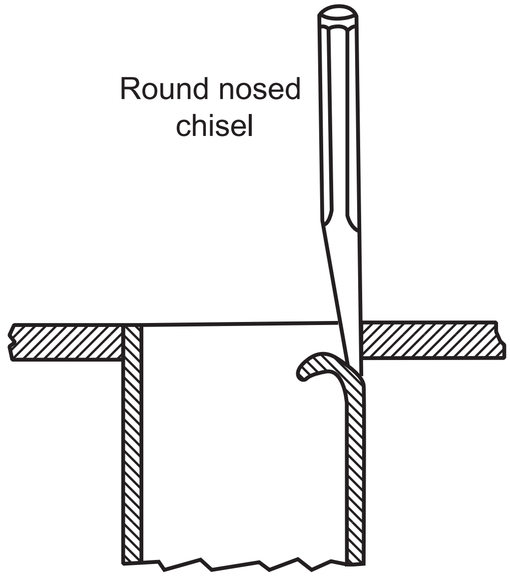
1. Cut off the bead at each end of the tube by using a flat chisel (Figure 4), or grind the bead off. In either case, take care not to damage the tube sheets.

Figure 4 – Removing Tube Bead



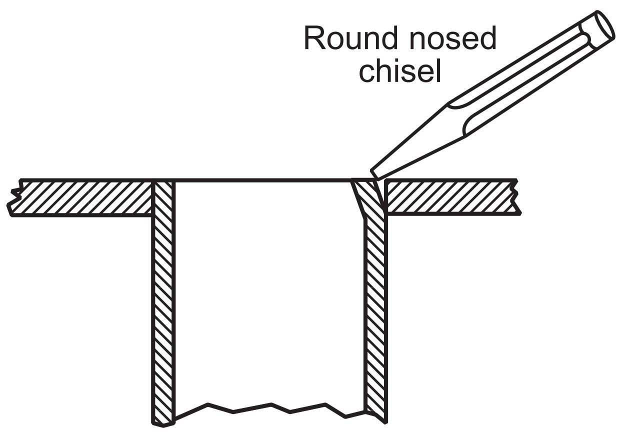
2. Cut two grooves in each tube end, on opposite sides, with a round nosed chisel. The grooves should be about 4 cm long (Figure 5). Take care not to damage the tube seating surfaces.

Figure 5 – Cutting Slot in Tube End



3. Break away the ends of the tube from the tube seats, and close in or collapse the ends (Figure 6).

Figure 6 – Collapsing Tube End



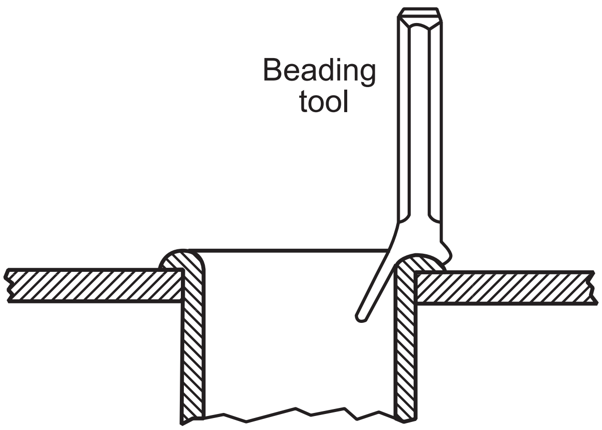
4. Remove the tube from the boiler.
5. Check the holes in the tube sheets for roundness, smoothness, and cuts. Clean off any roughness with emery cloth.
6. Check the length of the replacement tube. It should extend through each tube sheet, a distance equal to twice the tube wall thickness, to provide sufficient material to form beads on each end.
7. To prevent cracking during expansion, anneal the tube ends to soften them. Heat the tube ends to a blood-red colour. Then, allow them to cool slowly by covering them with sand or lime to keep the air away.
8. Thoroughly clean the outside of the tube ends, and polish them with an emery cloth.
9. Slide the tube into the holes in the tube sheets.

10. Expand the tube ends. If a **flare-type expander** is used, the ends will be flared at the same time. If a straight expander is used, the ends can be flared with a ball peen hammer.
11. Bead the tube ends with a beading tool (Figure 7). A power impact hammer may be used to drive the beading tool. If required, seal weld the tube end.

On Track

It is unlawful to have any welder other than the holder of a Pressure Welder's Certificate and a valid Performance Qualification Card to do any welding on any pressure part of the boiler. This includes seal welds of boiler tubes.

Figure 7 – Forming the Bead



12. Lightly expand the tube ends again, since the beading process may have loosened them.
13. Fill the boiler completely with water, and apply a hydrostatic test to check the tightness of the tube ends.

Chapter Summary

This chapter covered the regular maintenance of packaged firetube boilers and cast iron boilers. Scheduled maintenance activities, including daily checks and pre-shutdown checks, were discussed. Many of these activities involved preparing a boiler for annual inspection. This included:

- Fireside cleaning
- Waterside cleaning
- Refractory maintenance
- Removal of various inspection openings
- Examination of controls and limits

Dry and wet layup procedures were also covered. Here, correct storage methods were discussed, so that boilers do not sustain damage from corrosion or freezing during dormant periods.

Leaks that were undetected during operating periods may become evident during shutdown. This chapter discussed ways of performing temporary and permanent repairs to leaking firetubes.

A common thread throughout the chapter is the need for the Power Engineer to interact regularly with the local boiler inspector. This interaction ensures the boiler is properly prepared in a timely manner for inspection; the repair work is identified; and all repairs are performed in accordance with applicable codes.

CHAPTER 4

Boiler Cleaning

LEARNING OUTCOME

When you complete this chapter you should be able to:

Discuss the procedure for preparing a boiler for inspection and cleaning, and describe mechanical and chemical boiler cleaning methods.

LEARNING OBJECTIVES

Here is what you should be able to do when you complete each objective:

1. *List the steps and precautions to prepare a boiler for inspection.*
2. *Describe the internal inspection of a boiler.*
3. *Describe the methods and tools used to mechanically clean boilers.*
4. *Describe two methods used to chemically clean boilers.*

Chapter Introduction

Boiler inspections are required at regular intervals to ensure ongoing safe and efficient boiler operation. Insurance regulations and local laws require periodic inspection of boilers by authorized inspectors. In addition, operating staff should conduct their own inspections at more frequent intervals.

The **National Board of Boiler and Pressure Vessel Inspectors** classifies boiler inspections into two categories: external and internal.

The external inspection is conducted while the boiler is in service. This type of inspection consists of a visual examination of the boiler, its fittings, and its auxiliaries. Some of the items checked include the functioning of limits and controls, misalignment, settling, and clearance for expansion. One of the main purposes of the inspection is to observe operation and maintenance practices.

The internal inspection consists of a thorough examination of both the waterside and the fireside of the boiler. This type of inspection requires the boiler to be shutdown, cooled, and drained. As well, manholes and handholes must be opened.

ASME Boiler and Pressure Vessel Code Sections VI and VII explain how to prepare boilers for inspection. The **National Board Inspection Code** is the guide used by boiler inspectors.

Objective 1

List the steps and precautions to prepare a boiler for inspection.

Boiler Inspection Preparation

External Inspection

The external boiler inspection determines whether a boiler can operate safely. It involves both external observation and operational checks. External inspection of a boiler does not require any preparation, other than having the boiler in operation prior to the inspection, and providing access to the inspector. Typical **Boiler and Pressure Vessel Acts** require boiler operators to provide reasonable assistance to the inspector, and to fully disclose any known boiler defects. The local authority with jurisdiction should always be consulted for any special preparation requirements and for inspection scheduling.

During an external inspection of a steam boiler, the inspector may check for:

a) Leaks

b) Hot spots

c) Safety valve operation, set point, and capacity

d) Proper burner operation, including:
   - Air damper operation
   - Flame pattern and colour
   - Firing rate control valve function and condition
   - Safety shut-off valve operation and condition
   - Air flow proving switch response
   - Flame safeguard operation, including proper flame failure response

e) Set point accuracy of limit controls, such as pressuretrol, high pressure cut-off, and fuel pressure limits

f) Water level control accuracy and low water cut-off function

g) Pressure gauge accuracy

h) Venting effectiveness and chimney/breaching condition

i) Correct pressure rating of replacement fittings

j) Flue gas temperature

k) Housekeeping, general maintenance, and condition

l) Up-to-date log book entries

Preparation for Internal Inspection

An internal inspection involves a detailed examination of the fireside and waterside of a boiler. The first step is to remove the boiler from operation. The boiler then requires extensive preparation before the internal inspection can begin.

Before the inspection, follow the steps and safety precautions listed below. Figure 1 shows a typical valve lineup prior to an internal inspection.

1. Operate all soot blowers (if applicable) to clean the fireside surfaces as much as possible. Be sure the boiler load is above 50% load when operating the soot blowers.
2. Increase the frequency of bottom blowoffs, water column blowdowns, and low water cut-off blowdowns to remove as much sludge and sediment from the boiler prior to taking it off line. This will make cleaning easier when the boiler is opened.
3. Reduce the load on the boiler. When the firing rate is at minimum, put the controls in manual. If the boiler is coal fired, make sure the pulverizers run until they are empty.
4. When the burner is shut down, allow the boiler to cool until the pressure is 175 kPa, and then open the drum vents.
5. If the boiler is coal fired, operate the bottom ash system as the boiler is cooling down, to get rid of as much bottom ash as possible.
6. Shut down, isolate, and lock out the chemical feed pumps and the boiler feed pumps.
7. Isolate the boiler by closing and locking out the:
    a) Steam header block valves
    b) Non-return valve
    c) Feedwater block valves
    d) Chemical feed lines
    e) Continuous and surface blowdown lines
    f) Fuel block valves
8. Lock open the non-return valve drain.
9. Close the air dampers for all fans.
10. Block in and lockout the steam supply to the:
    a) Soot blowers
    b) Atomizers
    c) Feedwater pump turbines (if applicable)
    d) Draft fan turbines (if applicable)
11. Open the circuit breakers for the:
    a) Feed pump motors
    b) Fan motors
    c) Chemical feed pump motors
    d) Retractable soot blower motors
    e) Rotary air heater drives
    f) Coal pulverizers
    g) Coal feeders

12. Tag all block valves that have been locked closed or locked open with a brightly colored "DO NOT OPERATE" tag. Make a list of all the valves and circuit breakers tagged in this manner. This will make it easier to account for all these tags when they are removed in preparation for starting up the boiler again.

CAUTION

Preparation of a boiler for internal inspection involves lockout and tagout. All personnel within the power plant should be trained in lockout/tagout practices. Follow all site-specific and jurisdictional lockout and tagout procedures.

13. When the boiler water has cooled to about 90°C, open the blowdown valves, and drain the boiler.

On Track

Allow the boiler and furnace to cool sufficiently before draining. This will prevent damage to the boiler, and prevent internal deposits from baking onto the heating surface. However, the boiler should be drained while there is sufficient heat remaining to dry out the interior of the boiler when ventilated through open manholes and handholes. Therefore, 90°C is a suitable temperature for draining a boiler.

14. Open the boiler drums by removing the steam drum manhole covers first, and then the lower drum manhole covers. It is important to open the manholes in this order. This will prevent steam burns caused by the circulating effect, which forces the steam out of the steam drum manway if the top cover is removed last.
15. With the blowoff valves open, flush out the boiler with a high-pressure water hose. The flushing should start at the top, so that all the sludge and sediment can flush out through the blowoff valves. It may be necessary to disconnect the blowoff valves to prevent large pieces of scale from becoming stuck.

CAUTION

If the boiler is connected to a common blowoff header, make sure no steam or hot water can enter the boiler when other boilers are blown off. Otherwise, workers inside or near the mud drum can receive serious and life-threatening burns.

16. When the boiler has been drained, lock the blowoff valves closed and tag them.
17. Open the fireside access door.

CAUTION

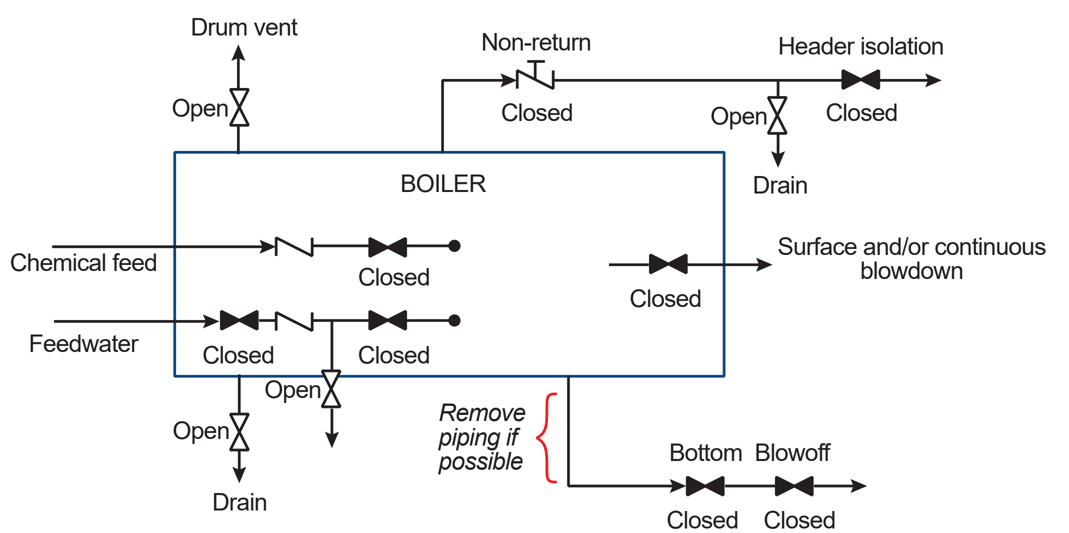
Boiler watersides and firesides are confined spaces. A confined space entry permit must be obtained before work can proceed. All work performed must follow confined space entry procedures.

Before entering, the boiler must be thoroughly ventilated, and the atmosphere tested. There must be a safety watch at the boiler entrance whenever someone is inside the boiler. All workers inside the confined space and the safety watch personnel must be trained in confined space entry and confined space rescue. All appropriate PPE must be worn. This includes protective clothing, protective eyewear, and gloves.

Use portable lamps of 12 V or less, with current supplied from transformers or batteries. This will eliminate the danger of electrocution to workers inside the boiler. Extension cords must be grounded and equipped with ground fault circuit interrupters. Lighting must be properly guarded with waterproof fittings, and explosion-proof light bulbs. Flashlights are usually better for illuminating surface irregularities during internal inspections of boilers and vessels.

18. Clean the fireside surfaces of the boiler of fly ash, clinkers, and soot. Usually, the waterside is not cleaned of scale until the inspector has examined it.

Figure 1 – Typical Valve Lineup Prior to Inspection



Objective 2

Describe the internal inspection of a boiler.

Internal Inspection

An internal inspection consists of a waterside inspection and a fireside inspection.

Waterside Inspection

Once the boiler has been shut down, isolated, and locked out, the inspection can begin. The waterside inspection includes the boiler drums, drum internals, the visible parts of the tubes, tube connections, waterwalls, superheaters, economizer, and fittings.

After pressure parts have been examined for deposits and scale, they may be cleaned internally using either mechanical or chemical methods. This provides a clean metal surface for further inspection.

If a detailed inspection report is required, such as when a boiler is offered for sale, or if it is to be chemically cleaned, use a reputable chemical company to inspect and analyze waterside deposits. The chemical company will measure the deposit thickness, and remove a piece of deposit for lab analysis. The analysis of the deposit is as important as the thickness, because a dense deposit like iron oxide may hinder heat transfer much more than a less dense calcium deposit.

When examining the waterside surfaces, the inspector will be looking for signs of corrosion, pitting, and cracking of the metal. Stays must be checked for looseness and cracking at the fastened ends. Particular attention is paid to manhole and handhole openings and drum connections, such as safety valves and steam outlet connections. All drum welds are examined closely.

To allow inspection for scale or other deposits, the plugs in the water column, feeder, and low water cut-off connection piping connections must be removed. Pressure control lines are also opened to permit inspection. Pigtails, if used, should be available for inspection, or replaced with new ones.

After the waterside inspection has been completed, the inspector may wish to close up the boiler and carry out a hydrostatic test.

Fireside Inspection

When inspecting the fireside of a boiler, the inspector may require the removal of sections of refractory or insulation, in order to facilitate inspection of tube or drum surfaces. Refractory and insulation is normally removed only on the inspector's request.

The fireside surfaces are examined for bulges and blisters, which indicate overheating. Ends of firetubes are checked for signs of leakage, and the tubesheet ligaments for cracking. Tubes adjacent to soot blowers are examined for signs of erosion due to direct steam impingement. Refractory and brickwork of the burners, baffles, and furnace walls are checked for deterioration.

During the inspection, it is the duty of the Power Engineer to assist the inspector, and point out any defects known to exist in the associated plant equipment.

Hydrostatic Test

A **hydrostatic test** enables an inspector to check the tightness of the pressurized parts of a boiler. The test also helps to find small leaks, such as hairline cracks and weeping tube seats, which cannot be easily discovered when the boiler is depressurized. Detailed requirements for hydrostatic tests are described in:

- **The ASME Boiler and Pressure Vessel Code, Section VII, Recommended Rules for the Care of Power Boilers**
- **The ASME Boiler and Pressure Vessel Code, Section VI, Recommended Rules for the Care of Heating Boilers**
- **The National Board Inspection Code**

The procedures for heating boilers and power boilers are somewhat different. The following procedure covers a hydrostatic test for a power boiler.

Power Boiler Procedure

1. Close the manholes and handholes. Ensure that no debris or tools have been left in the drums.
2. Close all valves, except the vent valve and feedwater supply valve. Gauge glass connections must be closed during the test.
3. Remove the safety valve, and blank off the flange or bushing. Alternatively, put a clamp on the valve to hold it closed during the test.
4. Remove or block off any control that cannot withstand hydrostatic test pressure. These may include pressuretrols, high pressure cut-offs, water feeders and alarms, and low water cut-offs.
5. Fill the boiler with water between 20°C and 50°C. Water colder than 20°C will make the boiler susceptible to brittle fracture. Water hotter than 50°C will create burn hazards.
6. Make sure all air is vented from the highest points of the boiler as it is being filled. When water starts to flow out of the vent valve, close the valve.

CAUTION

All air must be vented from the boiler. If air remains inside during the hydrostatic test, it will be compressed. If the vessel is weak, this compressed air may cause a dangerous vessel failure.

7. Pressurize the boiler slowly, by means of a pump, to 1 ½ times the **maximum allowable working pressure (MAWP)** stamped on the boiler. Hold the pressure at this point, with the pump shut off, and all valves closed. This pressure must be held for as long as it takes the inspector to complete the inspection. The inspector may request the pressure to be reduced to the MAWP during the inspection.
8. Visually inspect all accessible pressurized parts for signs of leakage. Also, observe the pressure gauge for any drop in pressure that would indicate a leak. Mark locations of any leaks, if found.
9. After the test, crack open a drain and allow the pressure to slowly bleed off. Do not release the pressure rapidly.
10. When the pressure reaches zero, close all drains unless intending to drain the boiler further. If so, be sure to open the drum vent.

Objective 3

Describe the methods and tools used to mechanically clean boilers.

Boiler Cleaning

The frequency of waterside cleaning depends on the:

- Operating schedule
- Operating conditions
- Feedwater quality
- Water treatment control

The removal of deposits from boiler surfaces by mechanical means involves the use of hand tools or power driven tools. Hand tools consist of such items as scrapers, brooms, wire brushes, steam, water, or air lances. Power tools consist of those that either cut or knock the deposit from the surfaces.

In a watertube boiler, the scale forms on the inside surfaces of the tubes. Various types of tools can remove this scale, including rotary wire brushes, cutters, and drill heads. Small water-driven motors, compressed air driven motors, or electric motors may power these mechanical cleaning tools. After being attached to drive motors, these tools are manually guided through the water tubes.

If a cutter head is used, a stream of water is directed into the tube to provide cooling for the cutter heads, and to wash the scale out.

After mechanical cleaning is complete, the tubes are flushed with high-pressure water to remove the loose scale from the tube walls.

Mechanical waterside cleaning methods are used mostly on smaller watertube boilers. Larger watertube boilers are more complex in design, making headers and other areas inaccessible. Long, bent tubes are difficult or impossible to clean mechanically. Removing drum internals is time consuming. In terms of time and labour hours, mechanical cleaning of large boilers is often very expensive, and does not always ensure clean surfaces.

Figures 2, 3 and 4 show a variety of mechanical cleaning heads for watertube boilers.

Figure 2 – Wire Brush Cleaners (Air or Water Driven)

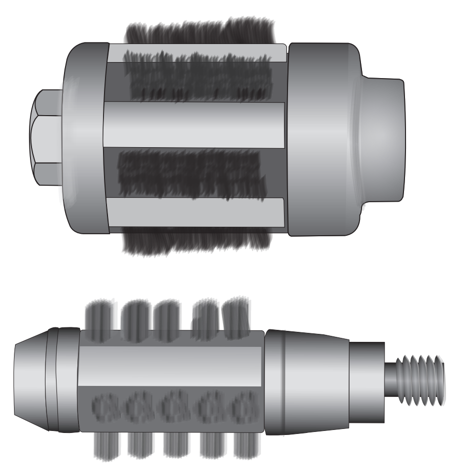


Figure 3 – Air-Driven Tube Cleaner

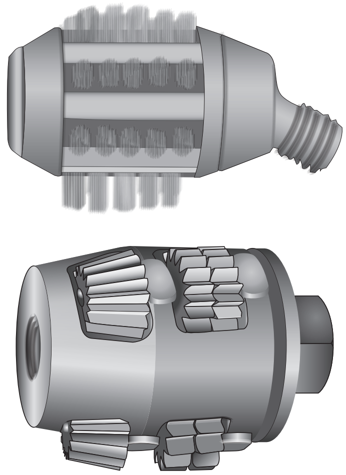
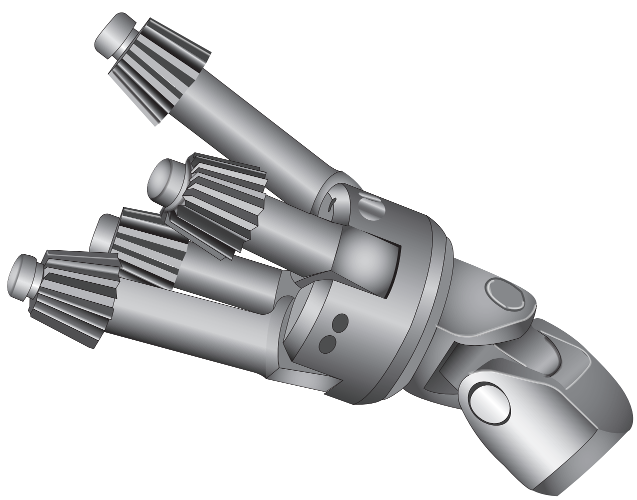


Figure 4 – Scale Cutting Head



There are no satisfactory methods to mechanically clean the scale from firetube boilers. These boilers are cleaned of excess scale buildup exclusively by chemical cleaning methods.

Objective 4

Describe two methods used to chemically clean boilers.

Chemical Cleaning Methods

The trend to clean large boilers is towards chemical cleaning. This normally demands the services of a chemical company or consultant. Also, complex piping and pumping systems must be erected. This expenses may not be warranted for cleaning smaller boilers.

A chemical solution may be used to dissolve scale deposits and remove them from the metal surfaces. Two such methods are discussed in general terms below.

Alkaline Boil Out

One method of chemical cleaning is the **alkaline boil out**. It removes oil, grease, or other contaminating materials from the waterside of new boilers after erection or installation. This method of cleaning is also used whenever oily substances have contaminated the boiler water during operation.

The chemicals used for the boil out are usually some combination of **caustic soda**, **soda ash**, **sodium phosphate**. In some cases, they may also include **sodium nitrite** and **sodium sulfite**. For this process, add chemicals to the boiler water. Then raise and maintain the steam pressure in the boiler for a period of time (usually about 48 hours). This will dissolve any deposits present on the drum and tube surfaces. Strong alkaline solutions attack **austenitic stainless steels**. Do not use strong alkaline cleaning solvents if a boiler has non-drainable superheaters made of austenitic stainless steel.

Inhibited Acid Cleaning

Another widely used method is inhibited acid cleaning, which uses an acid to dissolve the scale. An **inhibitor** is added to the acid to prevent or minimize the attack of the acid on the metal. Many different types of inhibitors may be used; starch, arsenic, and barium compounds are common.

When using an acid cleaning method, follow the proper technique. As well, make sure that safe work procedures are in place. It is advisable to perform the procedures under the direction of experienced personnel. This will ensure:

1. The right type of acid is used to remove the deposit. This means the deposit must be analyzed first.
2. Adequate piping systems are installed for the admission, temperature control, circulation, and removal of the acid.
3. The boiler is isolated from the steam header.
4. All parts of the boiler not being cleaned are isolated from the rest of the boiler. These areas can be isolated by using valves, blanking off connections, or filling parts (such as superheaters) with demineralized water.
5. Brass and bronze parts are removed or replaced with steel parts.
6. All valves that are exposed to the cleaning acid are made of steel.
7. All gauges and meters are isolated.
8. The spent solvent can be disposed of safely and in accordance with environmental regulations.

9. The boiler is adequately vented. Hydrogen is produced by the reaction of acid with iron, and this could cause a fire or explosion. In addition, poisonous gases, such as hydrogen sulfide (H_2S), can also be generated.
10. The boiler room is adequately ventilated.
11. Personnel handling the acids and inhibitors are supplied with proper safety clothing. This includes masks, goggles, rubber gloves, and aprons.

The most common acid used is a 5% solution of inhibited **hydrochloric acid**, since it removes scale very effectively. It is also less expensive than most other acids. However, it is corrosive and can cause damage if not used properly. Two general methods to acid clean boilers are the circulating and the soak methods.

In the circulating method, the acid solution is pumped continuously through the boiler at a temperature of about 65°C, until the cleaning action is completed as shown by tests.

In the soak method, the acid solution is pumped into the unit at a temperature of about 65°C. It is allowed to soak for a predetermined time, based on the type and thickness of scale in the boiler.

After acid cleaning, the boiler is drained, and then thoroughly flushed with clean, warm demineralized water. After flushing, to neutralize any remaining acid, the boiler is boiled out with an alkaline solution, such as soda ash. This step is followed by draining, flushing, and inspection. The acid cleaning is now complete.

Many other acids can also be used, if they are more effective for the specific task than hydrochloric acid. One of these is sulfamic acid, which is often used for small boilers and other plant equipment, such as condensers and compressor water jackets. Sulfamic acid is easier to handle, less corrosive than hydrochloric acid, and does not produce noxious fumes when dissolving. However, it is expensive and reacts much more slowly.

Chelating agents can effectively perform chemical cleaning while the boiler remains in operation. Compared to acids, chelating agents are less dangerous to use, but more expensive. Satisfactory on-line cleaning has been achieved over periods of 30 to 120 days by using an excess of **chelants**, over the amount normally required. This method of cleaning can only be used when chelants are part of the regular internal treatment program.

One advantage of chelants is that they can be used to remove existing scale from a boiler without removing the boiler from service. However, this practice is discouraged for heavily scaled boilers. If a carefully controlled amount of excess chelant is injected, the chemical will absorb calcium, magnesium, and iron from the existing scale. Great care must be taken to not remove scale too quickly; it can lead to sloughing and collecting of the sludge into locations that can restrict water circulation.

Extreme overfeeding of chelant can result in the loss of protective **magnetite** layers on the boiler metal. In more extreme cases, chelant overfeed can cause the boiler metal to corrode. This can occur if the free chelate in the water exceeds a mere 1 ppm.

In comparison to conventional phosphate treatment, chelants require closer control, due to the potential corrosion hazard. Complete oxygen removal is mandatory, because oxygen seriously hampers the effectiveness of chelation. Oxygen also causes pitting to become more prevalent. There must be ZERO OXYGEN in the boiler water when overfeeding chelant!

Chelant feed systems must be designed with non-corrosive materials (like stainless steel) for tanks, injection pumps, lines, and nozzles. Any yellow metal (copper, brass) will be eaten by the chelant!

Chelates are more costly and may be uneconomical if the feedwater hardness exceeds 2 ppm. However, chelants do remove metal ions, and have the ability to remove existing scale. The additional cost of chelants is usually more than offset by the considerable cost of boiler downtime and off-line cleaning.

Further information on boiler cleaning can be found in the **ASME Boiler and Pressure Vessel Code, Section VII, Recommended Rules for Care of Power Boilers.**

Chapter Summary

At regular intervals, jurisdictions formally inspect boilers to ensure their continuing safe and efficient operation. Power Engineers, however, are boiler inspectors whenever they are on shift.

This chapter covered internal and external inspections, and the steps necessary to prepare boilers for each inspection type. It is important to consider what a boiler inspector examines during the inspection. Power Engineers can be prepared for inspection by pre-examining boilers, and ensuring they are in tip-top shape before the inspector arrives.

This chapter provided guidance for preparing boilers for inspection, conducting inspections, and for cleaning boilers. With this information, and with further reference to the **ASME** and **NBBI** codes, Power Engineers can be effective boiler inspectors for the 364 days of the year that the jurisdictional inspector is not on-site.

UNIT SUMMARY

This concludes the unit on Boiler Maintenance. The following topics were introduced:

a) The safe and proper use of hand tools
b) The application of measurement and layout tools
c) Common types of power tools and how to use them
d) Working with ladders and scaffolds
e) Various methods of rigging and hoisting
f) The types of ropes, knots, and fasteners commonly used
g) Maintenance and service of firetube boilers, and
h) Methods to clean and inspect boilers.

Regular maintenance and service of a boiler is a key job for the Power Engineer.

Boiler inspection and maintenance preparation were presented, and applied information covered earlier on in the unit. Boiler lay-up procedures for both short and long-term storage were introduced. The tools most commonly used for servicing and inspecting boilers were discussed to provide a better understanding of how they are used.

It is necessary to have a basic understanding and familiarity of the equipment and tools needed for maintenance and service. This will help to avoid loss of production, injury to workers, and damage to equipment.

A self-assessment tool is available on MyPower LMS. Login using the unique user ID and password found on the inside front cover of Unit 1.

Notes

UNIT B-5

Knowledge Exercises and Unit Glossary

Chapter 1	Energy Plant Maintenance I	U5-9
Chapter 2	Energy Plant Maintenance II	U5-13
Chapter 3	Boiler Maintenance	U5-17
Chapter 4	Boiler Cleaning	U5-21
Unit B-5	Unit Glossary	U5-27

Knowledge Exercises – Chapter 1

Name: ______________________________ Date: ________________________________

Instructor: ___________________________ Course: ______________________________

Objective 1

1. How should a hacksaw blade be replaced? How should a hacksaw be stored?

____

____

2. A special wrench used to make a fastener a specific tightness is a _______________ wrench.

3. What should a worker do when they notice a tool is damaged?

____

____

4. The coarsest file type is the ______________________ file.

5. Identify six types of wrenches mentioned in the text.

   a) ____

   b) ____

   c) ____

   d) ____

   e) ____

   f) ____

Objective 2

6. A ___________________ tap is never used for starting threads.

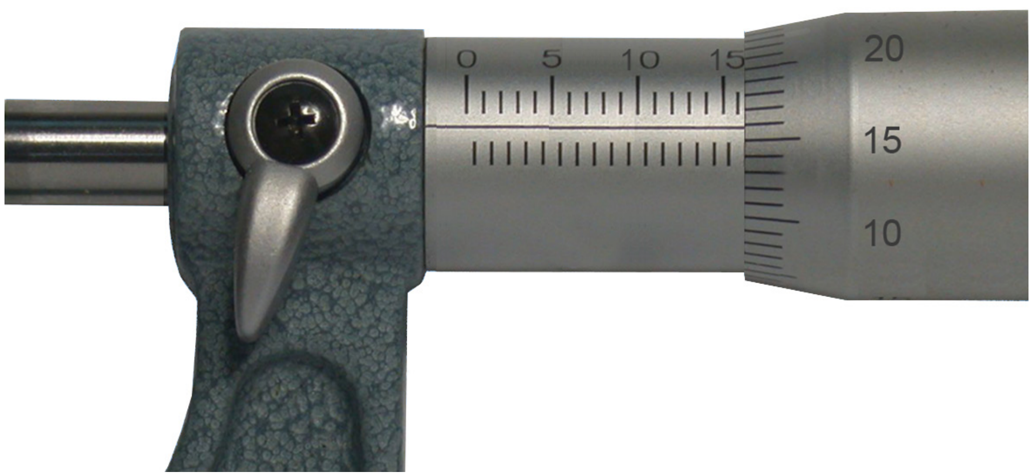
Chapter 1 (Cont.)

7. Describe the procedure for tapping holes by hand.

Objective 3

8. List the parts of a micrometer.

9. What is the reading of the following micrometer?



Objective 4

10. What methods are used to make layout lines highly visible?

Chapter 1 (Cont.)

Objective 5

11. When using grinders, how must workers protect themselves from:

a) Getting entangled in the grinding wheel

b) Particles thrown from normal grinding

c) Exploding grinding wheels

d) Fires

e) Burns

Knowledge Exercises – Chapter 2

Name: ______________________________ Date: ______________________________

Instructor: ___________________________ Course: ______________________________

Objective 1

1. List ten safety rules when using a step ladder.

2. A portable extension ladder is propped up against a 5.4 m high wall, in order to access a rooftop. The top of the ladder extends 60 cm above the top of the wall. The base of the ladder is located 90 cm away from the base of the wall. Explain why the ladder is unsafe as located, and what to do to correct the situation.

3. With respect to scaffolds, explain the purpose of the toe plate.

4. When do scaffolds require inspection?

5. What is the purpose of a yellow inspection tag on a scaffold?

6. Planks for scaffolds should have ___________ to prevent them from sliding off their supports.

Chapter 2 (Cont.)

Objective 2

7. Name three methods for determining the weight of an object before lifting it. Which of these is the best and most accurate?

Objective 3

8. A large air compressor is being hoisted onto a new base. Name five things the lift operator must know before hoisting the compressor into place.

9. Why should chain hoists only be used for vertical lifts?

Objective 4

10. Describe the make-up of a fiber rope. Why is it constructed this way?

11. Some synthetic fibre rope is cut to a desired length. What must be done to the ends of the rope to keep it from unravelling?

Chapter 2 (Cont.)

12. Why does some wire rope have a natural fibre rope core?

____

____

13. An eye made by using wire rope clips will have ________ percent of the strength of the rope.

14. The factor of safety used to determine the safe load for a new fibre rope is ___________.

15. The rope most susceptible to heat is one made of _______________________.

Objective 5

16. A bolt is marked "8.8". What is its minimum tensile strength, in MPa? What is its minimum yield strength, in MPa?

____

____

____

17. Describe the situation where a castle nut and a jam nut would be used.

____

____

Knowledge Exercises – Chapter 3

Name: ______________________ Date: ______________________

Instructor: ______________________ Course: ______________________

Objective 1

1. Describe the checks a Power Engineer should perform on a boiler on a daily basis.

a) ______________________

b) ______________________

c) ______________________

d) ______________________

e) ______________________

f) ______________________

g) ______________________

h) ______________________

i) ______________________

J) ______________________

2. List the checks a Power Engineer should do to a cast iron steam boiler, prior to taking the boiler out of service. Why are these checks done?

a) ______________________

b) ______________________

c) ______________________

____

Chapter 3 (Cont.)

3. Name four signs that a burner needs servicing.

a) ______

b) ______

c) ______

d) ______

4. What must be done to a burner to ensure it is operating with correct air to fuel ratio?

______

5. To assist the waterside cleaning of a steam boiler, it is helpful to increase the ______ while the boiler is still hot and under pressure.

Objective 2

6. List the steps for performing a dry layup.

a) ______

b) ______

c) ______

d) ______

e) ______

f) ______

g) ______

h) ______

7. When is a wet layup preferable to a dry layup?

______

______

Chapter 3 (Cont.)

8. When is a dry layup preferable to a wet layup?

Objective 3

9. List three ways a Power Engineer can detect leaks when a boiler is in operation.

a) ______

b) ______

c) ______

10. List three ways a Power Engineer can identify leaks when a boiler is opened up for annual maintenance.

a) ______

b) ______

c) ______

Objective 4

11. What may cause a firetube to "droop" along its length? How can drooping tubes be detected?

12. What causes waterside corrosion of boiler tubes?

13. What is a repair? What is an alteration?

14. The final step in replacing a firetube is a ____________________ test.

Chapter 3 (Cont.)

15. Who is permitted to weld on a boiler shell?

Knowledge Exercises – Chapter 4

Name: ______________________________ Date: ________________________________

Instructor: ___________________________ Course: ______________________________

Objective 1

1. List the valves that are locked shut when preparing for an internal inspection.

a) ____

b) ____

c) ____

d) ____

e) ____

f) ____

g) ____

2. List the valves that are locked open when preparing for an internal inspection.

a) ____

b) ____

c) ____

d) ____

Chapter 4 (Cont.)

3. Make a simple sketch of a boiler shell properly prepared for internal inspection. Show all valves leading to or from the boiler.

4. What is a suitable boiler water temperature when draining a boiler? Explain why.

____

____

____

5. Other than valve and power lockout/tagout, list five safety precautions to observe when a steam or mud drum must be entered for internal cleaning or inspection.

a) ______________________________

b) ______________________________

c) ______________________________

d) ______________________________

e) ______________________________

Chapter 4 (Cont.)

Objective 2

6. Name nine things an inspector will check during an internal inspection.

a) ______________________________

b) ______________________________

c) ______________________________

d) ______________________________

e) ______________________________

f) ______________________________

g) ______________________________

h) ______________________________

i) ______________________________

7. What is the danger of conducting a hydrostatic test with cold water? What is the danger if the water is too hot?

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____

____

8. A hydrostatic test is performed by filling a boiler with water, venting all the ____________ from the boiler, and slowly raising the water pressure to ____________ times the MAWP.

9. Name three codes that contain information on conducting a hydrostatic test.

a) ______________________________

b) ______________________________

c) ______________________________

Chapter 4 (Cont.)

10. Explain why a safety valve must be removed or gagged during a hydrostatic test.

11. Why are pressure limit controls and water level controls removed during a hydrostatic test?

Objective 3

12. Mechanical waterside cleaning methods are used mostly on______________________ ____________________________ boilers.

13. Firetube boiler waterside scale removal is best performed using a ___________________ cleaning method.

Objective 4

14. A boiler that is newly erected or newly installed requires a __________________ _____________, using alkaline chemicals.

15. What types of impurities do alkaline chemicals remove from boiler watersides?

16. When chemically cleaning boilers, ______________________________ must be added to the acid to prevent or minimize the attack of the acid on the boiler metal.

17. Why is ventilation important when acid cleaning a boiler?

Chapter 4 (Cont.)

18. How can scale be removed from waterside surfaces while a boiler is in operation?

19. What conditions cause chelants to aggressively attack boiler metal?

Unit B-5 Glossary

Term	Definition
Alkaline boil out	The use of high pH chemicals in a solution to remove oily and greasy products left on waterside surfaces of boilers during their construction.
Allen wrench	An L-shaped metal bar with a hexagonal head at each end; used to turn bolts and screws having hexagonal sockets.
Alteration	A change in the elements of a boiler or pressure vessel. This includes modifications, such as adding or removing tubes, relocation of nozzles, and changing the maximum allowable working pressure.
Austenitic stainless steels	Steel alloys high in nickel and chromium, used in some superheater and reheater construction, due to their high temperature creep and corrosion resistance.
Beading	Bending the ends of exposed firetubes to protect the ends from overheating.
Beading tool	A tool used for beading firetubes.
Bolt	A cylindrical threaded fastener with a hex or square head.
Bowline	A knot used to form a loop that neither slips nor jams.
Bridle	A piece of lifting equipment that allows a load to be spread or shared between two points.
Cap screw	A threaded fastener for machine parts, which has threads along its whole length.
Carriage bolt	A large bolt with a round head; used to attach wooden panels to masonry or to other wooden panels.
Castle nut	A nut with slots cut into one end, so it may be secured with a pin or wire.
Caustic embrittlement	The intercrystalline cracking of steel caused by the presence of free NaOH, stress, boiler water leakage, and concentration of NaOH.
Caustic soda	A very high pH (basic) compound, it has various uses in power plants. Also called sodium hydroxide.
Chelants	Chemicals designed to bind to positively charged soluble metal ions, most commonly calcium and magnesium. They reduce scale deposits or remove pre-existing scale.
Chelating agents	See *chelants*.
Clove hitch	A double hitch knot, by which a rope is secured by passing it twice round a spar or another rope that it crosses at right angles in such a way that both ends pass under the loop of rope at the front.
Crosby® clip	A wire rope clip used to clamp the loose end of a length of wire rope, once it has been looped back to form an eye. These fittings consist of a U-bolt and a saddle secured by two nuts.
Dacron	A synthetic polyester with tough, elastic properties, used as a textile fabric and also to manufacture synthetic rope.
Dowel	A metal peg used for aligning and securing components of a structure.
Dry layup	A method of long-term storage for a boiler, where the waterside is kept free of moisture to prevent corrosion.
Extension ladder	A portable rung ladder that can be expanded in length.
Eye bolt	A metal bolt with a loop at one end, to which ropes or cables may be attached.

Term	Definition
Factor of safety	A term used to describe how much stronger a load-bearing system is than it needs to be for a regular load.
Figure eight knot	A strong knot that forms a secure, non-slip loop at the end of a rope.
Fixed rung ladder	A non-portable, permanent rung ladder
Flame retarders	Devices used in some firetubes to slow the flow of flue gas, thereby increasing the heat transfer to the boiler water.
Flare-type expander	A tube expander with an angled roller at the end. The roller adds a flare to the end of the boiler tube.
Flat washer	A washer used to spread the pressure of a nut or bolt when tightened.
Half hitch	A simple knot tied by passing the end of a line around an object, across the main part of the line, and then through the resulting loop.
Hemp	A natural fibre used for making rope.
Hex key	An Allen wrench.
Hoist	Device used for raising or lowering heavy or bulky objects such as machines or equipment.
Hydrochloric acid	A clear, colourless, fuming, poisonous, highly acidic aqueous solution of hydrogen chloride, HCl. Weaker solutions may go by the name muriatic acid.
Hydrostatic test	A pressure test on a boiler or vessel to test for leaks or strength. The vessel is completely filled with water, and the pressure is raised to 1.5 times the maximum allowable working pressure.
Inhibitor	An organic fluid added to acid that inhibits the attack of acids on metal surfaces during cleaning or scale removal.
Jam nut	A low profile nut, forced against a standard nut, to lock the two in place.
Lock washer	A washer designed to prevent the loosening of a tightened nut.
Machine bolt	A threaded fastener used with a nut to connect metal parts with a square or hexagonal head to be tightened by a wrench.
Magnetite	An iron oxide that forms in an operating boiler. It makes boiler waterside surfaces corrosion resistant (passive).
Manila	A natural fibre used for making rope.
MAWP	See *maximum allowable working pressure (MAWP)*.
Maximum allowable working pressure (MAWP)	The maximum pressure a boiler, pressure vessel or pressure piping system can be safely operated at, according to its design.
Nut	A small flat piece of metal or other material, typically square or hexagonal, that has a threaded hole through it for screwing onto a bolt as a fastener.
Nylon	A strong tough elastic synthetic material that may be fashioned into fibers, filaments, bristles, or sheets and is used to manufacture synthetic rope.
Phillips head	A fastener or screwdriver with a cross patterned head.
Polyethylene	A common thermoplastic that is resistant to chemicals and moisture, and is used to manufacture synthetic rope.
Reef knot	A simple knot used to secure a rope or line around an object.
Repair	Repair a boiler or pressure vessel in accordance with its original design.
Rigging	Process of moving heavy objects like equipment and machines using ropes, cables, rollers, hoists, etc.

Term	Definition
Rivet	A short, unthreaded metal pin that holds multiple metal plates together.
Robertson head	A fastener or screwdriver with a square head.
Rope clip	A Crosby Clip.
Round turn and two half hitches	A hitch knot used to secure the end of a rope to a fixed object.
Rung ladder	A non-folding ladder equipped with rungs as stepping surfaces.
Saran	A type of polyvinyl chloride, used to manufacture synthetic rope.
Scaffold	A temporary structure that holds workers and materials for work, such as construction, repair or maintenance.
Seize	To use small strings to bind the fibres of the cut end of a rope.
Set screw	A screw that passes through a threaded hole in a part, it tightens the contact of that part with another part.
Sheet bend	A knot used to temporarily fasten one rope through the loop of another.
Shoulder eye bolt	An eye bolt with additional material located at the loop-end of the bolt for reinforcement.
Sling	A flexible strap or belt used in the form of a loop to support or raise a weight.
Soda ash	Also called sodium carbonate. A high pH compound with a variety of powerhouse uses, including cleaning and water softening.
Sodium nitrite	A chemical compound with oxygen-scavenging characteristics (anti-oxidant).
Sodium phosphate	A chemical compound often used as a cleaning agent.
Sodium sulfite	A chemical compound with oxygen-scavenging characteristics.
Step ladder	A short, portable folding ladder; has flat steps, and a small platform.
Stove bolt	A bolt with a round or flat slotted head and a square nut; resembles a machine screw but usually has coarser threads and is used to join metal parts.
Stud	A rod that is threaded on both ends or on its entire length; used to fasten together machine parts or pipe flanges.
Tensile strength	The maximum load a material can bear while in tension, in Pa.
Thermal shock	The rapid, stress-inducing differential expansion of a material exposed to sudden temperature change.
Thimble	A metal ring, concave on the outside, around which a loop of rope is spliced.
Three-roller expander	A tool used to expand the diameter of a tube, to affix and seal a tube against a tubesheet.
Timber hitch	A knot used to attach a single length of rope to a cylindrical object.
Toe plate	A scaffold board or length of wood turned on its edge and run along the boundary of a working platform to prevent tools and other objects from falling; also called a toe board.
Tube expander mandrel	A tapered rod that exerts expanding force when inserted into a three-roller expander.
Washer	A metal ring placed under a nut or the head of a bolt.
Weep	A slight leak.
Wet layup	A method of short-term storage for a boiler, where the waterside is kept filled with treated water to prevent corrosion.

Term	Definition
Whipping	The act of binding twine or cord around the end of a rope to prevent its natural tendency to fray.
Yield strength	The maximum load a material can bear while in tension without experiencing deformation, in Pa.