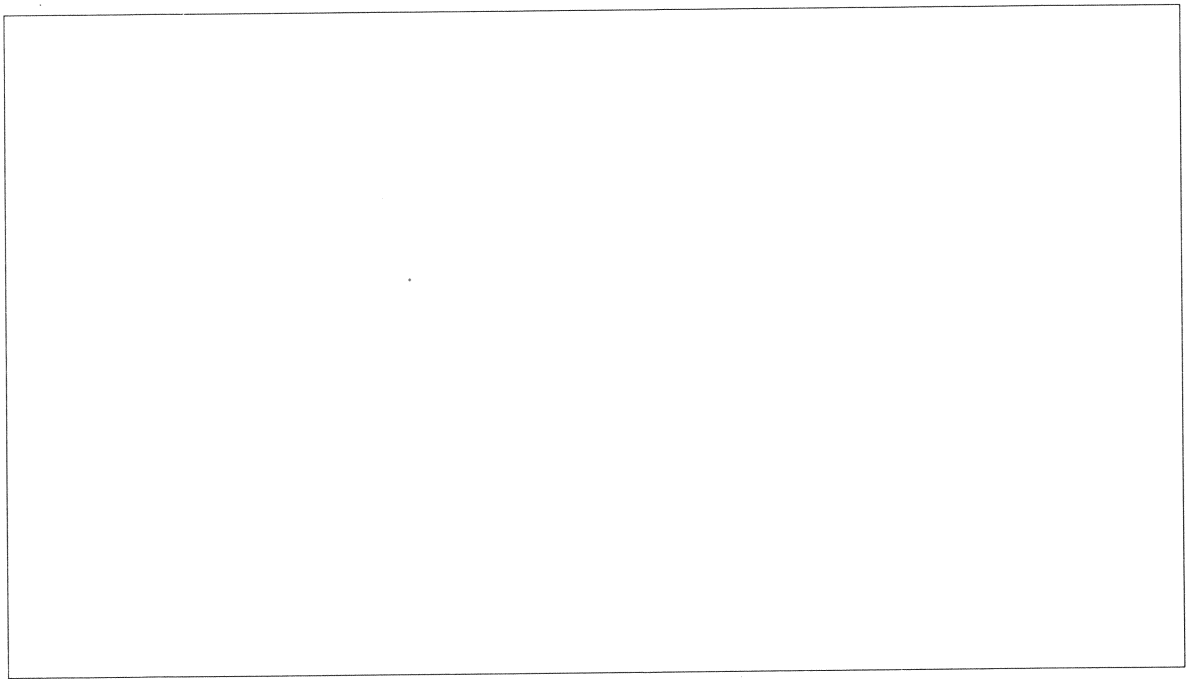
HEAVY MECHANICAL TRADES
FOUNDATION / LEVEL 1



Line A: Common Occupational Skills
Competencies A-1 to A-6

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Foreword

The Industry Training Authority (ITA) is pleased to release this major update of learning resources to support the delivery of British Columbia Heavy Mechanical Trades Program. It was made possible by the dedicated efforts of the Heavy Mechanical Articulation Committee of BC.

The Heavy Mechanical Articulation Committee of BC is a working group of heavy mechanical instructors from institution across the province and is one of the key stakeholder groups that supports and strengthen industry training in BC. It was the driving force behind the update of the Heavy Mechanical learning materials supplying the specialized expertise required to incorporate technological, procedural and industry-driven changes. The Heavy Mechanical Articulation Committee of BC plays an important role in the province's post secondary institutions as discipline specialists that share information and engage in discussion of curriculum matters, particularly those affecting student mobility.

ITA would like to acknowledge the Transportation Career Development Association of BC (TransCDA), which provides direction for improving industry training in the transportation sector and which led consultation on changes related to the BC Heavy Mechanical Trades Program learning materials (materials whose ownership and copyright are maintained by the Province of British Columbia through ITA).

Industry Training Authority
March 2013

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Line A: Common Occupational Skills

Competencies A-1 to A-6

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COMPETENCY A-1

Use Safe Work Practices

HEAVY MECHANICAL TRADES:
LINE A—COMMON OCCUPATIONAL SKILLS

Goals

Personal safety is very important. Your safety and the safety of others should be your first consideration. Before starting a job, many employers will require you to complete a risk assessment sheet recognizing hazards and ways to minimize risk. Most practices are common sense, but they are often forgotten or neglected. In the mechanical trades, there are many hazards such as chemicals, liquids, heavy machinery, acids, and flammable products. It's easy to take short cuts and neglect safety which can have terrible consequences. Many mechanics know someone who has hurt their back, eyes, limbs, or even lost their life. For your safety, and the safety of others, you must be aware of all safety issues, procedures, and required apparel.

Learning Task 1

Apply Personal Safety Precautions and Procedures

Workplace Safety

Accidents are often caused by carelessness. You must always be concerned with your own safety and the safety of others. Regular safety meetings and tool box safety talks should be a regular occurrence. Many shops have a safety committee to keep personal and shop safety current. The following is a general list of safety precautions you must observe in any work area:

- Understand the correct operating procedures and safety precautions before operating a piece of equipment.
- Make sure your clothing and personal protective equipment are appropriate, flame resistant, and functional.
- Watch for hazards and pay particular attention to moving objects such as equipment, dollies, or creepers.
- Develop good housekeeping habits such as cleaning the floor immediately after spilling oil or grease and sweeping the floor after completing a task.
- Immediately dispose of oily rags in an approved fireproof receptacle.
- Refrain from smoking in non-smoking areas as this will increase the risk of fire or explosion.
- Never work while under the influence of drugs, medications, or alcohol.
- Tag defective or unsafe equipment and report it to the appropriate person.
- Do not distract or interfere with the operator of a machine.
- Do not run in the shop.
- Do not work on a cluttered workbench.
- Avoid back strain by using hoists, cranes, and jacks.
- Never work under a heavy object that is supported only by a jack-stand. Always make sure that both jack-stands and blocks are properly placed.
- Make sure all jack-stands are approved and have tags indicating their rating.
- Do not work under a heavy object that is slung from a hoist.
- Be alert when moving about the shop.
- Do not engage in practical jokes or horse-play in the workplace.
- Do not use high-pressure air hoses to clean your clothes or body. The air can be forced under your skin or into your blood stream, which can cause death.

Notes

or ignorance - most dangerous hazard is the one you're not aware of.

* JHA

+ overhead cranes

- includes crane

- proper lifting techniques

- use appropriate slings

or hydraulics

+ or steam cleaner

• Use screens when grinding, welding, cutting

NOTES

Personal Apparel

You are required to have appropriate safety footwear and clothing before you're permitted to work. Many shops require steel-toed boots, safety glasses, and a high-visibility vest or coveralls to be worn at all times. You must be aware of the many important safety considerations for clothing, hair and beards, and jewelry that are common to all job sites.

Clothing

Close-fitting clothing must be worn if you're working near moving machinery. Clothing that is frayed or ragged is not allowed. Scarves, ties, hooded sweaters, cuffs, or gloves may become hazards. If a loose shirt cuff is caught in a machine, you risk having your arm injured or broken. Clothing may block your line-of-sight, resulting in an injury.

Figure 1. High Visibility Coveralls

Oily, greasy, and/or synthetic clothing (e.g., Rayon®, nylon, and polyester) may be hazardous when you're working near sparks or open flames. As well as being a fire hazard, oily or greasy clothes may cause skin irritation. Coveralls must be washed regularly to reduce oil and grease build-up.

Appropriate clothing should be used to protect your body as much as possible. On some jobs, special clothing is required. Leather clothing may be required when cutting or welding steel. Water-proof clothing is appropriate when power-washing heavy equipment. Short pants, short-sleeved shirts, and sandals are not acceptable on most job sites.

Do not tuck pant legs inside your boots when working with or near a torch or grinder. Hot pieces of metal may fall inside the boot resulting in injury. Some boots have covers to help deflect falling debris and prevent harm.

Hair and Beards

Caps or a hair net should be worn if you have long hair and beards should be trimmed. Either may be caught in machinery or catch fire from sparks or open flame. Beards may also prevent respirators from fitting properly which can result in the inhalation of hazardous materials.

Jewelry

Do not wear rings, metal watchbands, bracelets, or necklaces as these items can cause:

- an electrical burn if jewelry touches a live battery terminal and a ground at the same time
- a shock if you're working on live electrical equipment
- loss of a finger if your ring gets caught in a piece of machinery
- choking if your necklace gets caught in a piece of machinery

Personal Protection

When you're on the job site, you'll need to wear special personal protective equipment. The equipment you wear will depend on the hazards you expect to encounter.

Personal protective equipment can be divided into the following categories:

- head protection
- hand protection
- respiratory protection
- eye protection
- hearing protection
- foot protection

Head Protection

WorkSafeBC and some employers require that hard hats be worn in specific areas or when doing specific jobs. Typical hazards include:

- banging your head on sharp or hard objects
- being hit by falling objects
- receiving shocks when working near electrical apparatus

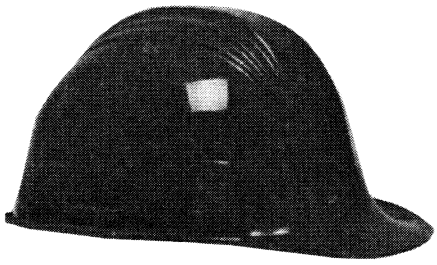

Figure 2. Typical Hard Hat

NOTES

may be color coded

NOTES

Hand Protection

Hand protection is often over-looked as a safety concern but this should not be the case as there is a wide variety of protective gloves. Today, many mechanics wear nitrile gloves to protect their hands from harmful solvents and contaminated oil. Continually exposing your skin to some products may cause serious health issues over time. Mechanics also wear leather welding and work gloves and even gloves that help absorb the repeated impact on your hands. When working around battery acid, you should wear acid-proof gloves. With high-voltage machines and trucks, you should wear rubber insulated gloves to protect against electrocution.

used with outer → gloves to preserve integrity
+ rated according to voltage –
some machinery can have up to 2000 V DC

Figure 3. Nitrile Gloves, Welding Gloves, and Mechanics Gloves

Gloves are manufactured from materials such as cotton, leather, rubber, metal, and other special synthetics and are tailored to meet every need for hand protection in every trade area.

- Leather or vinyl-coated gloves should be used when handling lumber or steel.
- Gauntlet-type welder's gloves should be used when welding or flame cutting.
- Special temperature-resistant gloves should be used when handling hot metal.
- Rubber or approved plastic-treated gloves should be used when handling acids and cleaning solutions.

NOTES

should be pliable enough to provide free movement of fingers

Respiratory Protection

After your brain and heart, your lungs are the most important organs in your body. It's important that you protect them and the rest of your respiratory system.

You may be exposed to airborne particles such as body filler, asbestos, clutch and brake dust, or to toxic gases and fumes. These are harmful if inhaled, so you must wear an approved respirator. Be sure to use the correct cartridge in your respirator for the hazard to which you are exposed. Efficient shop ventilation is also required to eliminate the buildup of harmful engine exhaust gases.

paint, solvent, caustic soaps (stem cleaner)

welding smoke + grinder dust

Figure 4. Respirators

NOTES

Eye Protection

Eye protection is one of the most important safety concerns of people on the job site. Eye hazards include:

- splashes from liquids, such as acids and caustics, aerosol cans - brake cleaner
- sparks flying from a grinder
- dust kicked up by compressed air
- "flash" from a welder

Wear specially designed and manufactured safety glasses (Figure 5) to protect your eyes when:

side shields

tinted lenses - yellow only

- working on live electrical equipment
- using cutting pliers to cut material
- soldering or de-soldering
- using an electric hand drill
- hammering
- working with tool steel

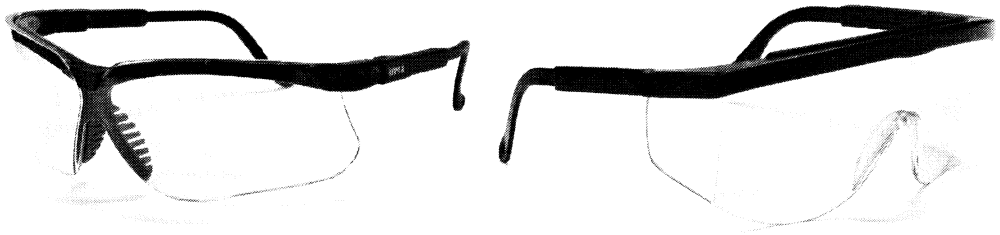

Figure 5. Safety Glasses

Wear safety goggles (Figure 6) to protect your eyes when:

- drilling or chipping
- hammering
- working with steel
- using a powder-actuated tool sandblaster
- solvent tank or aerosols

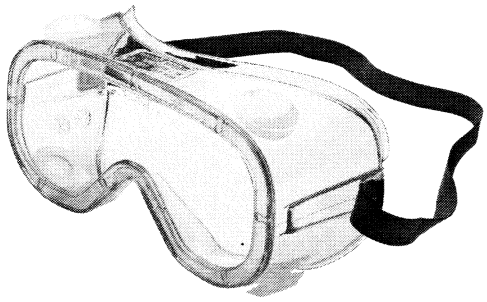

Figure 6. Safety Goggles

Wear a face shield (Figure 7) to protect your face when:

- using a grinder or wire wheel
- using a drill press
- using compressed air for cleaning
- steam cleaning

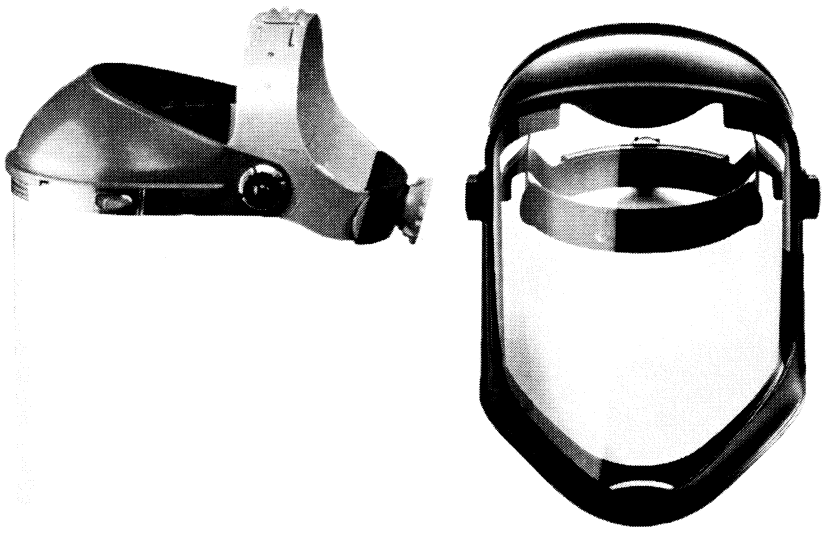

Figure 7. Full Face Shield

Prescription glasses, sunglasses, and contact lenses do not provide adequate eye protection.

Contact lenses may be worn in certain job situations, however, some jobs are too dangerous to allow them. Eyes have been severely damaged by sparks or molten metal striking the contact lens and fusing it to the eyeball.

Regardless of the job, whether grinding, chipping, drilling, or welding, use an appropriate, approved eye protection (i.e., Welding goggles or helmets are not acceptable when grinding).

Hearing Protection

WorkSafeBC requires that CSA-approved hearing protection be used at all times when the steady state noise level exceeds 85 decibels. Noise on the job site can affect you several ways. Moderate noise levels over a long period of time can cause a decrease in your ability to hear specific types of sound. High noise levels will impair your hearing. For example, the noise from diesel powered equipment can do permanent damage to your hearing. High noise levels can affect your mood, making you easily annoyed, irritable, and mentally fatigued as well as decreasing your ability to concentrate and stay alert.

NOTES

NOTES

must be comfortable

Consider the following points when choosing hearing protection:

- Select a type or style that will protect you in the job you are doing.
- Ear plugs should be pliable, fit each ear tightly and should be kept clean and free from damage.
- Ear muffs make it easier to hear certain signals in noisy environments.
- Headphones designed for music reproduction are not suitable for protection.

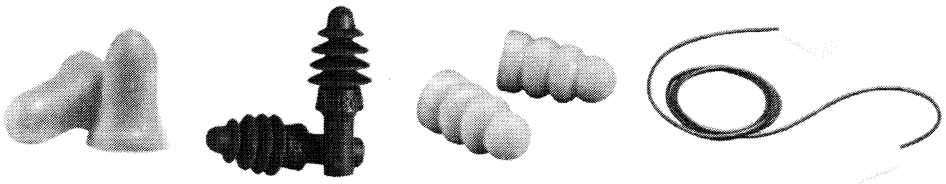

Figure 8. Rubberized Earplugs

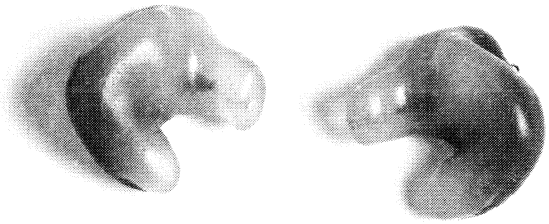

Figure 9. Custom Form-fit Silicone Rubber Earplugs

Figure 10. Earmuffs

Foot Protection

It's important to protect your feet just as you would your eyes, ears, or hands.

Hazards to your feet include:

- heavy falling objects
- sharp objects on the ground
- hot sparks or slag which may fall inside your boots

You must wear CSA-approved steel-toed safety boots which should be at least ankle height. Leather boots are required in a welding shop where sparks and molten slag present a hazard. In extreme cold conditions, steel-toed winter boots may be worn.

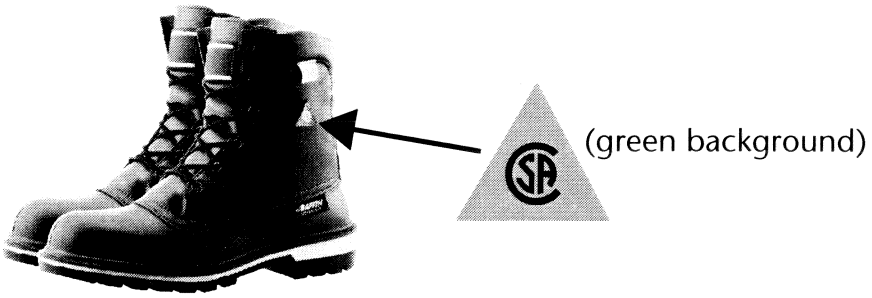

Figure 11. Leather Boots and CSA Label

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Learning Task 2

Lock Out Heavy Duty Equipment Prior to Service

Lockout Procedures

In areas where maintenance is being carried out on powered machinery, lockout procedures are essential to prevent the unexpected operation of a machine. Lockout must involve more than merely disconnecting the power source. Workers have been killed by machinery that is dead electrically but whose hydraulic systems were still functioning. The machines must be assessed thoroughly and all energy sources (including electrical, pneumatic, hydraulic, or gravitational) must be made inoperative, a state called "zero mechanical state."

Each maintenance worker must have their own lock and key (combination locks are not allowed) and only these locks should be used to lock out energy sources. The machine operator should be informed of maintenance plans and the lock should be tagged to identify who has locked out the machinery.

Only the maintenance worker who placed the lock and tag can remove it. Operators and other workers are strictly forbidden to remove either the tag or the lock.

These procedures apply to stationary industrial equipment and mobile equipment, including passenger cars, trucks, and heavy construction equipment.

Figure 1. Lockout Lock and Tag

When Is a Lockout Required?

Generally, a lockout is required any time a piece of equipment is shut down for maintenance or repair. The purpose of locking-out a machine is to prevent its inadvertent moving or starting while you are working on or around it. At times, you may need to work on a machine while it is operating. If so, do not install a lockout.

Installing a Lockout

Before you lock out the machine, it has to be de-energized. This means that any potential energy has to be removed or dissipated. The types of energy can be electrical, hydraulic, gravitational, or pneumatic. Once the energy is dissipated, then the lockout can be installed.

When installing a lockout, it must be positioned in a safe, visible location. It must be installed in a manner that will stop the machine from being operated or energized. The lockout tag must identify the person who installed it. The lock must be a key lock, not a combination lock. If there is shift change while the lockout is still attached, the lockout must be changed to a person on the next shift. A lockout may be installed on an isolation switch. The key may be removed from the ignition and a lockout tag attached to the key. The positioning of the lockout will depend on the type of machine and the type of work being performed. Before you start to work on a machine, you need to test the system to make sure it is de-energized. Once a lockout has been installed, only the worker who placed it is allowed to remove it.

Removing a Lockout

When the maintenance or repairs have been completed, the person who installed the lockout should remove it. If this person is not available, the service manager or supervisor must contact the person who installed it and ensure it is safe to remove. Once the lockout is removed, the machine is able to be operated as required.

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neutralize.

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Learning Task 3

Locate Shop Emergency Equipment and Procedures

Shop Emergency Equipment

You must be familiar with the following shop safety equipment:

- ventilation systems
- fire control systems
- eye wash/shower stations
- emergency exits
- meeting locations
- first aid facilities
- emergency shutdown systems (panic buttons)

Ventilation Systems

Workshops usually have some type of ventilation equipment for exhausting harmful dust or fumes. These may include:

- vacuum systems equipped with a hepa filter for the removal of brake dust
- shop exhaust systems for the removal of exhaust gases which must be used any time a gasoline, diesel, or alternate fuel engine is being operated
- ventilating equipment in body shops and spray painting booths to remove harmful dust and toxic paint fumes
- ventilation equipment used when workers are required to work in confined spaces, such as a large boiler or storage tank, especially during oxy-acetylene cutting or welding

Many other types of ventilation equipment may be found in the workplace. It's important to become familiar with the use of all ventilation equipment and systems.

Fire Control Systems

When you enter the workplace for the first time, note the location and type of fire-fighting equipment. The location of fire extinguishers should be clearly marked with signs or walls that are painted red. Access to fire extinguishers must not be blocked in any way.

NOTES

Figure 1. Fire Extinguisher Sign

Note any smoke detectors, heat detectors, and automatic sprinkler systems that are installed in your workplace as they are vital safety equipment. Find out how the system in your workplace operates and where the system components are located.

Eye Wash/Shower Stations

Employers are required to have eye wash/shower stations if worker's eyes or skin may be exposed to harmful or corrosive materials. The eye wash station may be fixed and plumbed with potable water. The eye wash station may be portable and have bottles of isotonic saline flushing solution. The work place may also have a shower station that you can stand under, much like a bathroom shower. This is important if you are covered in corrosive material. An eye wash station must be clearly marked with an identifying sign. Access to the eye wash station must be open at all times. It is important for your own personal safety to locate the eye wash station in your shop.

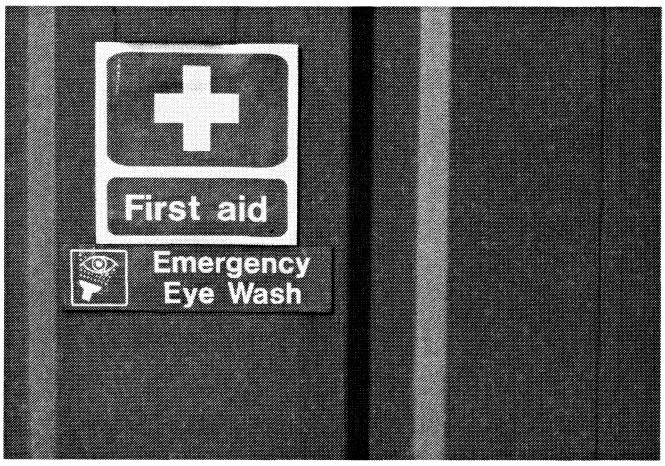

Figure 2. Eye Wash Station Sign

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Emergency Exits

There may be natural gas leaks, power outages, bomb threats, or earthquakes that require you to exit a building or shop. There must be an emergency exit in your work place that allows you to exit the building safely. The exit must be clearly marked and accessible at all times. The exit must not be through the overhead shop doors, but through the smaller entrance and exit doors provided in the shop. The over head shop doors may be powered by electricity and will not open with a power outage, so should not be used. There should be emergency lighting through the emergency exit in case of a power outage. An emergency exit drill should be done at least once year. It is your responsibility to be aware of all emergency exits and procedures.

Figure 3. Emergency Exit Sign

Meeting Locations

Every shop and building should have an emergency assembly or meeting location. Access to this assembly point should be clear at all times and is normally located away from the building and any explosive materials such as gasoline, diesel, propane, or natural gas. In an emergency, you should go directly to the assembly point. Once there, your employer will conduct a roll call to make sure everyone is out of the building. This should be practised at least once a year so that you're familiar with the procedure.

Figure 4. Emergency Assembly Sign

First Aid Facilities

Many industrial settings, and all British Columbia training institutions, are equipped with a first aid station staffed by a trained attendant. The person who staffs that station is able to perform a wide variety of services, from bandaging minor cuts to stopping major bleeding and splinting broken bones. The first aid attendant may be a full-time first aid person or be employed in another position as well as being the first aid person.

Find out where the first aid station is, who staffs it, and what services are available. If you sustain an injury, no matter how minor, ensure that the incident is reported and recorded in the first aid station log. Minor injuries can develop into major problems so to ensure proper coverage through WorkSafeBC, report all injuries promptly.

Figure 5. First Aid Sign

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Emergency Shutdown Systems

Many shops have emergency shutdown systems or "panic buttons." These systems are installed so that only one switch has to be thrown to kill power to multiple pieces of equipment. Emergency shutdown systems are used when a person is receiving an electric shock or is caught in a piece of machinery. Under these circumstances, you don't have time to find the "correct" switch.

When you enter a shop or an industrial setting for the first time, locate and learn how to use the emergency shutdown systems.

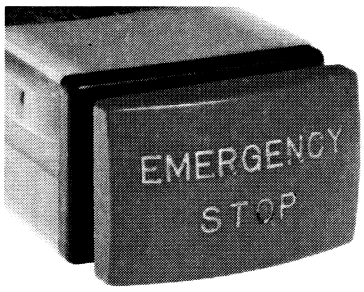


Figure 6. Emergency Shutdown Button

Learning Task 4

Describe the Conditions Necessary to Support a Fire

NOTES

Fire Triangle

It's important to understand what causes fires and what keeps them burning so that you'll have a better idea of how to extinguish them.

Before a fire can occur, three components must be present:

- fuel (a combustible material such as wood, gasoline, paper, or cloth)
- heat (sufficient to raise the fuel to its "ignition temperature")
- oxygen, usually in the form of air (to sustain combustion)

Figure 1. Fire Triangle

When they combine, as shown in the fire triangle diagram, the result is rapid combustion (fire). Keeping these three components separated will prevent a fire from occurring. It's important to realize that a fire can be extinguished by removing any one of the three components:

- Remove the fuel (combustible material) source from the vicinity of the fire. For example, if you shut off the valve of a gas main, the result will be starvation and the fire will go out.
- Remove the heat. For example, by applying water, the result will be cooling and dissipating the heat.
- Remove the oxygen. For example, if you cover the fire with a lid, wet blanket, sand, or use a carbon dioxide, foam, or dry chemical extinguisher, the result is smothering.

NOTES

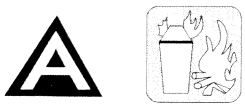
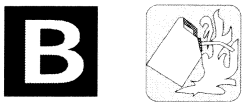
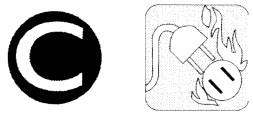
Learning Task 5

Describe the Classes of Fires According to the Materials Being Burned

Classes of Fires and Types of Extinguishers

Fires are divided into four main classes: A, B, C, and D. It is important to know the classification of a fire because that dictates the type of extinguisher required.

The symbols shown below may be the only indication you have of the best use for a fire extinguisher. Make note of the class letter and symbols so you will know what type of fire extinguisher should be used.

Symbol	Agent	Extinguisher characteristics
	Ordinary combustibles (wood, cloth, paper, rubber, and many plastics)	Heat absorption (cooling). Can often be extinguished with water.
	Flammable or combustible vapours	Prevention of vapour release. Combustion is interrupted by suffocating the fire.
	Energized electrical equipment	Must be non-conductive to provide safety to the user. A class A or B extinguisher may only be used after the electrical equipment has been de-energized.
	Combustible metals such as magnesium, titanium, zirconium, sodium, and potassium	Non-reactive heat absorption. Small fires can be smothered with dry chemical extinguisher or sand. Larger fires can be cooled with large volumes of water.

GREEN

RED

BLUE

YELLOW

Figure 1. Classes of Fires

Types of Fire Extinguishers

NOTES

Most shops carry modern, portable fire extinguishers. Although these extinguishers come in many sizes and colours, each will be clearly marked to indicate for which class (or classes) of fires it is intended.

Class A and B portable fire extinguishers are also rated for the size of fire they can handle. The number refers to the amount of fire extinguishing agent the fire extinguisher holds. A rating of 3A can extinguish roughly three times as much fire as a 1A. A 10B fire extinguisher has about ten times the capacity of a 1B fire extinguisher. This rating is expressed as a number:

- Class A fire—1 to 40
- Class B fire—1 to 640

This rating will appear on the label; for example, 2A10B:C. The larger the numbers, the larger the fire (of the specified class) the extinguisher can handle.

A "C" on the label indicates that the unit has been tested for use on electrical fires (class C fires). A rating of 4-A, 60-B-C is for a multipurpose dry chemical fire extinguisher. It is rated at 4 for a class A fire and 60 for a class B and C fire.

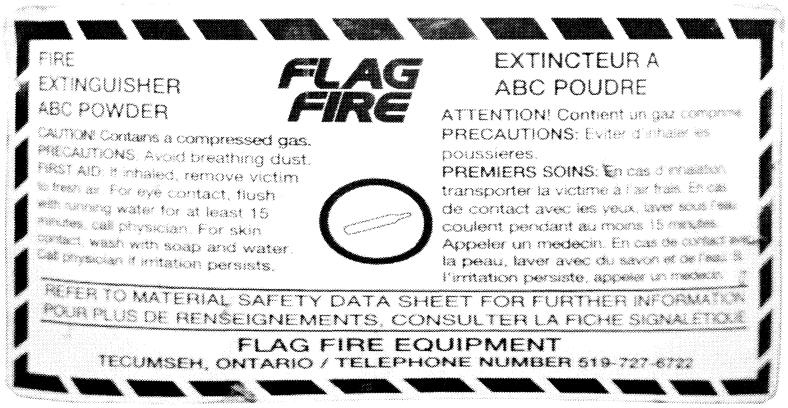


Figure 2. Fire Extinguisher Label Example

Extinguishers for class D fires are dry chemical and contain sodium chloride, copper, or graphite powder and are pressurized with nitrogen. They must match the type of metal that is burning and should not be used for other classes of fires. Because of the need to match the type of metal that is burning, you must consult your supervisor, supplier, or local fire department to identify which class fire extinguisher is best suited for your needs.

NOTES

Fire extinguishers are divided into five types:

- Water
- Dry
- Chemical
- CO_2
- Halon

Water-based extinguishers are to be used on class A fires only. They can be either the pump type or pressurized.

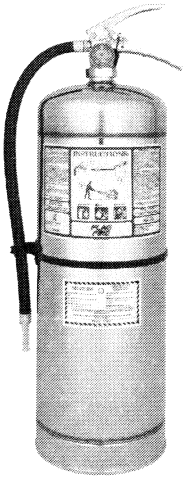


Figure 3. Water-based Extinguisher

Dry chemical extinguishers are designed for class B and C fires, depending on the agent in the cylinder.

Figure 4. Dry Chemical Extinguishers

NOTES

The most common dry chemicals used in fire extinguishers are:

- Triplex dry chemical—A multi-purpose dry chemical agent effective in extinguishing class A, B, and C fires; generally considered the best all-round fire extinguisher.
- Quick-aid dry chemical—A specially treated sodium bicarbonate dry chemical agent that is moisture resistant and free-flowing. It is effective and approved for use on class B and C fires. It offers the lowest cost per kilogram of the three dry chemical agents.
- Purple K dry chemical—A specially treated potassium bicarbonate dry chemical agent that is effective against class B and C fires. It is about twice as effective as the standard sodium bicarbonate dry chemical.

Carbon dioxide (CO_2) extinguishers should be used on class B and C fires. CO_2 fire extinguishers are recognizable by their fibre horn. They're less effective than a dry chemical extinguisher, but have the advantage of not leaving a residue that must be cleaned up.

Figure 5. CO_2 Fire Extinguisher

NOTES

Halon fire extinguishers are used on class B and C fires. Halon is effective, but environmental concerns have led to an international ban on production for most purposes. Until a suitable substitute for halon is approved, its use for extinguishing fires is permitted but halon fire extinguishers can no longer be purchased or refilled.

Figure 6. Halon Fire Extinguisher

It's important to know how to operate every fire extinguisher in your workplace. Each manufacturer uses a slightly different operating procedure, so you should look carefully at the markings and instructions on the extinguisher **before** you need to use it. The markings and instructions will tell you the types of fires the extinguisher is designed to extinguish and how it is to be used.

Fire extinguishers must be maintained in excellent condition, be located in accessible locations, and be well marked and ready for instant use. A qualified person must conduct any training in the use of workplace fire extinguishers.

After use the fire extinguisher must be recharged or replaced immediately.

Learning Task 6

Apply Preventative Fire Safety Precautions When Working Near, Handling, or Storing Flammable Liquids or Gases, Combustible Materials, and Electrical Apparatus

NOTES

Fire Prevention

Fire is only possible where there is a supply of combustible materials, oxygen, and heat. However, lack of caution, equipment failure, or simple human error can cause ignition. It is your responsibility to ensure all steps are taken to reduce the chance of fire when working near flammable materials.

Flammable Liquids and Related Equipment

The nature of flammable liquids makes them very vulnerable to ignition. As such the following storage precautions are mandatory:

- All containers must be of an approved type with a fire rating and clearly marked.
- All containers must have secure capping devices.
- All flammable liquids must be stored in approved storage containers (Figure 1).
- Open flames or lit cigarettes are prohibited within or near any liquid-gas storage area.
- Where drums are used as containers, they must have taps and a drip tray.
- Only sealed containers may be transported.
- Empty containers must be stored on end (i.e., upright).
- Spills must be cleaned up or covered with sand.

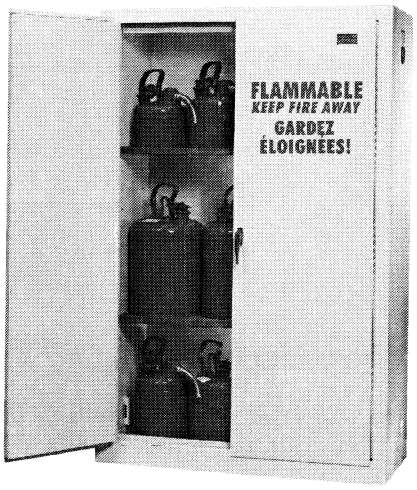


Figure 1. Flammable Liquid Storage Container

Any equipment that uses a flammable liquid requires the same precautionary measures as stored liquids. All tank or equipment leaks must be reported and repaired immediately.

NOTES

Drivers and operators must be warned of ignition hazards while refuelling such equipment. Smoking is not permitted and engines must be stopped. Some refuelling stations also have ground cables that attach to the equipment when refuelling.

Combustible Materials

Rubbish such as packing materials, sawdust, wood shavings, rags, or oil waste are fire hazards as they are a source of combustible material. The danger can be reduced with good waste management. The following precautions must be taken:

- Flammable waste liquids must be placed in approved containers for disposal according to waste disposal regulations.
- Open fires require a permit and must be constantly supervised.
- Fire extinguishers must be available at, or near, any fire lit for the disposal of rubbish.
- Oily rags must be retained in metal bins with sealed lids.
- Oil spills must be cleaned up immediately.

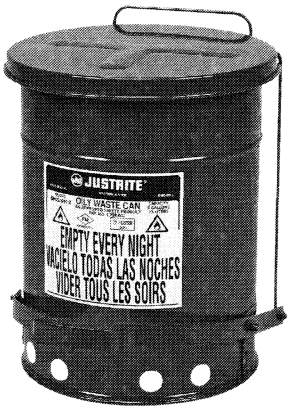


Figure 2. Oily Waste Disposal Container

Shop Electrical Wiring and Equipment

All electrical wiring, whether permanent or temporary, must be installed safely so it will not cause fires. The following precautions are necessary for shop wiring:

- All temporary or permanent wiring at ground level must be buried or protected from foot and vehicular damage with ramps.
- All portable, electric-powered hand-tools must be connected with flexible rubber or sheathed PVC cables.
- Adequate breaker protection against excess current must be included.

Vehicle Electrical Systems

NOTES

You should observe extreme caution when servicing vehicle electrical systems. Serious fires can result from short circuits in the wiring. Batteries that are being charged or exposed to a heavy discharge such as a cold or no-start situation give off very explosive gases (hydrogen) which can cause an explosion if a spark is present. When removing the batteries, always disconnect the ground wire first. To avoid an explosion, always connect the jumper batteries to the correct battery terminals when jump-starting an engine. All wiring leading to the starter motor and switch must be protected from sharp edges, mechanical, and/or heat damage. When installing a new cable, always insulate and route it in a manner to avoid damage.

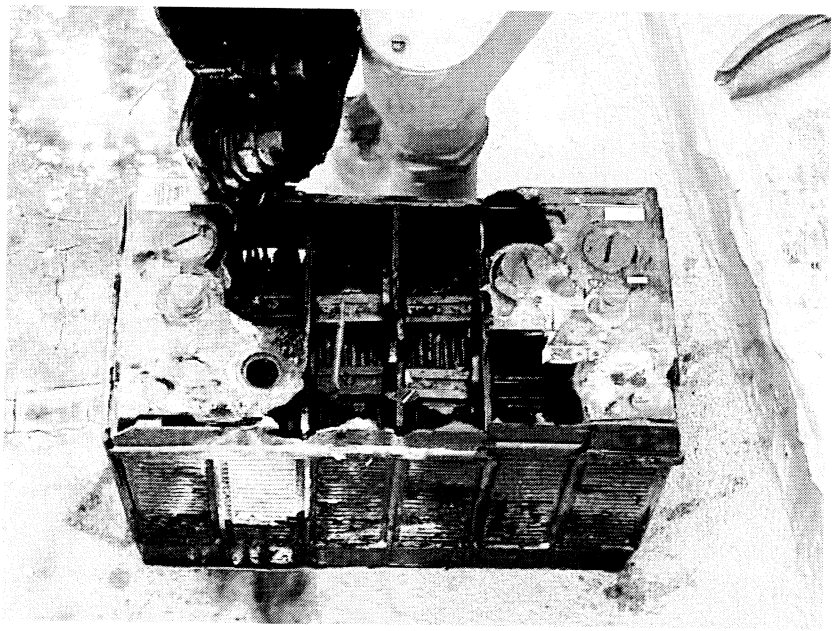


Figure 3. Damaged Battery

NOTES

Learning Task 7

Describe the Considerations and Steps to be Taken Prior to Fighting a Fire

Preparing for a Fire

It's important to be prepared and know the steps you must take in the event of a fire. The more prepared you are, the better your chances of successfully extinguishing the fire. Quick reactions can greatly decrease any resulting damage. Some critical points to consider:

- Regularly inspect and maintain fire extinguishers so they are ready to use.
- Replace or recharge a fire extinguisher after each use.
- Clearly mark the locations of all fire extinguishers and ensure clear access to each.
- Conduct emergency fire drills at least once each year.
- Know how to use a fire extinguisher.
- Know the types of fires and the appropriate fire extinguisher for each.
- Know the location of all fire alarms.
- Know the location of the breaker panel in the event of an electrical fire.
- Consider using a fire-spotter when cutting or welding.
- Keep fire extinguishers close by when working in the field.
- Post emergency phone numbers where they are accessible to everyone in the shop.
- Have a first aid kit available.
- Keep emergency exits clear at all times.
- Know the location of the nearest emergency exit and assembly point.

It is everyone's responsibility to be prepared in the event of a fire. The employer should supply training in the proper use of the fire extinguishers. You must be aware of your surroundings and your co-workers and work together in the event of fire.

Learning Task 8

Describe the Procedure for Using a Fire Extinguisher

Fighting a Fire

If a fire breaks out in your shop, whether small or large, you may be the first person to deal with it. Basic fire fighting techniques are critical and the better trained you are, the greater your odds of dealing with a fire in a quick and effective manner. Some critical points to consider:

- Think before acting. Make sure what you are about to do is the best method for fighting this particular fire.
- Call for help. "Fire! Fire! Fire!" lets other workers know there is a fire and that you may need assistance.
- Phone 911. Depending on the size and type of fire, it might be best to phone 911 immediately.
- Instruct unneeded workers to exit the area immediately.
- Use the correct type of fire extinguisher. Some fires may spread if you use an incorrect extinguisher.
- Know that a fire extinguisher is only appropriate for small fires.
- Use the P.A.S.S. (pull, aim, squeeze, sweep) steps when using a fire extinguisher.
- Keep fighting until the fire is out or your extinguisher is empty.
- Evacuate immediately if your extinguishers are empty and the fire is still burning or spreading beyond your control.
- Close all doors and windows when evacuating the area, but only if you are able to do so without danger.
- Never leave an extinguished fire unattended as they have been known to reignite.

When fighting a fire, the safety of you and your co-workers is of the utmost importance. If you're able to contain and extinguish the fire, do so. However, if the fire is getting out of hand, blocking your exit, or starting to box you in, leave the area immediately.

NOTES

NOTES

P.A.S.S.

To properly extinguish a fire with the appropriate fire extinguisher, there are four simple steps to follow. The acronym PASS stands for Pull, Aim, Squeeze, and Sweep:

1. PULL the pin which breaks the seal and allows the extinguisher to be used.

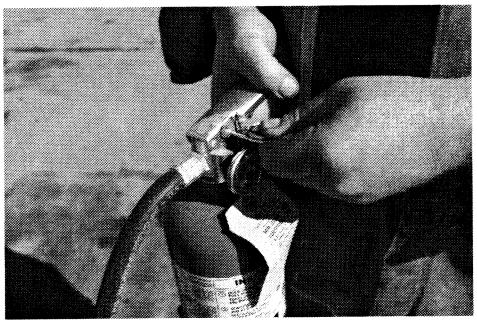
2. AIM the extinguisher nozzle at the base of the fire.

3. SQUEEZE the handle, which allows the extinguishing agent out of the canister.

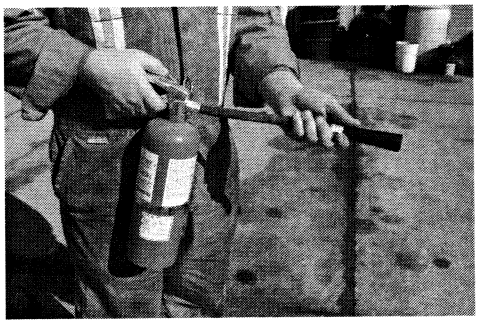
4. SWEEP the nozzle in a side-to-side motion until the fire is extinguished.

When you think the fire is extinguished, release the handle and verify that the fire is out. If the fire flares up again, spray it in a sweeping motion until it's extinguished. If your extinguisher is empty, you must decide whether to continue fighting the fire or exit the area. If you have called for help, your coworkers may assist you with other extinguishers. As a rule, call 911 or have someone call before you attempt to extinguish a fire. Even if you manage to put out a small fire yourself, call the fire department to have them inspect the area.

1. Pull the pin.



2. Aim the nozzle at the base of the fire.



3. Squeeze the handle and sweep the nozzle.

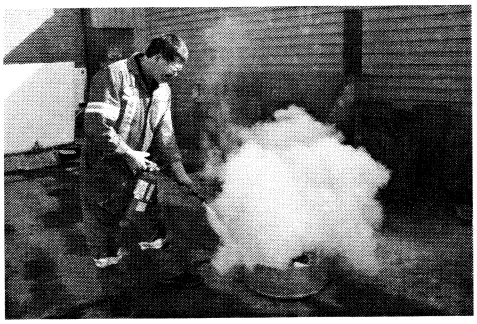


Figure 1. Fire Extinguisher Procedures

Learning Task 9

Describe Fire Suppression Systems

NOTES

Fire Suppression Systems

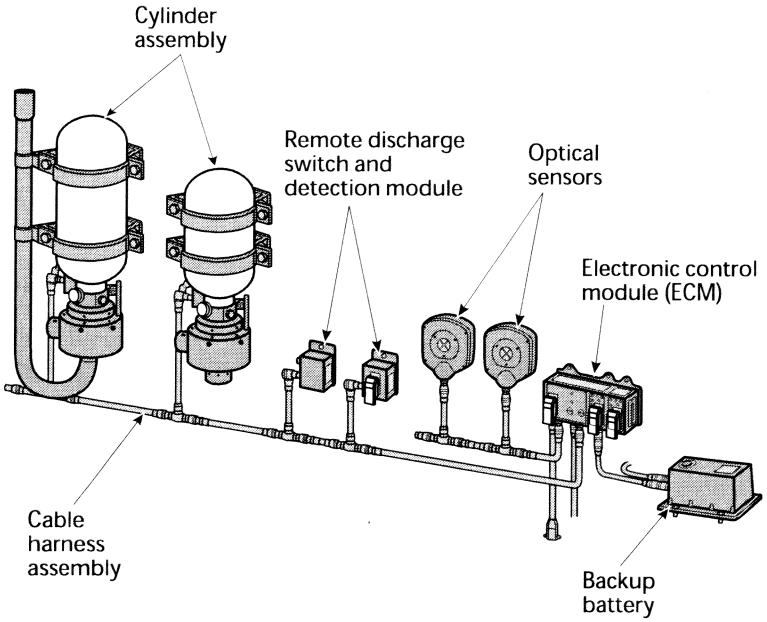


Figure 1. Fire Suppression Systems

Fire suppression systems are designed first and foremost to protect human life. Fire suppression systems are designed and installed to quickly and efficiently suppress a fire before it can reach the operator or passenger areas.

An off-road commercial vehicle can be a huge mining drag-line, a construction dump truck or bulldozer, or a forestry machine. A fire in any of these vehicles is not only life-threatening, but can destroy an expensive, hard-to-replace vehicle as well as spread to surrounding forest. Many of these machines are left unattended and an electrical fire can occur when no one is around. These vehicles typically work long hours under demanding conditions. Breaks in a fuel or hydraulic line can result in a rapidly expanding fire. Electrical shorts, particularly in larger mining vehicles such as shovels and drag-lines, can also start fires. Often these fires start in parts of the vehicle where the operator can't see smoke or flames until it's too late.

Fire suppression systems are designed to alert the operator and to suppress the fire. If the oxygen is removed, or the temperature is cooled, the fire will go out. These automatic systems suppress the fire in its earliest stages before it becomes fully established and spreads into highly combustible areas. As a result, damage is limited and equipment down time is minimized.

NOTES

Fire Suppression Components

Most fire suppression systems have similar components regardless of the manufacturer:

- The ECM (Electronic Control Module) is the brains of the system. It has to monitor the sensors and make logical decisions and activate solenoids and warning systems.
- Sensors detect heat or fire.
- Tanks store the chemical extinguishing agent.
- Spray Nozzles are positioned in precise locations throughout the machine.

Electronic Control Module (ECM)

The ECM is programmed to make logical decisions based on inputs from various sensors. Once it has received a signal from a sensor that has detected a fire, it must react within milliseconds. The quick response is critical to reduce the size of the fire and thus the damage. The ECM also warns the operator of the emergency. ECMs must be sealed and rugged in construction to protect them from the harsh environment.

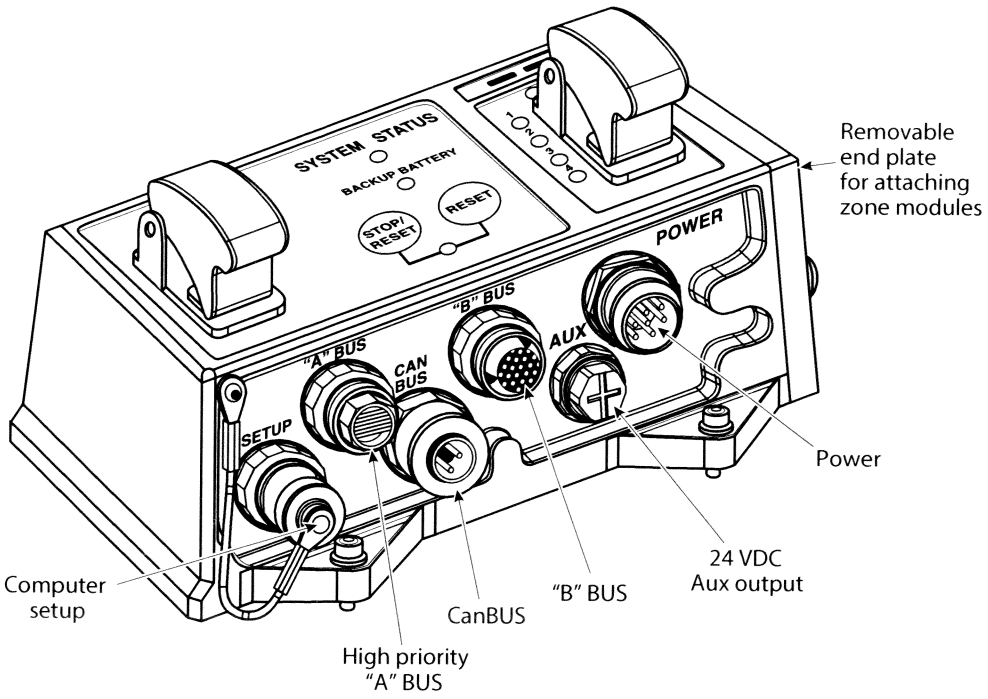


Figure 2. Electronic Control Modules

NOTES

Sensors

There are several types of sensors used in the fire suppression systems:

- Linear Wire Sensors—Usually wound throughout the engine compartment. This is a normally open sensor and when it burns, the two wires make contact and complete the circuit. When the ECM recognizes the closed circuit, it will activate the spray nozzles.
- Thermal Sensors—These sensors are a two wire sensor with normally open set of contacts. As the temperature increases, the points will close. The closed circuit tells the ECM that there is a fire in the compartment. The sensors may be pre-set for a specific temperature such as 121°C (250°F) or 176°C (350°F).
- Optical Sensors—These are the most advance sensors. They are able to detect the flame of a fire, but also differentiate between heat and smoke from a cigarette and that of an actual fire. Once the fire is detected, a signal is sent to the ECM, which in turn activates the spray nozzles.

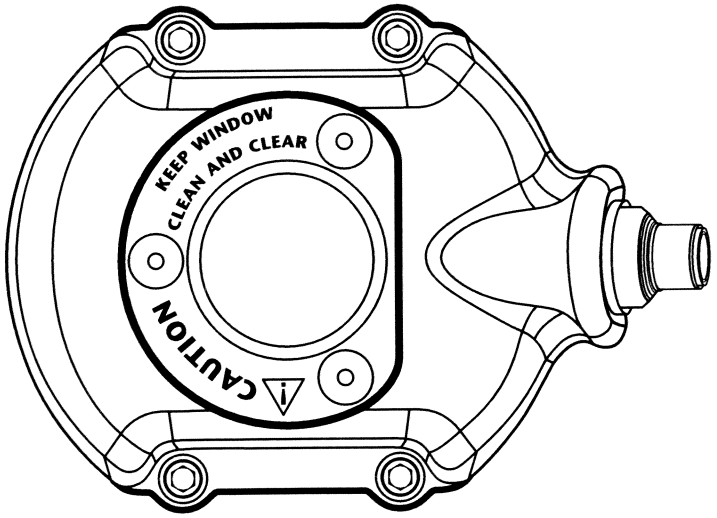


Figure 3. Optical Sensor

NOTES

Extinguishing Agent Storage Tanks

Storage tanks hold the extinguishing agent and are mounted strategically on the machine. Depending on the size of the machine and number of zones, there may one or more tanks. Each tank can range in size from 18–114 L (5–30 gallons) and can hold 4.5–113.4 kg (10–250 lb.) of extinguishing agent. The tanks hold the agent charge and are pressurized with nitrogen to approximately 5170 Kpa (750 psi). The tanks have solenoids mounted to the discharge port which are ECM controlled. Some tanks have a manual release which the operator can activate to discharge the agent. The extinguishing agent can be either a dry chemical or wet chemical charge. Both types smother the fire, but the wet chemical also cools the area. Some systems use a combination of both dry and wet chemicals to produce a very efficient fire suppression system.

Spray Nozzles

Spray nozzles are placed throughout the machine. In the engine compartment, hydraulic area, operator's station, or any area where there is potential of fire. The agent is expelled out of the nozzle at about 130 Kpa (20 psi), so it will not harm the operator.

Additional Equipment

In addition the main components, there are other important devices:

- A *back-up battery* in case the machine battery fails. This is important for two reasons: First if the machine is left unattended for extended periods, the machine batteries may become discharged. The back-up battery will still activate the fire suppression system in the event of a fire. The second reason is if the fire is electrical, or the machine batteries are damaged, the back-up battery will activate the fire suppression system.
- A *manual switch* controlled by the operator in case of a fire. There could be multiple switches located on the machine. The switch could be mounted in the operator's station, near the stairs of the machine, and at ground level. If there's a fire that the automatic sensors don't detect, the operator can manually activate the system. The switches have safety locks or covers to prevent accidental triggering.
- *Warning lights and buzzers* for the operator. The lights and buzzer will warn the operator that there is a fire and the system is going to discharge extinguishing agent. There are programmable features that may include delays for discharge or even shutdown of the machine.

NOTES

Typical Sequence of Operation of a Combination Dry and Wet Chemical System

1. Fire breaks out on a large excavator. Heat from the fire activates a sensor which alerts the ECM.

2. The ECM immediately sounds its integral alarm alerting the operator that a fire has been detected.

3. After a specified delay, the ECM activates the dry chemical system.

4. The pneumatic time delay begins its count-down prior to activating the wet chemical system.

5. Nitrogen from the expellant gas cartridge pressurizes the dry chemical storage tanks.

6. The dry chemical extinguishing agent is expelled from the tanks through a network of distribution hoses and discharge nozzles to the protected areas.

7. Immediately following the dry chemical discharge, nitrogen cartridges are activated and pressurize the wet chemical tanks.

8. The wet chemical agent is expelled from the tanks through a network of distribution hoses and discharge nozzles to the protected areas.

All of this happens within seconds of detecting a fire to protect the operator and the machine.

Working on Equipment with Fire Suppression System

There will be times when you will have to work on a machine that has a fire suppression system and you must take precautions to avoid accidentally setting it off. To prevent this from happening, consult with the manufacturer of the system and follow their recommended procedures. They will explain how to safely disable the system to prevent a discharge. To work on the fire suppression system itself, you'll need specialized training from the supplier.

Quiz A-1

1. Who is responsible for safety in the shop environment?

   a. just the mechanics
   b. just the foreman
   c. the shop manager
   d. everyone

2. Why should you remove any necklaces before starting work?

   a. they are expensive and could be damaged
   b. they could become tangled in a machine and cause personal injury
   c. they store magnetic energy that could damage an electronic control module
   d. they could get lodged in a drill chuck and damage the chuck

3. When is a face shield used?

   a. whenever you are in the shop
   b. while welding
   c. while using a bench grinder
   d. when working under the machine

4. When should hearing protection be used?

   a. anytime the steady state noise exceeds 85 decibels
   b. anytime the steady state noise exceeds 60 decibels
   c. only when using a air blow gun
   d. only when using an impact hammer

5. Other than earmuffs, what are the other types of hearing protection?

   a. tissue and plastic earplugs
   b. rigid foam and rubber earplugs
   c. rubberized and silicone rubber earplugs
   d. plasticized earplugs and fitted tissue

6. What type gloves must the mechanic wear when working with high voltage cables?

   a. nitrile
   b. leather
   c. rubber
   d. latex

7. What is the colour of the CSA safety tag for heavy work environment boots?

   a. yellow
   b. red
   c. blue
   d. green

8. How are oily rags disposed of?

   a. burned in high temperature furnace
   b. placed in a sealed fireproof container
   c. placed in a plastic bucket
   d. wrap them up and store them in a plastic bag

9. Why is it important to place a lockout tag on the machine you are working on?

   a. prevent battery drain
   b. prevent other mechanics from doing your job
   c. prevent unwanted start up of machine
   d. prevent unwanted repairs to machine

10. What must be done before removing any high pressure line?

    a. wash the line with alcohol
    b. spray the line with nitrogen
    c. de-pressurize the system
    d. maximize the pressure

11. Who is responsible for removing the lockout tag when the job is done?

    a. the person who placed the lock out tag
    b. shop foreman
    c. shop safety officer
    d. the lead hand of the last shift

12. What type of lock is used when locking out equipment?

    a. key lock
    b. combination lock
    c. barrel bolt lock
    d. electric strike lock

13. Fuel and heat are two of the components required to start a fire, what is the third component?

    a. carbon dioxide
    b. carbon monoxide
    c. oxygen
    d. nitrogen

14. What class of fire is a fire burning diesel fuel?

    a. A
    b. B
    c. C
    d. D

15. What class of fire can be extinguished with water?

    a. A
    b. B
    c. C
    d. D

16. Where is a 20 litre diesel storage tank stored?

    a. near an exit in the shop
    b. in an approved storage container
    c. in a well ventilated parts room
    d. in an approved cardboard box

17. What is done after discharging a fire extinguisher?

    a. place it back in the exact same location
    b. clean off horn and wash with soapy water
    c. recharge or replace immediately
    d. tag fire extinguisher location "empty"

18. When using a fire extinguisher, what does "PASS" refer to?

    a. pressure, aim, scour, sweep
    b. pull, aim, squeeze, sweep
    c. point, admit, squish, select
    d. pull, admit, squeeze, subject

19. What is done if all the fire extinguishers are emptied and the fire is still spreading?

    a. use large rags to smother the fire
    b. blow the fire out with compressed air
    c. evacuate the building immediately
    d. cover the fire with fire blankets

20. What must be done before working on a machine with an automatic fire suppression system?

    a. discharge the storage tanks
    b. disable the system
    c. disconnect the ground cable
    d. cut the power wire

Goals

When you have completed the Learning Tasks in this Competency, you will be able to:

- navigate through the *Occupational Health and Safety (OHS) Regulation* located on the Web
- describe the core requirements for OHS
- locate the general hazard requirements for different on-the-job materials

It is intended that you read through the *OHS Regulation* as you work through this Competency so that you'll be able to complete the tasks at the end of each topic.

Learning Task 1

State the "Core Requirements" of the Occupational Health and Safety Regulation

NOTES

The information for this Learning Task may be referenced on the WorkSafeBC web site:

- http://www.worksafebc.com
- http://www2.worksafebc.com/publications/OHSRegulation/Home.asp

Each topic has been summarized to guide you to the original information in the *OHS Regulation.*

Definitions

Since safety is so important in the workplace, it's important to know exactly what each term means. If you're unsure, consult the definitions found in part 1 of the *OHS Regulation.*

Task

Refer to part 1 of the *OHS Regulation* and document the definition of "*sensitizer.*"

_____

_____

Rights and Responsibilities

All employers, supervisors, and workers have rights and responsibilities. Part 3 of the *OHS Regulation* outlines these rights and responsibilities. The information is divided into a number of subtopics to help you locate the necessary information.

Health and Safety Programs

3.1 When program required
3.2 Small operations
3.3 Contents of program
3.4 Incident investigation reports

NOTES

Task

Document how often small businesses should have safety meetings. (Cite applicable section numbers and titles.)

Work Place Inspections

3.5 General requirement
3.6 Inspection of tools and equipment [Repealed]
3.7 Special inspections
3.8 Participation of the committee or representative

Task

Document how a work place inspector is chosen if the shop is non-union. (Cite applicable section numbers and titles.)

Right to Refuse Work

3.12 Procedure for refusal
3.13 No discriminatory action

Task

Document the procedure you must follow if you refuse to operate equipment due to unsafe conditions. (Cite applicable section numbers and titles.)

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NOTES

General Conditions

The *OHS Regulation* addresses every aspect of the workplace environment. Failure to follow this part of the *OHS Regulation* is a contravention of the *OHS Act* and could lead to fines.

Buildings, Structures, Equipment, and Site Conditions

4.1 Safe workplace
4.1.1 Snow avalanche assessment
4.2 Safe buildings and structures
4.3 Safe machinery and equipment
4.4 Conformity to standards
4.5 Manuals and information
4.6 Reassembly
4.7 Information on rated capacity
4.8 Rated capacity
4.9 Inspection and maintenance records
4.10 Authorization
4.11 Startup
4.12 Circumvention of safeguards

NOTES

Task

Document the procedure to follow once a piece of machinery has been reassembled. (Cite applicable section numbers and titles.)

Emergency Preparedness and Response

4.13 Risk assessment
4.14 Emergency procedures
4.15 Maintenance of equipment
4.16 Training
4.17 Notification of fire departments
4.18 Notification of utility service providers

Task

Document how often emergency drills should be performed in the workplace. (Cite applicable section numbers and titles.)

Violence in the Workplace

4.27 Definition
4.28 Risk assessment
4.29 Procedures and policies
4.30 Instruction of workers
4.31 Advice to consult physician

Task

Document the procedures an employer must follow if a risk assessment has identified violence in the workplace. (Cite applicable section numbers and titles.)

Working Alone

4.20.1 Definition
4.20.2 Hazard identification, elimination and control
4.21 Procedures for checking well-being of worker
4.22 Training
4.22.1 Late night retail safety procedures and requirements
4.22.2 Mandatory prepayment for fuel
4.23 Annual review

NOTES

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Task

You're working on a construction site alone and at night. This is considered a high-risk situation. Document the procedures you must follow to work in this type of situation. (Cite applicable section numbers and titles.)

Ergonomics (MSI)

4.46 Definition
4.47 Risk identification
4.48 Risk assessment
4.49 Risk factors
4.50 Risk control
4.51 Education and training
4.52 Evaluation
4.53 Consultation

Task

Document the procedures that must be followed when you exhibit signs or symptoms of MSI. (Cite applicable section numbers and titles.)

Illumination

4.64 Definitions
4.65 Illumination levels
4.66 Means of illumination
4.67 Brightness, reflectance and glare
4.68 Illumination measurement
4.69 Emergency lighting

Task

You're measuring engine components using a precision micrometer. Document what lux level is recommended to perform this task. Document what you can do if the shop lighting is not up to the desired luminance level. (Cite applicable section numbers and titles.)

Indoor Air Quality

4.70 Application
4.71 Submitting plans
4.72 Design and operation
4.73 Building modifications
4.74 Distribution
4.75 Balancing
4.76 Ventilation openings
4.77 Discharged air
4.78 Preventive maintenance
4.79 Investigation
4.80 Temperature and humidity

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Task

Document the procedures to follow if the ambient outdoor levels for carbon dioxide are at 350 ppm and the indoor carbon dioxide levels are at 450 ppm. (Cite applicable section numbers and titles.) Discuss this with your instructor.

Environmental Tobacco Smoke

4.81 Controlling exposure
4.82 Designated areas
4.83 Public entertainment facilities

Task

A customer is examining the work done on one of his machines. The machine is in a shop area. The customer is smoking and not aware of shop regulations. Document the *OHS Regulation* and the procedure that the service manager should follow. (Cite applicable section numbers and titles.) Discuss this with your instructor.

Occupational Environment Requirements

4.84 Eating areas
4.85 Washroom facilities
4.86 Change areas
4.87 Unsafe water

Task

You're sent to a construction job site. There are no indoor facilities. Document the employer requirements for washroom facilities. (Cite applicable section numbers and titles.)

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Learning Task 2

Locate the "General Hazard Requirements" of the Occupational Health and Safety Regulation

The information for this Learning Task may be referenced on the WorkSafeBC web site:

- http://www.worksafebc.com
- http://www2.worksafebc.com/publications/OHSRegulation/Home.asp

Chemical Agents and Biological Agents

Part 5 of the *OHS Regulation* deals with the identification, handling, and storage of hazardous substances as well as preventative and emergency procedures.

Workplace Hazardous Materials Information System (WHMIS)

Task

While working in the shop area, you notice a new product for shop cleaning. You cannot find any MSDS information on the MSDS records. Document the steps you should take at this time. (Cite applicable section numbers and titles.)

Containers and Storage

Task

A technician leaves a pail of partly used engine oil in the corner of the shop. The welding department has been asked to perform some welding on a machine in the same area as the oil. Summarize the section that deals with oil storage. (Cite applicable section numbers and titles.)

Flammable and Combustible Substances

Task

Inspect your oil dispensing room and document your findings based on the regulation for this section. (Cite applicable section numbers and titles.)

NOTES

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Substances Under Pressure

Task

You need to change an empty acetylene bottle in the torch cart. The new full bottle has been stored on its side. Document the procedures you must follow to use the new full bottle of acetylene. (Cite applicable section numbers and titles.)

Controlling Exposure

Task

Document the meaning of "*TWA limit.*" (Cite applicable section numbers and titles.)

Ventilation

Task

Inspect your shop make-up air system and document your findings. (Cite applicable section numbers and titles.) Discuss this with your instructor.

Internal Combustion Engines

Task

You're operating a diesel engine in the shop. The engine is the latest model with no visible exhaust emissions. The exhaust extraction system is faulty. Is there another method to safely run the engine in the shop? Refer to *Sections 5.72–5.75* in the *OHS Regulation* and document your findings. (Cite applicable section numbers and titles.)

NOTES

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Hazardous Wastes and Emissions

Task

Inspect your shop waste oil storage container areas. Refer to *Sections 5.76–5.79* in the *OHS Regulation* and document your findings. Discuss this with your instructor.

Personal Hygiene

Task

Document what an employer must provide for an eating area when the job site is an asbestos mine. (Cite applicable section numbers and titles.)

Emergency Washing Facilities

Task

Inspect the emergency eye wash station in your shop. Refer to *Sections 5.85–5.96* in the *OHS Regulation* and document your findings.

Emergency Procedures

Task

A 454 L (100 gallon) fuel tank has ruptured in the shop. The fuel has drained out of the tank and covered the shop floor. Document the emergency procedures, from emergency plan to actual clean-up, that must be followed as per *Sections 5.97–5.104* in the *OHS Regulation.*

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Substance Specific Requirements

Part 6 of the *OHS Regulation* deals with asbestos, biological agents, cytotoxic drugs, lead, pesticides, rock dust, and toxic process gases. The most common hazards for the heavy trades are asbestos, pesticides, and rock dust.

Asbestos may be found in old equipment that is being restored, gaskets, brake linings, clutch linings, etc. There are asbestos mines in Canada and equipment may be covered with asbestos dust.

Pesticides are used in some agricultural areas and the equipment may have chemical overspray on the machinery that you're repairing.

Rock dust is a fine by-product of some mining processes such as drilling and blasting. The equipment may have a fine dust covering areas that you must repair. You will also find fine dust particles in air inlet filters of engines. They should never be blown out (due to the risk of silicosis).

Task

You must change a drill steel drive chain. What safety procedures must you follow to protect yourself from rock dust? Document these items and discuss this with your instructor. (Cite applicable section numbers and titles.)

Noise, Vibration, Radiation, and Temperature

Part 7 of the *OHS Regulation* covers the effects of short- and long-term exposure to noise, vibration, radiation, and temperature. The guidelines in this part establish minimum safe levels and what must be done to allow higher than normal exposure levels.

Task

You're working in –5°C (23°F) weather. What shelter is the employer obligated to supply? Document your findings. (Cite applicable section numbers and titles.)

NOTES

Personal Protective Clothing and Equipment

Part 8 of the *OHS Regulation* covers the minimum standard for personal protective equipment.

Task

Document the supervisor's responsibility, the worker's responsibility, and discuss this with your instructor. (Cite applicable section numbers and titles.)

NOTES

Confined Spaces

Part 9 of the *OHS Regulation* covers the minimum standards for working in confined spaces.

Task

You're preparing to remove a transmission from a large loader. You'll be standing in the tight space between the torque converter and the transmission. Reference part 9 to decide if this is considered a confined space. Document your findings and discuss this with your instructor. (Cite applicable section numbers and titles.)

De-energization and Lockout

Part 10 of the *OHS Regulation* deals with minimum lockout procedures when working with equipment.

Task

An apprentice needs to move a machine to perform his duty. He is not aware that a technician is working on the machine. The machine that he wants to move does not have any lockout devices or "do not start" tags. What should the apprentice do at this time? Document this information and discuss this with your instructor. (Cite applicable section numbers and titles.)

NOTES

Fall Protection

Part 11 of the *OHS Regulation* deals with the requirements of systems used to prevent workers from falling.

NOTES

Task

You're repairing a cable sheave at the end of a crane boom, using a forklift with a wooden pallet on the forks as a means to reach the sheave. The boom is 15 feet above the ground. Refer to part 11 of the *OHS Regulation* and document the minimum standards for fall protection. (Cite applicable section numbers and titles.)

Tools, Machinery, and Equipment

Part 12 of the *OHS Regulation* deals with the safety standards and requirements for all varieties of equipment.

Task

You have just installed a new fan and belts on a crawler dozer and have decided to leave the fan guarding off so that it will be easier to service the fan and belts in the future. Refer to part 12 of the *OHS Regulation* and document the minimum standards for fans and belts. (Cite applicable section numbers and titles.)

Ladders, Scaffolds, and Temporary Work Platforms

Part 13 of the *OHS Regulation* deals with the minimum safety standards and requirements when working at an elevation.

Task

Refer to part 13 of the *OHS Regulation* and document the minimum standards for platform requirements when using a forklift for a temporary work platform. (Cite applicable section numbers and titles.)

Cranes and Hoists

Part 14 of the *OHS Regulation* deals with the minimum safety standards and requirements when working with cranes or hoists.

Task

A crane operator is using his cell phone while operating a crane. Refer to part 14 of the *OHS Regulation* and document the minimum standards for crane warning devices. (Cite applicable section numbers and titles.)

NOTES

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Rigging

Part 15 of the *OHS Regulation* deals with the procedures used when working with rigging.

Task

You're installing cable clips (clamps) on a 13 mm (½ in.) cable. How many clips, what spacing, and to what torque should the nuts be tightened? Refer to part 15 of the *OHS Regulation* and give your answer in both metric and imperial measurements. (Cite applicable section numbers and titles.)

Mobile Equipment

Part 16 of the *OHS Regulation* deals with requirements for using any form of transportation.

Task

A spotter is assisting while you're using a forklift to move an engine from a storage shed to the main shop. The spotter decides to ride the forklift back to the shop rather than walk. Refer to part 16 of the *OHS Regulation* and document the minimum standards for riders. (Cite applicable section numbers and titles.)

Transportation of Workers

Part 17 of the *OHS Regulation* deals with safety issues when transporting workers.

Task

You must travel by boat to a construction site. The owner of the boat tells you that you have to operate the boat, as there is no one else available. Refer to part 17 of the *OHS Regulation* and document the minimum standards for boat operators. (Cite applicable section numbers and titles.)

Traffic Control

Part 18 of the *OHS Regulation* deals with the use of signs, barricades, cones, barriers, detours, or other techniques and devices to manage the flow of traffic.

Task

A mine haul truck has been parked on the side of the road for repairs. Refer to part 18 of the *OHS Regulation* and document the minimum standards for safe parking. (Cite applicable section numbers and titles.)

NOTES

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Electrical Safety

Part 19 of the *OHS Regulation* deals with safety procedures and requirements when working with electricity.

Task

You're working on a low-voltage control system on a new electric drive crawler dozer. Refer to part 19 of the *OHS Regulation* and document the minimum standards for the lockout procedures on this machine. (Cite applicable section numbers and titles.)

Goals

When you have completed the Learning Tasks in this Competency, you will be able to:

- describe the purpose of the Workplace Hazardous Materials Information System (WHMIS) Regulations
- explain the contents of Material Safety Data Sheets (MSDS)
- explain the content of a WHMIS label
- describe current environmental standards
- apply WHMIS regulations

Learning Task 1

State the Legislation that Requires Suppliers of Hazardous Materials to Provide MSDSs

NOTES

Hazardous Product Act

The federal *Hazardous Products Act* (HPA) and the *Controlled Products Regulation* (CPR) define which products are included in the Workplace Hazardous Materials Information System (WHMIS) as a controlled product. The *Hazardous Product Act* also defines what information suppliers must provide to employers for use in the workplace.

The Workers' Compensation Board (WCB) administers the *Hazardous Products Act* in British Columbia. WorkSafeBC officers enforce the federal requirements on suppliers under the *Hazardous Products Act.*

Sales and Import Requirements Apply

Suppliers selling a controlled product for use in a workplace in Canada must:

- provide a material safety data sheet (MSDS) for the product
- ensure the product or its container is labelled with the required information

Controlled Products Regulations

The *Controlled Products Regulations* (CPR) specify the types of materials and format of the information on MSDSs, the layout and information on supplier labels, conditions for exemption, and the guidelines that define a controlled product.

The CPR can be viewed at the following website:

http://laws-lois.justice.gc.ca/eng/regulations/SOR-88-66/FullText.html

Task

Read the section on "Controlled Products" from the *Hazardous Products Act.*

NOTES

Ingredients Disclosure List

The Ingredients Disclosure List (IDL) is an alphabetical list of chemicals identified by their common name. The Chemical Abstracts Service (CAS) registry number is provided for products where available. Each chemical has a corresponding concentration "cut-off" of either 0.1% or 1.0%.

The criteria used to decide to include an ingredient in the IDL are more open than the criteria used to decide what is a WHMIS-controlled product. As a result, some substances have been included on the IDL that are not considered hazardous enough to be WHMIS-controlled products.

Hazardous Materials Information Review Act

The purpose for the *Hazardous Materials Information Review Act* (HMIRA) is to provide an ongoing avenue to review WHMIS, HPA, CPR, and IDL.

The HMIRA can be viewed at the following website:

http://laws-lois.justice.gc.ca/eng/acts/H-2.7/index.html

Task

Reference the *Hazardous Materials Information Review Act*. What is the purpose of Section 11, subsection 4?

Hazardous Materials Information Review Regulations

The *Hazardous Material Information Review Regulations* (HMIRR) establishes the criteria for the HMIRA. Suppliers, employers, and employees will access this information to process claims.

The HMIRR can be viewed at the following website:

http://laws-lois.justice.gc.ca/eng/regulations/SOR-88-456/index.html

Task

Browse the *Hazardous Materials Information Review Regulations*. This will help familiarize you with information-related regulations.

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Learning Task 2

State the Purpose of the Workplace Hazardous Materials Information System (WHMIS)

Protection of Canadian Workers

For the protection of Canadian workers, WHMIS was developed to detail the necessary training, product information, and labels when working with hazardous materials.

Some materials that have been used for years (and thought to be harmless) are now known to be hazardous. Proper handling of hazardous materials requires careful planning, training, and use of personal protective equipment or controls.

Common, hazardous materials include:

- compressed gas (acetylene, nitrogen, oxygen)
- flammable and combustible materials (solvents)
- oxidizing materials (epoxy hardeners)
- solvents, coatings, and sealers
- asbestos and silica
- acids and alkalis

The Workplace Hazardous Materials Information System (WHMIS) provides you with information about any hazardous materials you work with. It does this through:

- labels
- material safety data sheets (MSDS)
- worker training and education

The law requires all employers to train workers in WHMIS for the specific controlled products they will be working with or near. This training should occur as soon as new products are introduced. There should also be a general updating on new products at least once a year.

Recognition of Rights

Worker's Rights

Workers have the right to training and information on hazardous products before they use these products.

Employer's Rights

Employers have the right to training, information on hazardous products, to request that all workers receive training in hazardous products, and the right to receive information from regulators regarding regulation changes.

Supplier's Rights

Suppliers have the right to training, MSDS information on the products they sell, labels for the products they sell, and the right to receive information from regulators regarding regulation changes.

Regulator's Rights

Regulators have the right to update or change any regulations with the *WHMIS Act*, perform inspections, and impose judgment and fines if necessary.

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Learning Task 3

Describe the Key Elements of WHMIS

Material Safety Data Sheet

A Material Safety Data Sheet (MSDS) is the part of WHMIS that provides basic information on a material or chemical product. It contains information on the properties and potential hazards of the material, how to use it safely, and what to do if there is an emergency.

The MSDSs provided by different manufacturers or suppliers might not look identical, but they must contain the same basic information.

NOTES

MATERIAL SAFETY DATA SHEET FOR ODORIZED PROPANE

1. Chemical Product and Company Identification

Product Name: Odorized Commercial Propane
Chemical Name: Propane
Chemical Family: Paraffinic Hydrocarbon
Formula: C_3H_8
Synonyms: Dimethylmethane, LP-Gas, Liquefied Petroleum Gas (LPG), Propane, Propyl Hydride

Name & Address:	Transportation Emergency Number:	Emergency Number:
WHISPER GAS 111 Sigh Avenue Trail, BC 1T8 T0T	CANUTEC **1-613-996-6666**	*123-456-7890* **For Routine Info, Call:** *100-234-5678*

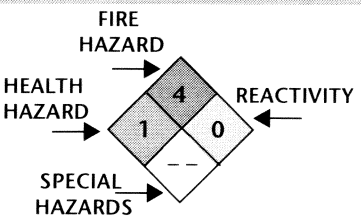
2. Composition/Information on Ingredients

INGREDIENT NAME /CAS NUMBER	PERCENTAGE	OSHA PEL	ACGIH TLV
Propane /74-98-6	87.5–100	1000 ppm	Simple asphyxiant
Ethane /74-84-0	0–5.0		Simple asphyxiant
Propylene /115-07-1	0–10.0		Simple asphyxiant
Butanes /various	0–2.5		Simple asphyxiant
Ethyl Mercaptan /75-08-1	16–25 ppm	0.5 ppm	0.5 ppm

3. Hazards Identification

EMERGENCY OVERVIEW

DANGER! Flammable liquefied gas under pressure. Keep away from heat, sparks, flame, and all other ignition sources. Vapour replaces oxygen available for breathing and may cause suffocation in confined spaces. Use only with adequate ventilation. Odour may not provide adequate warning of potentially hazardous concentrations. Vapour is heavier than air. Liquid can cause freeze burn similar to frostbite. Do not get liquid in eyes, on skin, or on clothing. Avoid breathing of vapour. Keep container valve closed when not in use.



Severe	4
Serious	3
Moderate	2
Slight	1
Minimal	0

*(Ref. NFPA 704)

POTENTIAL HEALTH EFFECTS INFORMATION
ROUTES OF EXPOSURE:
Inhalation: Asphyxiant. It should be noted that before suffocation could occur, the lower flammability limit of propane in air would be exceeded, possibly causing both an oxygen-deficient and explosive atmosphere. Exposure to concentration >10% may cause dizziness.

Figure 1. Sample MSDS First Page

NOTES

Labelling of Containers of Hazardous Materials

Workplace labels are required on containers for each controlled product produced and used on-site, on secondary containers after a product has been transferred from the original container, and on containers where the supplier label is missing or not readable.

Workplace labels must have seven pieces of information on the label:

- product identifier
- supplier identifier
- MSDS statement
- hazard symbol
- risk phrases
- precautionary measures
- first aid measures

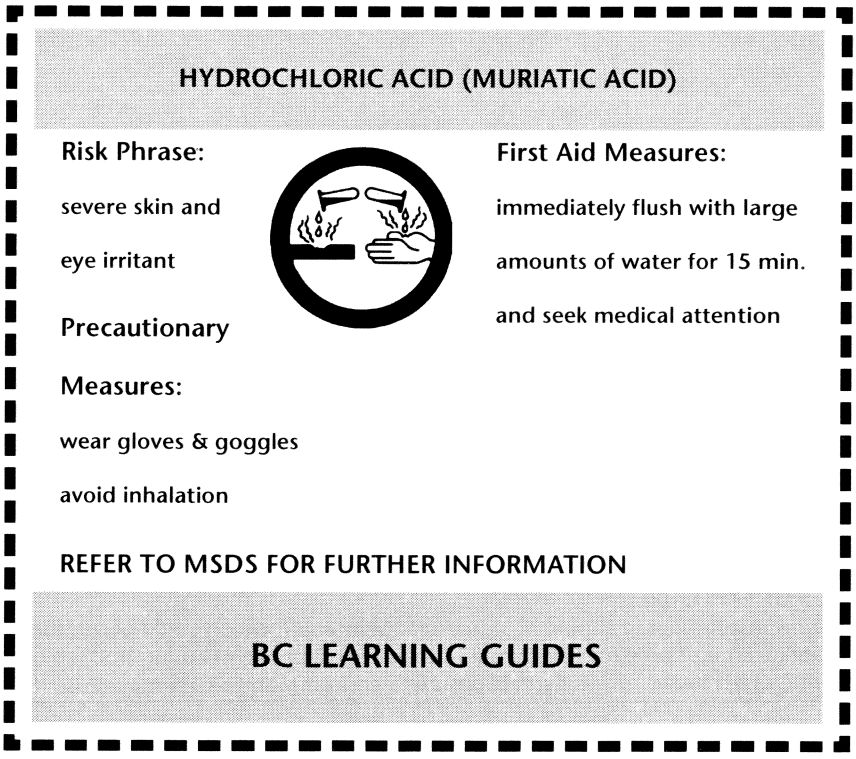


Figure 2. Typical Workplace Label

Labelling Workers Education

Employers must establish an education program for their workers. Workers need to understand WHMIS and the hazards of the controlled products that they work with or near. Education programs about WHMIS must be followed up with procedures for handling, storing, disposing of, and dealing with spills and accidents with their controlled products.

An e-Learning course located on the web has been developed by CCOHS:

http://www.ccohs.ca/

This course familiarizes workers with the system used across Canada to provide safety information about hazardous products in their workplaces. You will learn about the WHMIS symbols and their meaning, the labels on products, and material safety data sheets (MSDS).

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Learning Task 4

Describe the Responsibilities of Suppliers under WHMIS

WorkSafeBC administers WHMIS legislation in BC. The WHMIS Core Material Manual can be found at the following website:

http://www.worksafebc.com/publications/health_and_safety/whmis/pub_40_20_20_20.asp

Material Safety Data Sheets

The supplier is required to meet these responsibilities:

- have an MSDS for each controlled product sold
- disclose all relevant information at the time of sale
- each MSDS must show a date of no more than three years before the date of sale or importation, and be updated when this period expires or as soon as new information becomes available
- MSDS sheets must be available in both English and French at the time of sale
- each MSDS must be given to the purchaser on, or prior to, the date of sale of a controlled product
- identify, subject to the HMIRA, at the request of an inspector
- provide any information in the supplier's possession to any physician or nurse for diagnosis or medical treatment in an emergency

Task

Reference WorkSafeBC, WHMIS Core Material Manual, Chapter 1, subsection 1.2 and 1.3. What is the HMIRA?

Labels

The supplier must fulfill these responsibilities:

- develop or obtain supplier labels for all controlled products sold
- apply supplier labels to all controlled products sold

Task

Reference WorkSafeBC, WHMIS Core Material Manual, Chapter 4, subsection 4.3.1. Is engine oil sampling included in this section? (Lab tests)

NOTES

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Learning Task 5

Describe the Responsibilities of Employers under WHMIS

Material Safety Data Sheets

The employer must fulfill these responsibilities:

- ensure that an up-to-date supplier MSDS is obtained
- validate the date of preparation of each MSDS
- add any new hazard information to the supplier MSDS
- prepare an MSDS with the necessary information required by WHMIS if the employer produces a controlled product
- update each employer-prepared MSDS at least every three years
- produce a new MSDS if the employer or worker adds any ingredient to a bulk chemical purchase
- ensure that all MSDSs are readily available at the work site
- ensure that all workers who work with, or in proximity to, a controlled product receive instruction on specific MSDS information

Task

Reference WorkSafeBC, WHMIS Core Material Manual, Chapter 5. Document the Disclosing Information for the employer.

Labelling

The employer must fulfill these responsibilities:

- ensure that all workers who work with, or in proximity to, controlled products are instructed in supplier and workplace labels and other identifiers
- ensure that all controlled products or their containers have a proper label applied at the time of entry into the workplace
- ensure that no controlled products are handled in the workplace unless the proper label has been applied
- provide worker education to ensure that supplier labels are not removed, defaced, or altered
- develop and apply workplace labels to any controlled products or their containers when:
    - the employer produces a controlled product
    - an existing label becomes illegible or is accidentally removed and a replacement supplier label is not available

Task

Reference WorkSafeBC, WHMIS Core Material Manual, Chapter 4. Document how the employer deals with an imported product for use at the employer's work site.

NOTES

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Worker Education

The employer has the basic responsibility for educating and training workers. Specifically, the employer must meet these requirements:

- implement a program of worker education on controlled products that covers:
  - the principles and application of WHMIS
  - the required information on WHMIS labels and MSDSs
  - the use of other means of identification such as signs, placards, colours, numbering, lettering, or other codes

- implement a worker training program covering:
  - procedures for the safe storage, handling, use, and disposal of controlled products
  - procedures in an emergency involving a controlled product
  - procedures when fugitive emissions are present

Task

Reference WorkSafeBC, WHMIS Core Material Manual, Chapter 6. Document how often the employer must review their education and training program.

Learning Task 6

Describe Information to be Disclosed on an MSDS

NOTES

Canada's federal controlled products legislation requires that every MSDS have nine descriptive or informational sections. The following pages present a basic sample of an MSDS.

Product Information

Section 1 of the MSDS contains product information:

MATERIAL SAFETY DATA SHEET (MSDS)	
SECTION 1: PRODUCT INFORMATION	
Section items	**Guide key**
Product Identifier:	**CONFIRM: Same as Product Identifier on WHMIS label on product?**
Product Code:	
Manufacturer's Name and Address:	**CONFIRM: Same as Manufacturer on WHMIS label on product?**
Supplier's Name and Address:	
Business No.:	**CALL for more product information, if needed**
Emergency No.:	
Product Use:	**CHECK: Is this in line with your intended use of the product?**

NOTES

Hazardous Ingredients

Section 2 of the MSDS describes hazardous ingredients:

SECTION 2: HAZARDOUS INGREDIENTS	
Section items	**Guide key**
Ingredients:	**In some cases the manufacturer has been given permission to withhold the name of an ingredient because it is "confidential business information." However, even if the ingredient is "secret," all hazards associated with it must be reported in the appropriate sections of the MSDS.**
CAS #	
Wt.%	**Occupational Exposure Limits/Threshold Limit Values are usually given in this section of the MSDS. In Canada, exposure limits might vary provincially. CHECK the OHS Regulation for applicable standards.**
LC50 (ppm)	
LD50 (mg/kg)	

Task

Reference WorkSafeBC, WHMIS Core Material Manual, Chapter 5. Document the meaning of LC_{50} and LD_{50}.

Physical Data

Section 3 of the MSDS contains physical data information:

SECTION 3: PHYSICAL DATA	
Section items	**Guide key**
Physical State (gas, liquid, or solid):	**CONFIRM that the description of the material matches the physical state and appearance of the material you have. If it does not, you might have the incorrect MSDS, or the material might be old, or it might have decomposed during shipping or storage. In this case, the information on the MSDS might not apply**
Appearance and Odour:	
Odour Threshold (ppm):	
Vapour Pressure (mm Hg):	
Evaporation Rate:	
Freezing/Melting Point (deg C):	
% Volatile (by volume):	**Ask your supervisor for advice.**
Density (g/ml):	
Specific Gravity:	**The rest of the information in this section is used to identify the conditions under which the material might be hazardous and to develop specific work site procedures for exposure control, storage, handling, and spill cleanup**
Vapour Density (Air = 1):	
Boiling Point (deg C):	
Solubility in Water (at 20 °C):	
pH:	
Coefficient of Oil/Water Distribution:	

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Fire and Explosion

Section 4 of the MSDS contains information concerning fire and explosion:

SECTION 4: FIRE AND EXPLOSION HAZARD	
Section items	**Guide key**
Conditions of Flammability:	**This information is used to plan the type and placement of fire extinguishers, and the fire response procedure for the work area**
Flash Point and Method:	
Lower Explosive Limit (LEL) (% by volume):	
Upper Explosive Limit (UEL) (% by volume):	
Auto-ignition Temperature:	**If the material is a potential fire hazard, you should be trained in the special handling precautions and procedures required to prevent a fire, as well as in the fire response procedures at your work site.**
Extinguishing Media:	
Hazardous Combustion Products:	
Explosion Data:	
Sensitivity to Mechanical Impact or Static Discharge:	

Reactivity

Section 5 of the MSDS contains information about the material's reactivity:

SECTION 5: REACTIVITY DATA	
Section items	**Guide key**
Unstable: [ ] yes [ ] no	**This section describes the conditions that cause the material to become unstable. Unstable materials decompose (break down) and could cause fires or explosions, or could form new chemicals that are more toxic or flammable than the original material.**
If unstable: under which conditions?	
Incompatible Materials:	
Hazardous Polymerization: [ ] yes [ ] no	
If yes, under which conditions?	
Hazardous Decomposition Products:	

Task

Reference WorkSafeBC, WHMIS Core Material Manual, Chapter 5, Section 5. List the items that affect chemical stability. Does gasoline fit in this section?

NOTES

NOTES

Toxicological Properties

Section 6 of the MSDS contains toxicological properties information:

SECTION 6: TOXICOLOGICAL PROPERTIES/HEALTH HAZARD DATA	
Section items	**Guide key**
Routes of Entry/Exposure:	**This section describes the ways you can be exposed to the material and the harmful effects of such exposure.**
[ ] Skin Contact	
[ ] Skin Absorption	
[ ] Eye Contact	
[ ] Inhalation	
[ ] Ingestion	
LD50:	
LC50:	**Acute exposure takes place over a short period of time (minutes, hours, or days) Chronic exposure takes place over months and years.**
Effects of Acute Exposure to Product:	
Effects of Chronic Exposure to Product:	
Exposure Limits:	
Irritancy of Product:	
Sensitization to Product:	
Reproductive Toxicity:	
Carcinogenicity:	**"Carcinogenic" means "able to cause cancer."**
Teratogenicity:	**A "teratogen" is a substance that can cause birth defects.**
Mutagenicity:	**A "mutagen" is a substance that causes changes in the DNA of cells.**
Names of Toxicologically Synergistic Materials:	**1 + 1 = 3. When chemicals are "synergistic in their toxicology," exposure to BOTH chemicals causes more damage than exposure to one of them on its own.**

First Aid

Section 7 of the MSDS contains first aid instructions:

SECTION 7: FIRST AID MEASURES	
Section items	**Guide key**
Inhalation:	**This section describes actions to be taken immediately if exposed to the material. You must know the first aid information BEFORE beginning to work with the material. If medical treatment is required, send the MSDS to the emergency facility with the victim.**
Skin:	
Eyes:	
Ingestion:	

Preventative Measures

Section 8 of the MSDS contains information on preventative measures:

SECTION 8: PREVENTIVE MEASURES	
Section items	**Guide key**
Engineering Controls:	**This section provides the following information:** • general guidance on required PPE • how to store the material safely • precautions for the safe use and handling of the material • instructions for spill cleanup
Personal Protective Equipment:	
Gloves (type of material):	
Eye Protection:	
Respiratory Protection:	
Clothing:	
Storage Requirements:	
Handling Procedures and Equipment:	
Leak/Spill Cleanup:	
Waste Disposal:	**NOTE: Waste disposal instructions must be checked against local and provincial regulations**
Special Shipping Information:	

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Preparation Information

Section 9 of the MSDS contains preparation information:

SECTION 9: PREPARATION INFORMATION	
Section items	**Guide key**
Prepared by (Group, Department, etc.)	**You must have an UP-TO-DATE MSDS. CHECK the date the MSDS was prepared: WHMIS requires that an MSDS be no more than three years old.**
Phone #:	
Preparation Date:	

Learning Task 7

Identify Symbols Found on WHMIS Labels and their Meaning

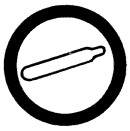
CLASS	SYMBOL	EXAMPLE
Class A: Compressed Gas		oxygen
Class B: Flammable and Combustible Material		acetone
Class C: Oxidizing Material		chromic acid
Class D: Poisonous and Infectious Material 1. Materials causing immediate and serious toxic effects		ammonia
2. Materials causing other toxic effects		asbestos
3. Biohazardous material		blood products
Class E: Corrosive Material		hydrochloric acid, sodium hydroxide
Class F: Dangerously Reactive Material		acetylene

Figure 1. WHMIS Symbols

Notes

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Class A—Compressed Gases

A product, material, or substance is considered Class A if it's contained under pressure and meets any one of four additional criteria.

Task

Reference WorkSafeBC, WHMIS Core Material Manual, Chapter 2. Identify the four additional criteria for a product, material, or substance to be considered Class A.

Class B—Flammable and Combustible Materials

There are six divisions within this class:

- flammable gases
- flammable liquids
- combustible liquids
- flammable solids
- flammable aerosols
- reactive flammable materials

Division 1—Flammable Gases

A product, material, or substance is considered Division 1 if it's a compressed gas (Class A), and at normal atmospheric pressure forms a flammable mixture with air when the compressed gas is released with a source of ignition.

NOTES

Division 2—Flammable Liquids

A product, material, or substance is considered Division 2 if it has a flashpoint less than 37.8°C (100°F) when tested in accordance with the applicable method.

Division 3—Combustible Liquids

A product, material, or substance is considered Division 3 if it has a flashpoint of 37.8°C (100°F) or more but less than 93.3°C (200°F) when tested in accordance with the applicable method. Examples: kerosene, mineral spirits.

Division 4—Flammable Solids

A product, material, or substance is considered Division 4 if it meets any one of four criteria:

- causes fire through friction or through retained heat
- ignites readily and when ignited burns so vigorously and persistently as to create a hazard
- ignites readily and burns with a self-sustained flame at a rate of more than 2.54 mm per second (0.1 in. per second) along its major axis
- meets the criterion for flammable solids (Division 1 of Class 4) of the TDG Regulations.

Division 5—Flammable Aerosols

A product, material, or substance is considered Division 5 if it's packaged in an aerosol container and produces a flame projection or a flashback of any length.

Ignition may be due to the flammability of either the aerosol itself or the propellant. Examples: propane, butane, isobutane, and dimethyl ether.

Division 6—Reactive Flammable Materials

A product, material, or substance is considered Division 6 if it meets either of two conditions:

- it's spontaneously combustible and liable to spontaneous heating under normal conditions of use
- it emits a flammable gas or becomes spontaneously combustible on contact with water or water vapour

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Class C—Oxidizing Materials

A product, material, or substance is considered Class C if it meets either of two conditions:

- it causes or contributes to the combustion of another material, whether or not the product is itself combustible
- it's an organic peroxide that contains the bivalent O-O structure

Class D—Poisonous and Infectious Materials

A product, material, or substance is considered Class D due to a broad range of adverse effects; from acute lethality to mutagenicity and cancer.

Materials Causing Immediate and Serious Toxic Effects

Criteria deal primarily with the capability of materials to cause death to test animals in short-term tests.

Materials Causing Other Toxic Affects

Criteria deal with effects other than immediate and serious. For example: skin and eye irritation; long-term effects such as chronic toxic conditions; mutagenicity; sensitization; cancer.

Biohazardous Infectious Materials

This Division of Class D applies to materials which cause disease or are reasonably believed to cause diseases. Examples: viruses, bacteria, rickettsia, fungi, protozoa, and helminths.

Class E—Corrosive Materials

A product, material, or substance is considered Class E if it destroys or irreversibly alters living tissue by chemical action at the point of contact. Examples: sodium hydroxide, hydrochloric acid, hydrofluoric acid.

Class F—Dangerously Reactive Materials

A product, material, or substance is considered Class F if it meets any one of three criteria:

- it undergoes vigorous polymerization, decomposition, or condensation
- it becomes self-reactive under conditions of shock or increased pressure or temperature
- it reacts vigorously with water to release a gas that has an LC_{50} no more than 2500 ppm by volume of gas

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Learning Task 8

Apply WHMIS Regulations as they Apply to Hazardous Materials Used in the Shop

There are three main concerns when dealing with hazardous materials in a shop:

- how to handle the hazardous materials
- how to store the hazardous materials
- how to dispose of the hazardous materials

The MSDS for each material will have the necessary information for all three concerns.

Some of the more common hazardous materials you will deal with include:

- solvents
- caustic cleaners
- cleaning solutions
- alcohol
- gasoline
- diesel fuel
- liquid petroleum gas
- compressed natural gas
- asbestos
- battery acids
- refrigerants
- brake fluid
- anti-freeze
- lubricants
- tracing dyes

Solvents

The most common cleaning liquid used is solvent. The solvent normally used in shops is a petroleum product which is quite safe. It's not very flammable as it has a high flash point. There are various types of tanks used when cleaning with solvent.

It's recommended that you use nitrile gloves and safety glasses while working with solvent-cleaning tanks. This prevents the solvent from penetrating your skin or spraying into your eyes.

NOTES

Solvent is also used with an air siphon gun when cleaning assemblies. The siphon gun draws solvent from a container and propels it with a flow of air, creating a pressurized fog. This is an effective cleaning method, but it can create an explosive hazard under certain conditions and is also a respiration hazard. For these reasons, this cleaning method is not recommended.

If solvent is spilled, it must be cleaned immediately with spill pads or floor-dry.

Storage and Disposal

Solvents are stored in a cleaning tank or in 20-litre containers.

Solvents must be disposed of according to regulations for hazardous goods. It's recommended that a recycling program be established to eliminate inappropriate disposal. Consult local ordinances and requirements and follow the recommendations for proper disposal.

Caustic Cleaners

Caustic cleaners are another type of cleaning solution composed of various chemicals such as caustic soda, lye, or acids such as carbolic acid. They are used for harsh or heavy-duty cleaning operations and require a special cleaning tank that heats the solution.

This type of cleaner is referred to as a hot tank cleaner. The acidic solution will dissolve dirt and nonferrous metals when submerged in the solution. You need to wear approved gloves, a full-body apron, and face shield when working with this type of cleaner.

In cases of spillage, the acid is diluted with water, washing the acid compound to a holding tank system or down the shop drain.

This type of cleaner has faded out as it's very dangerous and the chemicals get into the shop drainage system. The new system that has replaced it is referred to as a parts washer. The washer is similar to a large dishwasher that sprays a heated cleaning chemical on a rotating turntable. It is much safer than the caustic cleaner and the chemicals are contained in a closed system allowing for easy disposal.

Storage and Disposal

New caustic cleaners are stored in 20-litre containers.

The supplier will pick up the used cleaner in containers for disposal.

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Cleaning Solutions

Many modern cleaning solutions (such as brake clean, or electrical cleaner) are considered non-toxic. However, even though the cleaning solution itself may be considered non-toxic, it may wash out toxic products. This new mixture may be hazardous and should be treated as such.

Cleaning solution is sprayed on a component with a hand pump or aerosol can. You should be in a well-ventilated area or wear proper lung protection. The component then is wiped dry with towels. Always wear approved gloves and safety glasses.

Spilled cleaning solution must be wiped up immediately as it may contain toxic materials.

Storage and Disposal

Cleaning solution is usually purchased in 20-litre containers then poured into 1-litre pump containers.

The product is disposed of with the towels used to dry the component.

Alcohol

Alcohol is a unique volatile liquid which is not only a type of fuel used in internal combustion engines, but is also an excellent cleaning agent for specific jobs. It's most commonly used for cleaning the rubber parts in brake systems. These rubber parts will be damaged if a petroleum-based solvent is used. Alcohol must be used in a well-ventilated area.

Gasoline

The most hazardous aspect of gasoline is that it's extremely flammable and the various chemicals that control its ignition and stabilize it are very toxic. You must take precautions if you're required to handle gasoline.

Never handle gasoline when there is a spark, flame, or hot object present. Avoid spilling gasoline on the floor or on your skin. Never, under any circumstances, use gasoline for cleaning parts.

Store gasoline only in those containers that are approved for fuel use. This is especially critical if you're storing gasoline inside a shop or building.

Use caution when pouring gasoline through a funnel. Any funnel, metal or plastic, can have a static charge build-up in it simply as a result of the fuel flowing through it. Always insert the funnel into the neck of the tank so that it touches the tank and is grounded.

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Storage

Outside, above-ground gasoline storage tanks must be located more than 12.2 m (40 ft.) from any building.

Oxidation and gum deposits are also problems to consider when storing large amounts of gasoline. Refiners of gasoline add an inhibitor that will protect the fuel for six months to a year under normal storage conditions. This time is greatly reduced if the gasoline is exposed to sunlight and to high storage temperatures. There are also certain metals, such as copper, that cause gum to form more quickly.

Storing only the quantity of gasoline that you can use in 30 days can reduce potential gum deposits. Gum deposits, as well as loss through evaporation, is reduced in underground tanks since the fuel remains cooler.

Protection against water and dirt is also important. The same precautions for reducing evaporation loss also help reduce moisture condensation in the tank. Condensation occurs more rapidly in above-ground tanks. The greater the temperature variation in a storage tank, the more air it "breathes in and out." The fresh warm air that is "breathed in" may contain more moisture than it can hold when the temperature drops. This causes moisture to condense on the inside of the tank and collect beneath the fuel. This moisture must be occasionally drained or pumped out in order to avoid freezing or rust formation. Failure to do so will result in damage to vehicles using the gasoline.

Disposal

Disposal of gasoline is not generally a problem because the fuel is consumed and the need for disposal is rare. If a tank of "bad" gasoline needs to be disposed of, contact the fuel supplier.

Gasoline should never be poured into a drainage system. In addition to the potential for an explosion and fire, disposing of gasoline in this manner is an environmental hazard.

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Diesel Fuel

Diesel fuel is one of the safest fuels to handle due to its high flash point. However, it does contain chemical stabilizers and other toxic chemicals. Avoid spilling diesel fuel on your clothing, as it may cause skin irritation or damage and can create a fire hazard.

In spite of the relative safety of handling diesel fuel, there is still the need to employ common sense.

Storage and Disposal

Storage requirements for diesel fuel are similar to those for storing gasoline. Evaporation is not a major concern with diesel fuel. The main consideration when storing diesel fuel is to avoid contamination from dirt and water. Great care must be taken to keep the fuel clean.

Should you need to dispose of diesel fuel, contact the fuel supplier.

Liquid Petroleum Gas

The handling of liquid petroleum gas (LPG) is quite different from the handling of either gasoline or diesel fuel because of its nature. LPG can either be all propane, all butane, or a combination of the two gases.

Currently, LPG is either all propane or mostly propane because of the high demand for butane in the chemical industry. Both products are gases and cannot be used through a regular gasoline tank. Both must be stored and handled in high-pressure containers to keep them in liquid form. Butane boils at approximately 0°C (32°F), while propane boils at –42°C (–44°F).

When confined to a closed container, the gas pressure varies with the outside temperature. Butane develops 255 kPa pressure at 38°C (37 psi at 100°F) while propane develops 1340 kPa (195 psi) pressure at the same temperature.

LPG is quite a bit heavier than air. For this reason, you must be careful when using LPG, as any gas that escapes will accumulate in low areas and could result in an explosion or fire.

Do not touch LPG with your bare hands, as it "freezes" and can burn your skin. Wear leather gloves and safety glasses when handling LPG containers.

Storage and Disposal

Since LPG is kept under pressure and is highly flammable, the National Board of Fire Underwriters for construction of LPG storage tanks has established rigid standards. You can tell if your tank has met Underwriters Laboratories' standards by reading the label on the name plate.

The nameplate also tells whether the tank is designed for above-ground or underground use, its working pressure in pounds per square inch, the capacity of the tank, the name of the supplier, and other information you may need to know (Figure 1). You should also note the date of manufacture or a listed expiry date.

Figure 1. LPG Name Plate

LPG has an odour additive to help you detect leaks in a storage tank or system. If a leak is suspected, never use an open flame to locate the leak. A soap solution should be used to locate a leak.

If you're involved in the filling of a propane tank of any size, make sure the tank is filled to only 80% of its capacity. This will give the fuel room to expand if the tank warms up and will prevent unwanted gas from escaping through the tank relief valve.

LPG must be stored in pressure-type tanks outdoors in their normal operating position. At ambient temperatures, it changes to gas unless kept under pressure. Consequently, storage of LPG is an entirely different problem from storing gasoline or diesel fuel.

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There is no problem in protecting fuel quality. There is virtually no evaporation from the pressure tank, nor does the fuel change chemically during storage. This enables you to have as large a tank as you wish and to keep the fuel indefinitely.

Because LPG fuel does not deteriorate in storage, there is seldom any need for disposal. If a storage tank needs to be emptied, the fuel supplier simply empties the contents into their own storage tank.

Compressed Natural Gas

Compressed natural gas (CNG or methane) is a viable alternate fuel for motor vehicles. It's a fossil fuel in gaseous rather than liquid form and it's kept under pressure as it leaves the ground. Compressed to about 20 MPa (3000 psi), natural gas can be stored in moderate quantities. Natural gas makes an excellent fuel. CNG has an octane rating that is approximately 130 which means that it can be used in diesel engines.

Since CNG is lighter than air, leaks will rise and dissipate. However, caution must be employed when equipment is indoors as overhead ignition sources may cause leaking gas to combust.

CNG has safety advantages over gasoline or propane:

- it requires a temperature greater than 700°C (1292°F) to ignite, while gasoline and propane will ignite at 450°C (842°F)
- it has an air-fuel ratio range of 4:1—14:1 for combustion, a narrower range than for gasoline

Storage and Disposal

CNG tanks are built to withstand extreme pressure and are tested at 34.5 MPa (5000 psi) or higher depending upon the tank. The tanks are heavy, rugged, and well-secured. They are less susceptible to collision damage than ordinary gasoline tanks.

As with LPG fuel, the fact that CNG does not deteriorate when stored means that disposal is seldom a requirement. Contact the fuel supplier in the rare cases where disposal is necessary.

Asbestos

Asbestos is no longer being used for gaskets, brake, or clutch surfaces. However, you may have to service and repair old machines that still contain asbestos.

Asbestos (or more precisely, asbestos dust) is very harmful if inhaled over an extended period of time. The dust settles into the air sacs of the lungs and is directly linked to lung cancer. In the mechanical trades, asbestos dust may be found in brakes (where asbestos may be one of the major substances in the lining material), in dry clutch disc facings (a compound whose main component is asbestos), and in gaskets.

Avoid disturbing asbestos dust in a way that will cause it to become airborne, which will create a health hazard. Do not blow the dust off the brake or clutch parts with compressed air. Always use proper, detailed procedures and use approved equipment for clean-up.

Other asbestos products that you will come in contact with are woven asbestos blankets used to protect components from sparks or flame during cutting or welding operations, and compressed asbestos board used for the same purposes. These items are not health hazards in themselves. Only airborne dust particles are harmful and must be avoided. Use approved respiratory equipment when necessary.

Disposal

Asbestos dust is very dangerous. If you're called upon to store or dispose of any asbestos material or products containing asbestos, avoid handling them in any way that would create airborne particles. Asbestos materials must be disposed of in approved, clearly marked containers according to regulations.

Battery Acids

Sulphuric acid is used in storage batteries. Sulphuric acid (or any acid) must be handled with extreme care. Acids can cause serious skin and eye burns. They can damage clothing or equipment if spills are not neutralized and cleaned up immediately. When you must work with acid, wear appropriate protection. Approved gloves, face shields, eye protection, and full-body aprons must be used.

If an accidental spill occurs and the acid comes in contact with your skin, immediately flush the area with large quantities of cold water. If acid has splashed into your eyes, flush with cold water and then consult a first aid attendant or physician. If the acid comes in contact with equipment or your clothing, you should use baking soda along with plenty of cold water to neutralize and flush away the acid.

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Storage and Disposal

Acids are usually stored in special containers that must be clearly marked with the appropriate warning signs and any special handling procedures that may be required. Pay attention to these signs and directions. Ignoring the special directions is very dangerous.

Acids must be disposed of through special processes at disposal centres.

Refrigerants

Refrigerant gases are environmentally dangerous. You must hold special certification to handle and purchase refrigerants. You don't need a certification to repair or inspect if there is no contact with refrigerants.

For many years, the refrigerant used in air conditioning systems was Refrigerant-12 or Freon (also known as R-12). The chemical substance ($CC_{12}F_2$) was used as the heat carrier medium because of its ability to change state from a liquid to a gas very easily within the temperature range of an air conditioning system.

R-12, and any product based on chlorofluourocarbons (CFCs), has serious environmental hazards. R-12 contains CFCs and when released into atmosphere, travels up into the stratosphere, depleting the ozone layer. The ozone layer protects people, plants, and animals from harmful ultraviolet radiation. Because of its damaging effects to the environment, federal legislation and international agreements are mandating the phase-out of traditional R-12 refrigerant. By the year 2000, CFCs were no longer manufactured.

A temporary alternative refrigerant, R134a (CH_2FCF_2, also known as tetrafluoroethane) replaces R-12. R134a is a HFC (hydrofluorocarbon) based refrigerant and has no damaging effect on the ozone layer. It may, however, contribute to global warming. R134a is also regulated in the same manner as R-12 in regard to handling and recycling (you need to be certified to handle and purchase it).

Some of the differing properties of R134a are:

- approximately 8% less efficient than R-12
- requires a different refrigerant oil
- requires a different desiccant
- operates under slightly higher pressure, requiring a stronger and tighter system
- requires a different kind of hose due to its chemical properties

Since it's not interchangeable with R-12, you must have separate sets of hoses, gauges, and recycling equipment for R134a. An industry-wide changeover to R134a has taken place.

Observe the following safety precautions when handling refrigerant:

- Keep the service area well-ventilated. Freon, at atmospheric pressure and room temperature, is heavier than air. It will displace air in the room and can lead to possible suffocation.
- Always wear protective goggles when you're working on or near an air conditioning system. Refrigerant vaporizes so quickly it will freeze anything it contacts. If it contacts your eyes, serious damage may occur.
- If refrigerant enters your eyes, do not panic! Splash large amounts of cold water into your eyes as a means of raising the temperature. Do not rub your eyes. Apply several drops of sterile (clean) mineral oil to the eye. The oil will absorb the Freon and help flush it from the eyes. Follow this with a liberal application of boric acid solution.
- Take the injured person immediately to an eye specialist or hospital.

The European Union and Japan have begun to produce cars with A/C systems that are "green house gas" friendly. That means they will eventually ship cars to the U.S. equipped with an alternative refrigerant, such as CO_2, and will have to outfit their dealerships with the proper training and service tools. Shops will then have to service both R134a and CO_2 cars. Heavy-duty equipment and vehicles will also follow this practice. R744 (CO_2) will be the replacement refrigerant for R134a. CO_2 can also be used as a heating system.

Disposal

Do not discharge refrigerants directly into the atmosphere. Refrigerants must be removed by equipment designed to store it in pressure containers to prevent any escape to the atmosphere. Only certified persons may perform this removal. Environmental regulations require that refrigerants be recycled.

Keep refrigerants away from open flames. Never steam-clean, weld, solder, bake body finishes, or in any way subject the air conditioning system to excess heat. Refrigerants, when closed to the atmosphere, will build up high pressures with heat. These pressures can easily burst the system or blow out the safety plug, emitting the entire refrigerant charge into the atmosphere.

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Refrigerants are stored under pressure in special containers. These refrigerant containers must be handled with care. If exposed to excess heat (even direct rays from the sun), the container may blow a safety plug. The protective screw cap should always be over the valve to prevent physical damage. Containers have been known to explode (even when equipped with a safety plug). If tank warming during servicing is needed, use warm water or warm wet rags. Never use a torch, gas stove, or steam cleaner to heat the tank. Never heat the drum above 52°C (125°F).

Brake Fluid

Brake fluid is a composite of glycerine, alcohol, and other performance additives. It's quite toxic and it will burn if splashed in your eyes. Brake fluid is harmful to painted surfaces and will lift paint in a matter of seconds. Spills must be avoided and painted surfaces should be protected.

Storage and Disposal

Brake fluid is supplied in marked, sealed containers. Any fluid that is not used must be kept tightly sealed, preferably in the original container. Cleanliness as well as safety is important with brake fluid. It's hydroscopic, and will readily absorb water. Water-saturated brake fluid is dangerous as it will boil when in use in a vehicle braking system.

Do not mix brake fluid with waste oils.

If you need to dispose of brake fluid, store it in an identified container and contact an oil recovery/recycling company.

Anti-freeze

The main ingredient in most anti-freeze is ethylene glycol. This is a poisonous compound and so care must be employed with its storage and use. Due to its sweet smell and taste, spills are particularly dangerous in areas frequented by children or pets. Make sure to clean spilled anti-freeze immediately.

Storage and Disposal

New anti-freeze is stored in containers supplied by the manufacturer.

Used anti-freeze must be stored in large transparent drums that are labelled as used or recycled. If anti-freeze must be disposed of, contact the supplier to have it recycled. Do not discard anti-freeze in the garbage or down drains.

Lubricants

Lubricants, such as engine oil, hydraulic oil, transmission oil, and differential oil must be properly identified. These oils may be in pails or in drums. Used oils should be handled with approved gloves.

Storage and Disposal

Lubricants used in the heavy-duty trade should be stored in a fireproof area.

Disposal of used oils should be poured into large oil storage drums and a recycling company should be contacted to recover the oil and have it re-refined.

Tracing Dyes

Florescent dyes are added to closed systems to help identify the location of leaks. It's important that any dye put into a system meet the manufacturer's specification for that system. You must wear approved gloves and safety eye wear when handling any dye.

Check the MSDS sheet to identify special safety equipment used for that specific dye.

Storage and Disposal

Tracing dyes are stored in the manufacturer's container until used.

Tracer dyes are recovered by the same recycling company that collects used refrigerant and oils.

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Learning Task 9

Identify Current Environmental Standards

Environmental Protection Agency

The U.S. Environmental Protection Agency (EPA or sometimes USEPA) is an agency of the federal government of the United States charged with protecting human health and the environment. It has approximately 17 000 full-time employees.

The EPA conducts environmental assessment, research, and education. It has the responsibility of maintaining and enforcing national standards under a variety of environmental laws, in consultation with state, tribal, and local governments. It delegates some permitting, monitoring, and enforcement responsibility to U.S. States and Native American tribes. EPA enforcement powers include fines, sanctions, and other measures.

The EPA also works with industries and all levels of government in a wide variety of voluntary pollution prevention programs and energy conservation efforts.

Canada follows most of the EPA standards, particularly those concerning vehicle emissions.

Environment Canada

- Environment Canada works toward protecting the environment, conserving the country's natural heritage, and providing weather and meteorological information.
- Environment Canada moves forward through credible science, effective regulations and legislation, successful partnerships, and service to Canadians.
- Environment Canada works to repair the damage of the past, to collect and pass on knowledge, and to develop, implement, and enforce policies to prevent future issues.

Environment Canada's mandate is to:

- preserve and enhance the quality of the environment, including water, air, soil, flora, and fauna
- conserve renewable resources
- conserve and protect water resources
- forecast daily weather conditions and warnings
- enforce rules relating to boundary waters
- coordinate environmental policies and programs for the federal government

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Hazardous Materials

Hazardous Materials (HAZMAT) is a system of hazardous chemical classification and fire-fighting modes.

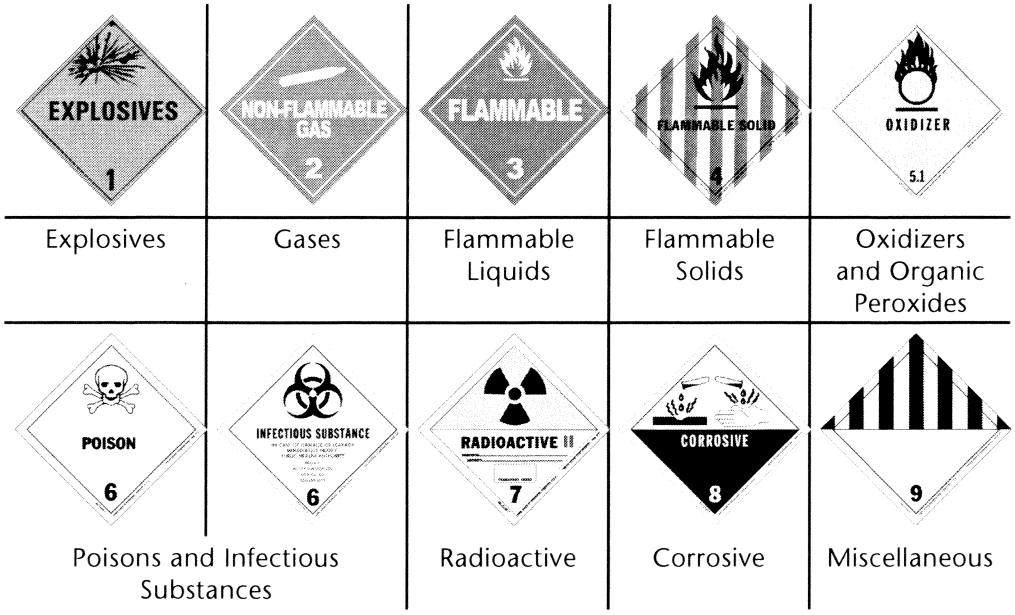

Figure 1. Examples of the Hazard Symbols

Dangerous goods are solids, liquids, or gases that can harm people, other living organisms, property, or the environment. They are often subject to chemical regulations. "HazMat teams" are personnel specially trained to handle dangerous goods. Dangerous goods include materials that are radioactive, flammable, explosive, corrosive, oxidizing, asphyxiating, biohazardous, toxic, pathogenic, or allergenic. Also included are physical conditions such as compressed gases and liquids or hot materials, including all goods containing such materials or chemicals, or may have other characteristics that render them hazardous in specific circumstances.

NOTES

Dangerous goods are often indicated with diamond-shaped signs or symbols (Figure 1). The colour of each diamond references its hazard:

- Flammable—red because fire and heat are generally of red colour.
- Explosive—orange, because mixing red (flammable) with yellow (oxidizing agent) creates orange.
- Non-flammable, Non-toxic Gas—green, due to the fact that all compressed air vessels were green in France after World War II.

All vehicles that carry dangerous goods, such as fuel, must show the diamond placard in the appropriate colours.

All buildings that carry dangerous goods in their pipes must have the pipes coloured and appropriate diamond placards to indicate the danger.

You must follow strict guidelines when working on trucks or machines that have diamond placards located at the rear.

Industry Standards

Many companies have additional guidelines for shop safety, handling of chemicals, storing of chemicals, and disposing and recycling of chemicals.

International Standards Organization 9001 (ISO 9001) is an international standard that some employers choose to follow. This standard establishes minimum guidelines for all shop record-keeping and shop standards for equipment and safety procedures. This is a very expensive and comprehensive way to control standards. Most aircraft service companies follow these standards. Other large, heavy-duty companies also choose to follow this standard. All employees working in such an environment must be trained on ISO 9001 Standards.

Safety

Many shops establish and regulate their own safety guidelines. Examples include:

- All employees must wear hard hats in designated areas.
- All employees must wear safety glasses in designated areas.
- All employees must wear safety coveralls with florescent strips.
- All employees must wear safety work boots in designated areas.
- All machines must be properly blocked by engineered stands and documentation for the date, time, and location that the machine was blocked. The technician and his supervisor must sign this document.
- An hour-by-hour logbook of all technicians' work must be maintained.
- All employees must attend weekly safety meetings.

Handling, Storing, Disposal, and Recycling of Chemicals

You must follow the basic safety requirements of WHMIS when dealing with chemicals. It does not matter what work environment you are in, you must follow best practices when dealing with chemicals and spills:

- Use absorbent mats instead of floor-dry as floor-dry creates dust that affects quality.
- Document all spills by type, location, and volume.
- Store chemicals, such as oils, in a special pressurized room to keep dust out.
- Use special biodegradable soaps to clean the shop floors.
- Document all chemicals recycled by work order number, type, and volume of chemical.

It's everyone's responsibility to identify areas of concern in the workplace. With proper training, desire to improve safety standards, and proper handling of chemicals, the workplace will become a safer work environment.

NOTES

COMPETENCY A-4

Use Hand Tools, Power Tools, and Shop Equipment

HEAVY MECHANICAL TRADES:
LINE A—COMMON OCCUPATIONAL SKILLS

Goals

When working in the mechanical trade you need to be aware of the clothing and protective equipment you must wear on the job site. You also need to be aware of the safety precautions to protect yourself and others from injury when working with tools and shop equipment.

The most important concept to remember is that you are responsible for your own safety and the safety of others. Unfortunately, they can be forgotten or overlooked unless you make safe practices a habit or an instinct. Too often a mechanic will take short cuts or neglect critical safety procedures when using tools. Improper use of tools and equipment can cause serious injuries and damage to the tools. Even a simple tool such as a screwdriver can cause a personal injury. The correct use of tools and shop equipment ensure the best results for yourself, your co-workers and employer.

Learning Task 1

Use Protective Equipment Associated with the Use of Tools and Shop Equipment

NOTES

When working in the mechanical trade, you need to be aware of the clothing and protective equipment you must wear on the job site. You also need to be aware of the safety precautions to protect yourself and others from injury when working with tools and shop equipment.

The most important concept to remember is that you are responsible for your own safety and the safety of others. This can be forgotten or overlooked unless you make safe practices a habit and an instinct. Too often a mechanic will take short cuts or neglect critical safety procedures when using tools. Improper use of tools and equipment can cause serious injury and damage to tools. Even a simple tool such as a screwdriver can cause personal injury. The correct use of tools and shop equipment ensures your own safety and the safety of your co-workers.

Personal Protection when Using Tools and Equipment

When working with tools and shop equipment, it's important that you wear appropriate personal protection equipment (PPE). Even when working in a familiar shop, you must be aware of what others are doing. There may be mechanics near you who are welding, grinding, or using an air chisel so you must protect yourself at all times.

Head Protection

A cap or beanie can protect your scalp and hair from burns when welding or cutting with a torch. Many employers have mandatory areas where hard hats must be worn. A hard hat should always be worn when working with overhead hazards. When working with an overhead crane, there's a chance that something could drop and hit your head. It may be a wrench or hammer or bolt that was left on top of the component being lifted. A chain could break and drop the component. Any of these items hitting you in the head can cause serious personal injury. The best way to prevent this is by wearing a hard hat anytime there's an overhead hazard.

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Hand Protection

There are several different types of hand protection available, depending on the tool or equipment being used:

- welding and cutting equipment—wear leather gauntlet gloves
- air impact tools—wear padded gloves
- washing in solvent—wear nitrile or chemical resistant gloves
- general work like drilling, moving parts—wear leather palm gloves

Lung Protection

Certain tasks produce harmful materials that contaminate the air you breathe. For example, an air impact wrench can spread harmful brake and clutch dust. Over time, these can cause serious health issues. Wearing a respirator, certified to filter the contaminants you're working with, is critical to protect your lungs.

Eye Protection

You should wear eye protection even when not required by your employer. Your eyes can be damaged any time during your work shift. Blowing off parts, hammering a pin, or grinding metal can all cause debris to enter and damage your eyes. Safety glasses, face-shields, welding goggles, and welding masks all protect your eyes from flying projectiles.

Ear Protection

Work environments can be noisy. Hammering, air impacts, air chisels, and grinders all produce noise. Many of these sounds damage particular portions of your hearing, causing you to lose the ability to hear certain tones. Protect your hearing by wearing ear muffs, custom plugs, or foam earplugs.

Foot Protection

Tools and equipment are typically very heavy and can cause damage if dropped on your foot. Job sites present many hazards that can result in a twisted ankle. For your protection, WorkSafeBC requires that you wear steel-toed boots. Select ones that give you support and cover your ankles. Many boots have a steel shank that prevents anything penetrating the sole.

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Clothing Protection

Your coveralls provide a protective layer when lying on the floor or when a working on a dirty or oily machine. Wear waterproof pants and jacket when power-washing a machine or when out in rainy weather. Leather pants and jackets protect you from slag, heat, and sparks when welding. Many coveralls have high-visibility (reflective) stripes allowing you to be seen more easily. View your coveralls as a sacrificial layer between your clothes and the shop environment.

Screening

There may be several workers in a shop, each creating a variety of hazards. One may be repairing an engine, while those on either side are repairing undercarriages or extending a frame. Screens and curtains are used to contain and control particles flying throughout the shop. They must be positioned to prevent the spread of hazardous materials. The curtain also shields the harmful rays from arc welding. Whether canvas, metal or transparent, correctly-positioned curtains will prevent you and your co-workers from arc welding flash.

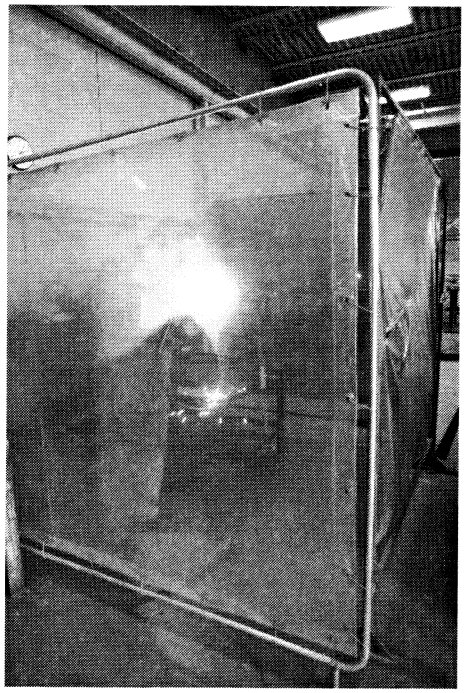

Figure 1. Correctly-positioned Curtains

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Guarding

Some equipment can be dangerous and should have guards positioned around them to keep other mechanics out of harm's way. Tools such as tire changers, wheel balancers, and a hydraulic press should have guards around them. Guards are also used when you're working on a machine and you want other mechanics to stay out of the area for their protection. Plastic pylon cones or caution tape can be positioned around the equipment as a visual indicator.

Figure 2. Correctly-taped Area

Ventilation

Workshops usually have some type of ventilation equipment for exhausting harmful dust or fumes. Many types of ventilation equipment may be found in the workplace. It's important to become familiar with and use the ventilation equipment or systems. These may include:

- Vacuum systems for the removal of brake dust when working on brakes.
- Exhaust systems for the removal of exhaust gases. These must be used any time a gasoline, diesel, or alternate fuel engine is being operated.
- Ventilating equipment in body shops and spray painting booths that remove harmful dust and toxic paint fumes.
- Ventilation equipment used when workers are required to work in confined spaces, such as a large boiler or storage tank, especially during oxy-acetylene cutting or welding.

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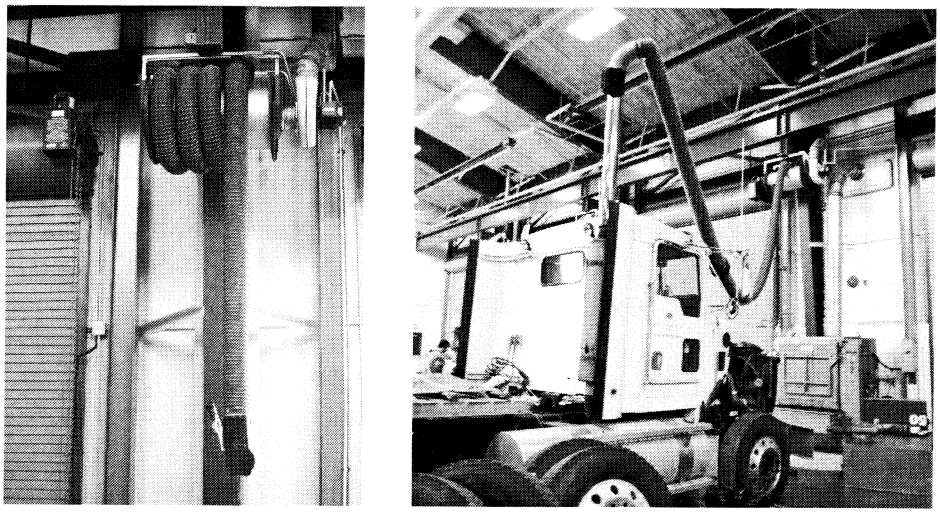

Figure 3. Ventilation System

Clean-up

The cleanliness of the work area, tools, and equipment is the responsibility of every mechanic. Clean up spills as soon as they happen. Keeping your work area clean is important as there's less chance of contaminating your work and it stops the spread of the mess throughout the shop. Follow these general clean-up rules:

- work areas, tools, and equipment should be cleaned up regularly
- the floor area should be swept daily and waste disposed of appropriately
- contain spills immediately
- use appropriate spill kits
- dispose of rags and hazardous waste appropriately
- recycle waste products as required
- if you are unfamiliar with shop equipment or procedures, ask your supervisor

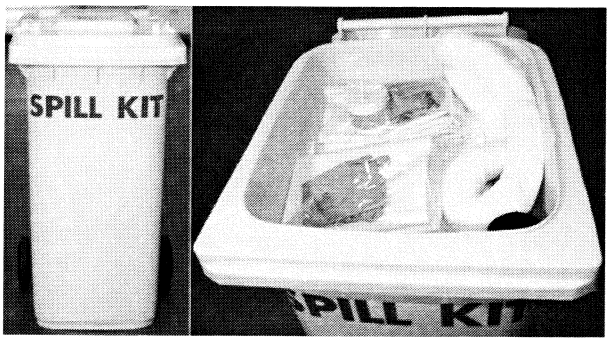

Figure 4. A Large Spill Kit

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Learning Task 2

Apply Lockout Procedures to Shop Equipment

When servicing or repairing a tool or equipment, you must attach a lockout tag/lock. The lockout will inform other mechanics that someone is working on this unit and not to attempt to start the tool or equipment. If the tool is damaged or inoperable, install a lockout tag/lock and identify the problem. It's a criminal offence to remove a lockout tag that has been installed by another person without their permission.

Figure 1. "Do Not Start" Tag

Learning Task 3

Select, Use, and Maintain Hand Tools

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Hazards

Hammers, wrenches, chisels, pliers, screwdrivers, and other hand tools are often overlooked as sources of potential danger. Hand tools may look harmless, but they're the cause of many injuries. An estimated 8% of all workplace injuries are caused by incidents associated with hand tools. These injuries can be serious.

Cuts, abrasions, amputations, and punctures: Hand tools designed to cut metal and wood can do serious damage to human flesh.

Repetitive motion injuries: Using the same tool in the same way, day after day, can stress your muscles and ligaments. Using the wrong tool, or using a tool incorrectly, can also cause problems. Carpal tunnel syndrome (inflammation of the nerve sheath in the wrist) and injuries to muscles, joints, and ligaments are becoming more common.

Loss of vision: You can injure your eyes if you don't wear eye protection when using striking and cutting tools. Flying chips of wood or metal are a common hazard, often causing permanent blindness.

Broken bones and bruises: Tools can slip, fall from ladders or even be thrown by careless employees, causing severe injuries.

Death: A hammer falling from three stories above is a lethal weapon.

Hand Tools Safety

Seven Basic Safety Practices

The misuse of common hand tools is a major cause of injury to maintenance and construction workers. Compared to power tools, hand tools appear simple and easy to use, but the record of injuries shows that this is not the case. Most hand tool accidents are caused by failing to follow one of seven basic safety practices:

- work with a safe attitude
- select the right hand tool for the job
- organize the work area
- use hand tools correctly
- keep hand tools in good condition

NOTES

- carry hand tools in a safe manner
- store hand tools safely

Work With a Safe Attitude

Unsafe	
Bored	I'm on "automatic pilot" because a job seems too simple.
Careless	I've got no real commitment to doing a good job.
Emotional	I'm actively angry, sad, upset, or extremely happy and excited.
Distracted	I'm thinking about things other than the job at hand—daydreaming, worrying.
Tired	I'm worn out from too little sleep or too many hours on the job.
Reckless	I think that safety rules aren't important or don't apply to me.
Under the influence	I attempt to work while under the influence of drugs or alcohol.
Sick	I'm ill and not up to the requirements of the job I'm trying to do.
Selfish	I forget that other workers are affected by what I do.
Safe	
Attentive	I'm focused on my task and aware of my surroundings.
Organized	I plan the steps I will take to complete my work safely and efficiently.
Calm	I have a steady, relaxed mood and my mind is clear.
Team player	I look out for the safety of other workers and co-operate to complete tasks.
Informed	I understand safe workplace procedures and ask questions when I don't understand.
Careful	I take recommended precautions, and I wear protective clothing and equipment.
Healthy	My vitality and sense of well-being are strong.
Straight & sober	I'm free of the effects of alcohol and drugs.
Serious	I recognize that my choices and actions affect my fellow workers.

Select the Right Hand Tool for the Job

Tool design: A hand tool is any device placed in the hand to make a task easier. Good-quality, well-designed tools have the following traits:

- comfortable weight
- good balance
- firm grip

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If a tool is poorly-designed or is not right for the job, it may:

- have to be held at an awkward angle
- cause tension and fatigue in the fingers, wrist, or hand

Consider whether the job requires a tool with a pistol grip or an inline grip. When a lot of power or torque is needed, choose tools that allow for a pistol grip: the hand makes a fist with four fingers on one side and the thumb on the other, similar to holding the pistol grip of a power drill.

Tools that can be used in either hand allow you to alternate hands, and the tool can be properly used by the 10% of workers who are left-handed.

The grip surfaces of hand tools should be non-slip, nonconductive, and slightly compressible to better distribute hand pressure. Avoid tools that have grooves for fingers. For most people, the grooves are either too big or incorrectly spaced. The resulting pressure ridges across the hand can damage nerves or create hot spots of pain. Grooves along the length of the handle are intended to prevent slipping, but they can also cut into your hand and create pressure ridges, particularly if you use the tool continuously.

Weight is often a problem with hand tools such as hammers and saws. To reduce hand, arm, and shoulder fatigue, the tool should weigh no more than 2.25 kg (5 lb.). For precision work, where the small muscles of the hand support the tool, it should weigh far less. Lighter is better. Heavy tools can be made easier to use by suspending or counterweighing them.

Good hand tools should have the following characteristics:

- well-balanced
- fits the hand comfortably
- not so heavy that it strains the arm or shoulder
- stays in the hand without requiring a tense grip
- can be used in either hand
- handle is made of non-conductive, non-porous, non-slip, slightly compressible material that provides good insulation
- handle grips do not cut into the hand or create pressure spots
- excessive force is not required in order for the tool to perform
- does not force the hand or wrist into awkward positions

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Organize the Work Area

Follow these basic practices to keep your work area well-organized:

- Keep the work area clean and tidy to avoid clutter that can cause accidents.
- Ensure that the work area is well-lit.
- Keep tools out of the path of other workers. Mislaid and loose tools cause a substantial portion of hand tool injuries. Do not leave tools where workers are moving or walking.
- Keep close track of tools, especially when working at heights. A falling tool can kill a co-worker.
- Store tools in belts, pouches, or other appropriate containers when they are not being used. Sharp-edged or pointed tools should be kept in sheaths.
- Protect tools from contact with water, oil, hot surfaces, and chemicals that might damage them.
- Use tools only on stable work surfaces.
- Stand on a clean, dry surface to prevent slipping when working with tools.
- Secure work with a vise or clamps if necessary.
- Adjust work surfaces to minimize reaching, bending, and other awkward postures.
- Vary tasks so you don't use the same tool all day, straining the hand, wrist, arm, or shoulder.
- Use a tool belt when working on ladders, scaffolding, or at heights
- Never leave tools unattended on ladders, scaffolds, or overhead work spaces.

Use Hand Tools Correctly

Here are some general rules for the correct use of hand tools:

- Follow manufacturer guidelines for choosing and using Personal Protective Equipment (PPE): safety eyewear, CSA-approved work boots, gloves, hard hats, etc.
- Do not use any tool until you have been taught how to use it properly.
- Use the right tool for the right job.
- Use the tool properly. Do not apply excessive force or pressure to tools.
- Match the size of the tool to the size of the job.
- Stay within the limitations of the tool. Do not push tools beyond their capacities or use "cheaters" to extend their capabilities.

NOTES

The risk of repetitive strain injury is affected by the position of your hands and body, repeated movement, tool type and design, and the area in which you work. The following techniques reduce risks associated with using hand tools:

- Change stance or posture—allow legs and back to release tension.
- Relax grip—release tension in hands.
- Change work surface—change position of back and arms relative to work.
- Change handle—change required tension in hand muscles.
- Reduce pressure—reduce tension in hands, arms, shoulders, and back.
- Reduce force—reduce muscular demands on hands, arms, shoulders, and back.
- Change tool—give body a rest from repetitive patterns of tool use.
- Change tasks—give body a rest from the muscular and mental demands of performing a task.

Be on the lookout for signs of repetitive stress. Early detection might prevent a serious injury.

Keep Hand Tools in Good Condition

Employers are required to ensure that all tools used on the work site are in safe condition. Procedures for the care, inspection, and safe use of all tools must be established and all workers must follow these procedures. Follow these good tool care practices:

- Keep hand tools in good condition: sharp, clean, oiled, and dressed. Worn tools are dangerous. Examples of unsafe tools include wrenches with cracked or worn jaws; screwdrivers with broken points or split or broken handles; hammers with loose heads, broken or split handles; mushroomed heads on chisels; and dull saws.
- Inspect tools for defects before use. Replace or repair defective tools.
- Remove metal slivers, wood slivers, sawdust, moisture, and grime from tools before they are stored. Never remove these particles with bare hands.
- Replace cracked, splintered, or broken handles on files, hammers, screwdrivers, or sledges.
- Keep cutting tools sharp.
- Cover sharp edges to protect the tool and to prevent injuries.
- Ensure that the handles of hammers fit tightly into the head of the tool.
- Replace worn jaws on pipe wrenches.
- Redress burred or mushroomed heads of striking tools.
- Store tools properly after each use.

NOTES

Proper maintenance and repair of tools requires adequate facilities, work benches, vises, safety glasses, repair tools, grinders, and good lighting. Employees specially trained in the care of tools should be in charge of these facilities. If this is not possible, tools should be sent out for repairs.

Carry Hand Tools in a Safe Manner

Follow these basic procedures to ensure that tools are carried and passed safely:

- Never throw, toss, or drop hand tools to the ground.
- Never throw, toss, or drop tools to other workers.
- Pass tools—handle first—directly to other workers.
- Do not overload your tool belt.
- Hang tools at the sides of your tool belt.
- Balance the weight of tools on both sides of your tool belt.
- Sharp and pointed ends of tools should be fully sheathed by the tool belt and pointed downward.
- Do not carry tools in your hands for more than very short distances.
- If you must carry a sharp tool in your hands, hold it with points and cutting edges directed toward the ground and away from your body.
- Never carry tools in your hands when on a ladder or while climbing on a structure.
- Never carry tools in the pockets of trousers or jackets.

Store Hand Tools Safely

Follow these basic guidelines for the safe storage of tools:

- Plan for the proper storage of tools when they are not in use.
- Use toolboxes, tool racks, shelves, or other storage devices.
- The devices or facilities for tool storage should be large enough to house all tools in a well-organized and safe manner.
- All tools must be cleaned before being stored.
- Dull or damaged tools must not be returned to stock.
- Store tools so that they are protected from excessive heat and moisture.
- On large work sites, there should be a procedure for control of tools, such as a checkout system at tool cribs.
- If there is a tool room attendant or supervisor, this person should be qualified by training and experience to pass judgment on the condition of tools for further use.

Wrenches

NOTES

Wrenches come in many shapes and sizes. You will use them to grip, fasten, turn, tighten, and loosen objects like nuts, bolts, pipes, and pipe fittings. There are two major kinds of wrenches:

- pipe wrenches, which are used to grip round or cylindrical objects
- general-use wrenches, which are used on nuts and bolts with flat, parallel surfaces (e.g., square, hexagonal, or 12-point)

Wrenches can be fixed-size or adjustable.

There is a correct wrench for every job. Oversize wrench openings will not grip securely. Do not use shims to compensate for an oversize opening. Using the wrong size wrench can cause slippage or round the corners of a bolt, making it difficult to turn even with a properly-sized wrench.

Fixed-size wrenches fit single, specific sizes. Metric wrench sizes are expressed as whole numbers (e.g., 8, 10, 14, 32) that correspond to the size in millimetres. Non-metric sizes—also called SAE (Society of Automotive Engineers)—are expressed as fractions of an inch (e.g., 1/4, 1/2, 3/4, 1 1/2). In Canada, we use both metric and SAE fasteners (nuts, bolts, etc.). You must choose the correct type and size of wrench to prevent personal injuries or damage to equipment.

Adjustable wrenches are generally recommended for light-duty jobs or when the proper, fixed-size wrench is not available. Be careful when using adjustable wrenches. They are likely to slip because it is difficult to set the correct size and the jaws tend to "work" as the wrench is being used.

The size of a wrench is usually stamped on or near its head. For example, a metric wrench with a 15 mm opening on one end and a 17 mm opening at the other end would be called a 15 mm x 17 mm wrench. The opening in the head of the wrench is slightly larger than the size marked. This allows it to slip over the nut or bolt easily. The size of the wrench refers to the distance across the flats of a nut or bolt (see distance D in Figure 1).

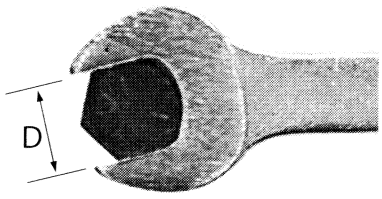

Figure 1. Open-end Wrench Size

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Open-end Wrenches

Open-end wrenches are characterized by their open end which allows them to easily slip onto a nut or bolt. They normally come in sets and are usually made of chrome steel for strength.

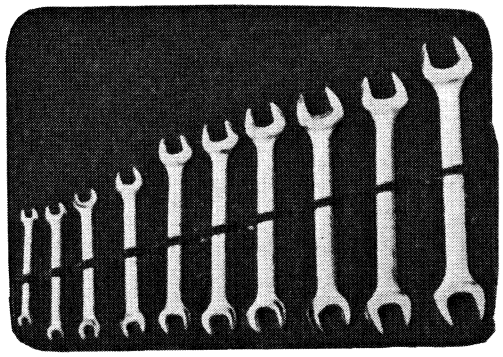

Figure 2. Open-end Wrench Set

Box-end Wrenches

Unlike the open-end wrench, the box-end wrench is made to grip the nut or bolt on all sides. This prevents slipping and allows greater leverage, but it means you have to be able to slip it over the top of the nut or bolt. As with the open-end wrench, each end of the box-end wrench is a different size and is stamped near the corresponding head. Commonly available in both 6 and 12 point box-end.

Figure 3. Box-end Wrench

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Combination Wrenches

A combination wrench (Figure 4) has an open-end wrench on one end and a box-end wrench on the other (both ends will be the same size). It has the speed of the open-end wrench for running a nut or bolt down snug, and the strength of the box-end wrench for completely tightening a nut or bolt. Combination wrenches have offset-heads open end are commonly available in both 6- and 12-point box-end.

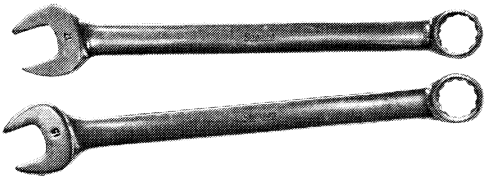

Figure 4. Combination Wrenches

Adjustable Wrenches

The adjustable wrench is very similar to the open-end wrench. The difference is that you can adjust the opening to suit the nut or bolt being turned. A knurled nut moves the adjustable jaw. Some models have a click locking mechanism.

The size of all adjustable wrenches is determined by the wrench length. This can vary from 100–600 mm (4–24 in.). For example, the 100 mm (4 in.) wrench has a 13 mm (½ in.) jaw capacity, while the 305 mm (12 in.) wrench has a jaw capacity of 33 mm (15⁄16 in.).

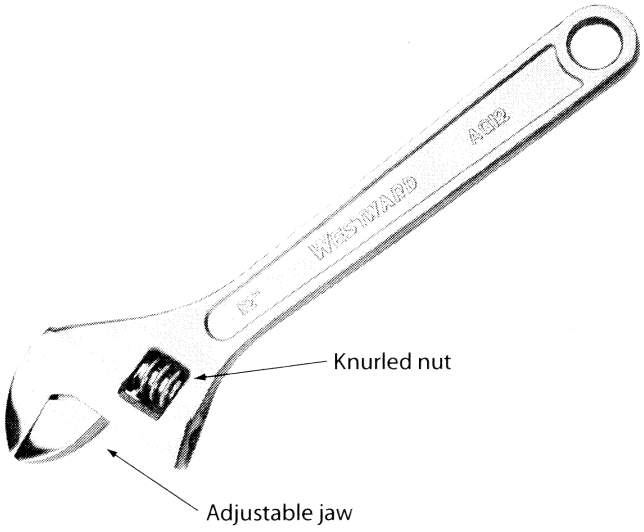

Figure 5. Adjustable Wrench

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Adjustable wrenches can be pulled in either direction, but they develop their greatest strength when pressure is applied to the side of the wrench with the fixed jaw (Figure 6). Always be sure to adjust the wrench as tightly as possible against the nut or bolt before turning. When applying force, you should always pull towards the adjustable jaw to prevent slippage and damage.

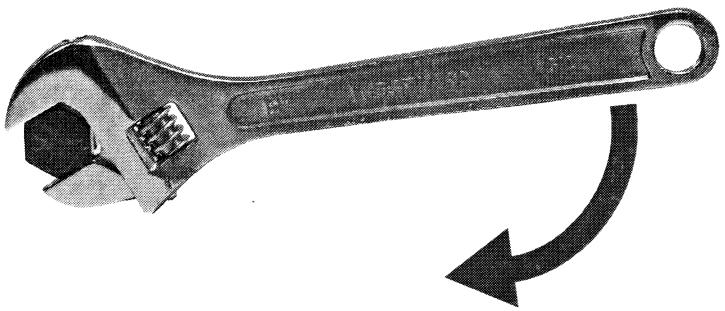

Figure 6. Correct Way to Use an Adjustable Wrench

Socket Wrenches

Standard sockets (top of Figure 7) are designed for turning both square and hexagonal fasteners. The 4- and 6-point sockets are stronger than the 8- or 12-point sockets because they have more contact area. Socket wrenches have a much wider application than other wrenches. They can reach into recesses that other wrenches cannot. They are unmatched for speed and ease in removal and installation. Some socket wrenches are thicker walled and are used with air impacts. There are 4-, 6-, and 12-point impact socket wrenches. The universal or swivel socket can be used at various angles. Deep sockets (bottom of Figure 7) enable you to loosen a nut on a stud or bolt where a standard socket would not be reach.

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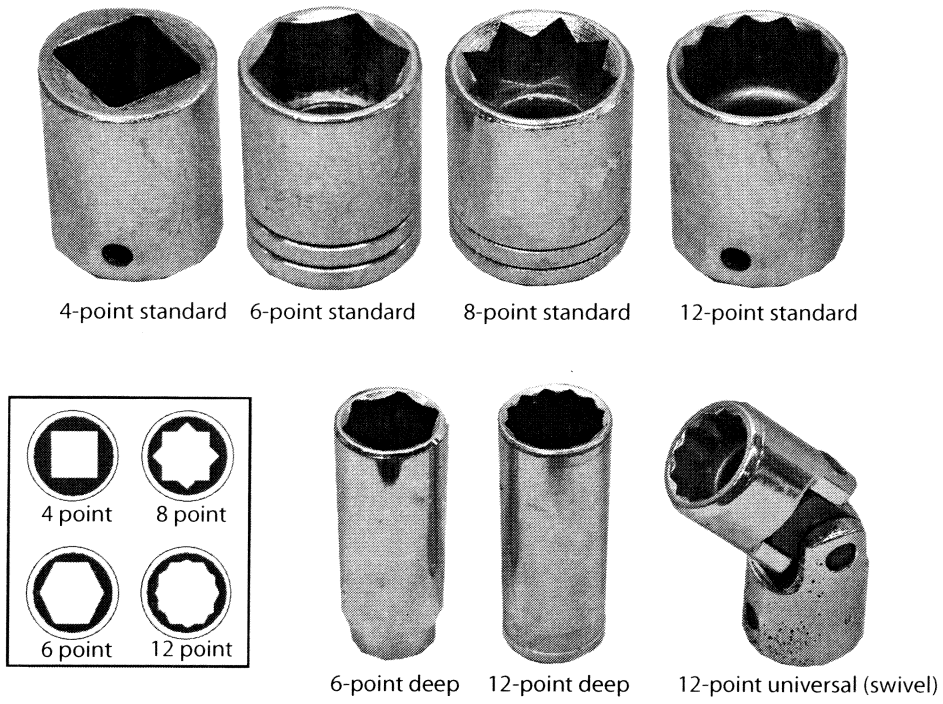

Figure 7. Sockets

The square drive is the square end of the socket that attaches to the socket handle (Figure 8). The square drives of sockets are normally referenced in imperial measure, from 1/4 in. to 2 in. (larger sizes are for heavy industrial use). The 1/4 in., 3/8 in., 1/2 in., and 3/4 in. sizes are the most common.

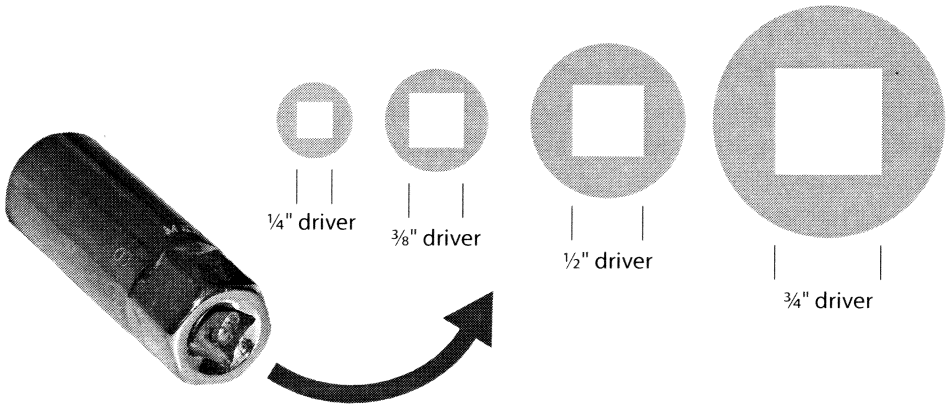

Figure 8. Square Drives

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The socket handles shown in Figure 9 all have a holding device that joins the socket handle to the socket. The small, half-exposed ball bearing, centred on one side of the square drive, is held in place with a bushing insert just slightly smaller than the bearing. This is known as the "friction-ball holding device." It permits you to change sockets quickly and easily.

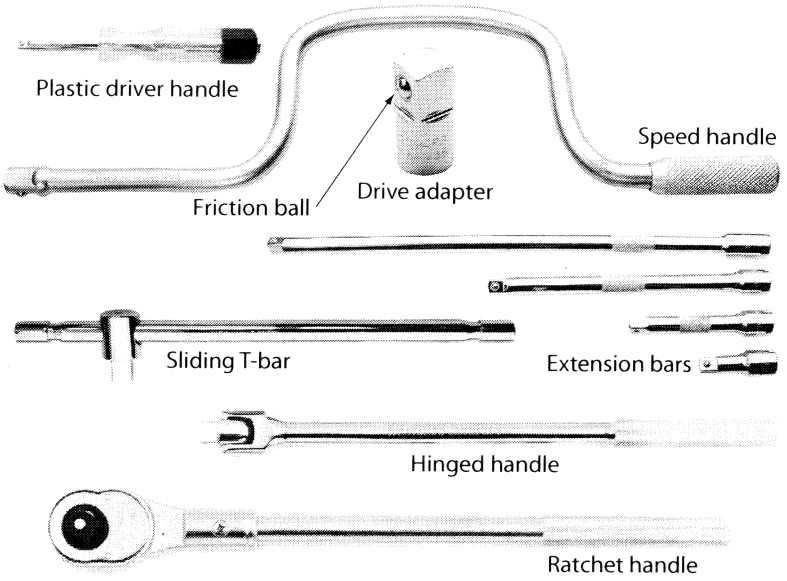

Figure 9. Socket Handles

Pipe Wrenches

Pipe wrenches (Figure 10) are used to turn pipe and other round objects. Pipe wrenches range in size from 240–1500 mm (6–60 in.). The bodies and handles of pipe wrenches are made of malleable iron or aluminum. Their replaceable jaws are made of hardened alloy steel. The sharp jaw teeth of pipe wrenches dig in and mar the surface when pressure is applied to the handle. Therefore, you should not use this wrench where appearance is important. Never use it to turn bolts or nuts.

Before using a pipe wrench, remove any grease or dirt from both the part to be turned and the pipe wrench jaws. Adjust the movable jaw so that the work is gripped near the centre of the jaws. Pull carefully until the wrench has a good bite on the work, and then exert force necessary to turn or tighten the work.

Never use a pipe wrench on a hardened surface because they will dull and chip the pipe's teeth.

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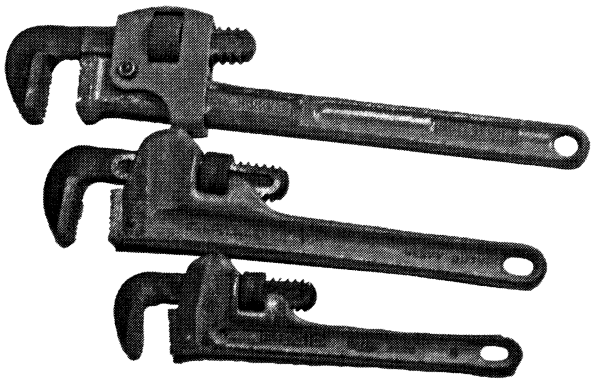

Figure 10. Pipe Wrenches

Hexagon Key Wrench (Allen Wrench)

The hexagon key or Allen wrench is an L-shaped bar of tool steel with a hexagonal or six-sided shape (on the left in Figure 11). It is made to fit the hexagonal hole in Allen screws. Allen wrenches are classified by the size of their hexagonal stock measured across the hex flats. They come in both imperial and metric measurements with the size stamped on the wrench. Allen wrenches are also supplied in socket-style wrenches (on the right in Figure 11). This makes them more effective when you need to use extra force to loosen an Allen screw. Be sure to clean out all dirt or foreign particles from the recessed opening in the screw in order to ensure total engagement of the tool.

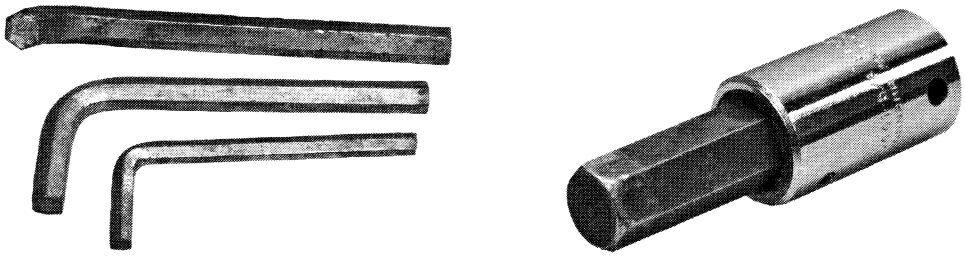

Figure 11. Allen Wrenches and Allen Socket

NOTES

Wrench Tips

Follow these safety tips when using any wrench:

- Discard damaged wrenches (e.g., open-end wrenches with spread jaws or box-end wrenches with broken or damaged points).
- Keep wrenches well-maintained.
- Clean and place wrenches in a tool box, rack, or tool belt after use.
- Use the correct wrench for the job: pipe wrenches for pipes and plumbing fittings; general-use wrenches for nuts and bolts.
- Select the correct jaw size to avoid slippage.
- Select a wrench with sufficient capacity and leverage to do the job.
- Pull on the wrench handle rather than pushing.
- Maintain a proper stance with feet firmly placed.
- Pull on a wrench slowly and steadily. Do not use fast, jerky movements.
- Position your body in a way that will prevent you from losing your balance and hurting yourself if the wrench slips or if the material being gripped suddenly breaks.
- When using a wrench above your head, stand to one side.
- Wear safety glasses or a face-shield where there is the possibility of flying particles or falling debris.
- Remove dirt and grime from inside the sockets to allow them to seat fully.
- Ensure that the jaw of an open-end wrench is in full contact (fully seated, flat, and not tilted) with the nut or bolt before applying pressure.
- When using an adjustable wrench, pressure should be applied to the side with the fixed jaw.
- Make sure adjustable wrenches do not "slide" open during use.
- When using a socket wrench, apply a small amount of pressure at first. This will tell you whether the ratchet mechanism is locking in the direction in which you are applying pressure.
- Support the head of a socket wrench when using a socket extension.
- Ensure that the teeth of a pipe wrench are sharp and free of oil and debris and that the pipe or fitting is clean to prevent unexpected slippage and possible injuries.
- Use a pipe wrench to turn or hold a pipe.
- Adjust the pipe wrench grip to maintain a gap between the back of the hook jaw and the pipe. This concentrates the pressure at the jaw teeth, producing the maximum gripping force. It also aids the ratcheting action.
- Check pipe wrenches regularly for worn threads on the adjustment ring and the movable jaw.
- Turn a pipe wrench so that the pressure is against the heel jaw.

NOTES

- Do not push on a wrench. Injury is more likely if you are pushing when the wrench slips.
- Do not use a wrench that is bent or damaged.
- Do not use a wrench on moving machinery.
- Always use the correct tool for the job.
- Do not insert a shim into a wrench for a better fit.
- Do not strike a wrench with a hammer or similar object to gain more force.
- Do not increase the leverage of a wrench by adding a sleeved extension (cheater) to increase tool handle length. Use a larger wrench instead.
- Do not expose a wrench to excessive heat as it can affect the temper of the metal and ruin the tool.
- Do not use worn adjustable wrenches. Inspect the knurl, jaw, and pin for wear.
- Do not pull on an adjustable wrench that is loosely adjusted.
- Do not use pipe wrenches on nuts or bolts.
- Do not use a pipe wrench to bend, raise, or lift a pipe.

Screwdrivers

Screwdrivers are to be used for only one thing, turning screws. Screwdrivers are available in a variety of lengths and handle sizes. Larger diameter handles give greater turning power, while smaller diameter handles increase the speed at which screws can be turned. The length of a screwdriver is measured from its handle to its tip. As a general rule, the longer the screwdriver, the easier it is to use. Lengths range from 38–300 mm (1½–12 in.) or more. Screwdrivers with very short lengths are known as "stubbies" and should only be used in locations inaccessible to a longer screwdriver.

Blade Screwdrivers

Blade or slot screwdrivers (Figure 12) are for turning screw heads with a single slot. Figure 13 shows how the blade of the screwdriver should fit the screw head. Note that the thickness of the blade must match the width of the screw slot and that the width of the blade must match the length of the screw slot. The tip of a blade screwdriver must be ground so that the wide faces are flat and almost parallel. Rounded tips tend to climb out of the slot under force.

NOTES

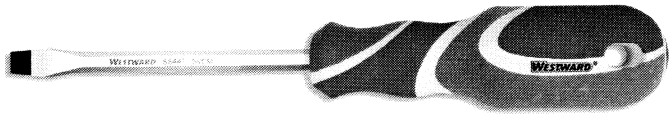

Figure 12. Slot Head Screwdriver

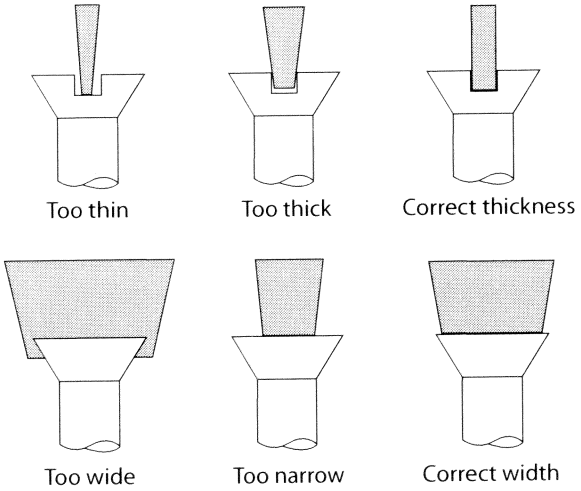

Figure 13. Incorrect and Correct Screwdriver Fit

Phillips Screwdrivers

Phillips screwdrivers (Figure 14) must match the size of the Phillips screws they are used on. If you use a screwdriver that is too small, the screw head and the screwdriver tip will be damaged as you apply force.

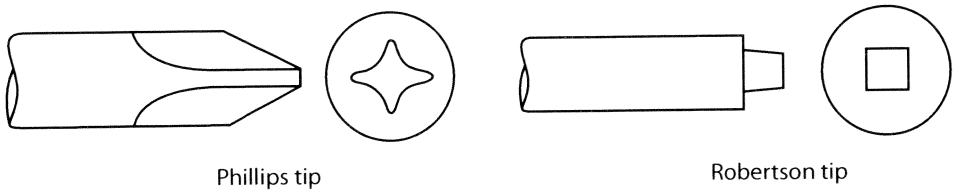

Figure 14. Phillips and Robertson Tips

Robertson Screwdrivers

Robertson screwdrivers have square tips (Figure 14). They must be matched to the screw. As with the Phillips, using a Robertson screwdriver that is too small may result in damage to the screw and screwdriver once force is applied.

NOTES

Robertson and Phillips screwdrivers are available in four point sizes and are normally colour coded (Figure 15).

Point size	Colour	For screw sizes
#0	yellow	3 and 4
#1	green	5, 6, 7
#2	red	8, 9, 10
#3	black	12 and 14

Figure 15. Point Size Colour Code Chart

Torx Screwdrivers

Torx screwdrivers (Figure 16) come in the following sizes: T7, T8, T9, T10, T15, T20, T25, T27, T30, and T40. The tips are extremely strong and are designed to be used with powered screwdrivers. Torx screw heads might appear to fit Allen wrenches, but you will find that as soon as any force is applied, the corners of the wrench or the screw will be damaged. Never use an Allen wrench on Torx screws.

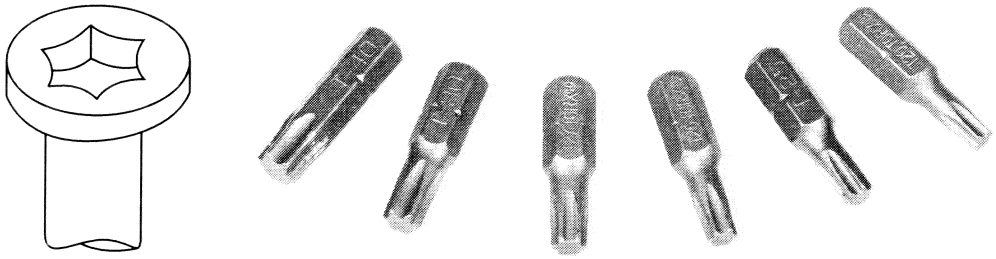

Figure 16. Torx Screw Head and Screwdriver Tips

Cutting Tools

There many hand tools that are used for cutting various materials such as hacksaws, files, shears, and chisels. They can be used to cut and shape materials like steel, aluminum, brass, and copper. You must learn the proper technique and maintenance of each of the cutting tools.

Hacksaws

Mechanics use hacksaws mainly for light-duty metal cutting. The hacksaw consists of a metal frame, handle, and saw blade. Adjustable hacksaws hold blades from 203–406 mm (8–16 in.) long (Figure 17). The non-adjustable type holds only the specific size blade it was made for. A hacksaw has a protective handle in case the blade breaks or your hand slips.

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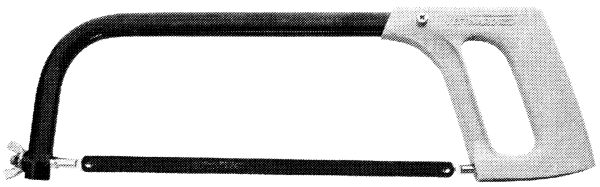

Figure 17. Adjustable Hacksaw

Hacksaw blades are made of hard, tempered steel (Figure 18). The blade can be flexible or all-hard. In a flexible blade, only the teeth are hardened whereas the all-hard blade is tempered throughout. Since hacksaw blades are tempered, they cannot be re-sharpened. Discard dull blades.

Figure 18. Hacksaw Blade

The pitch (number of teeth per inch) can be 14, 18, 24, or 32. The part number is stamped on each blade. It is a code number indicating the blade length (in imperial units) and number of teeth per inch. For example, code number 1018 identifies a blade 10 in. long, with 18 teeth per inch (Figure 19).

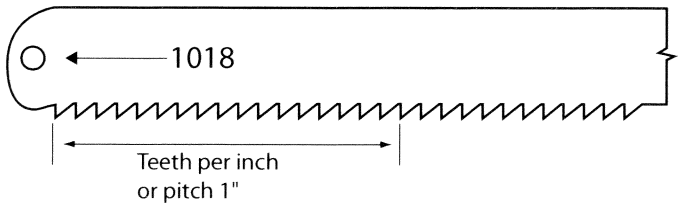

Figure 19. Blade Code Number

When you attach a hacksaw blade to the frame, be sure the blade is placed on the pins with the arrow on the blade pointing forward, away from the handle. If the arrow is not visible, ensure that the teeth of the blade face forward because all cutting is done on the forward stroke. There is no such thing as an all-purpose hacksaw blade. You must choose the right blade for the specific job. The hardness and thickness of the material to be cut will determine which blade you should use.

NOTES

A good rule to remember in choosing the right blade is to be sure that at least two teeth of the blade are in contact with the material being cut at all times (Figure 20). Soft materials such as aluminum, brass, soft steel, and copper should take a 14-pitch blade. Hard materials like drill rod and thin materials like sheet aluminum or thin wall tubing should take a 32-pitch saw blade.

To avoid ruining a hacksaw blade, always test the material to be cut by running the edge of a file along the area you are going to cut. If the material cannot be filed, it cannot be cut with a hacksaw.

The teeth of a hacksaw blade are alternately set in opposite directions from the sides of the blade. This angle makes the slot cut by the teeth slightly wider than the blade and prevents the blade from binding.

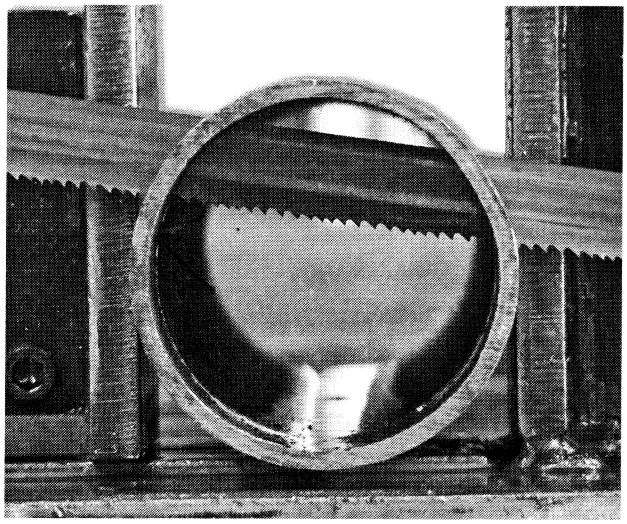

Figure 20. Blade Teeth in Contact

As the blade wears and the points of the teeth become dull, they straighten slightly and the cut made by the blade becomes narrower. As a result, a dull blade has a tendency to stick in the material being cut and breaks easily.

NOTES

Using a Hacksaw

Your technique is important when you use a hacksaw because the teeth are fine and the blade tends to be brittle. Follow these guidelines when using a hacksaw:

- Secure the material you are cutting in a vise or with a C-clamp.
- Secure the work piece low in the vise. If the material shifts while you are attempting a cut, the blade could break, the material could be damaged, or you could injure yourself.
- Be sure that the blade is tight in the hacksaw frame to prevent the blade from wandering during the cutting stroke.

Figure 21 shows the correct starting angle.

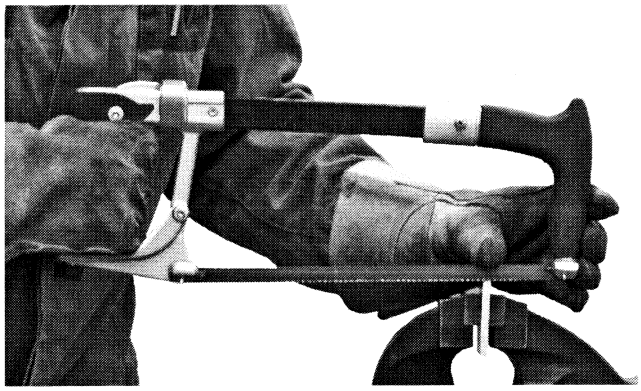

Figure 21. Correct Starting Angle

- Never start a cut with the saw held at a sharp angle to the material (Figure 22). This will break or dull the blade teeth and also violate the rule mentioned earlier about having at least two teeth contacting the material at all times.

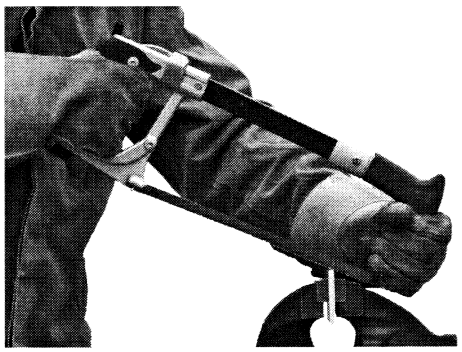

Figure 22. Incorrect Starting Angle

- Grasp the hacksaw securely, one hand on the handle and one hand on the frame.
- Like a file, a hacksaw cuts only on the forward stroke.
- Use a little downward pressure on the forward stroke but lift the saw slightly on the return stroke so that the teeth barely touch the material being cut.
- The stroke should be long and steady, using practically all the teeth on the blade.
- Use a lighter pressure on soft metals and thin materials. Use more pressure on hard metals and heavier materials.
- Too little pressure on the forward stroke will dull the teeth by rubbing them against the metal without cutting it.
- To ensure that the saw blade moves in a straight line, keep your shoulder, elbow, and forearm in line with the saw. This alignment is important to avoid any twisting or wobbling of the blade.
- Do not rush when using a hacksaw.
- Use no more than 60 forward strokes per minute. An ideal rate is 40 to 60 forward strokes per minute, with even pressure.

By following correct hacksawing procedures, you will use less effort, your cuts will be faster, the blades will last longer, and you won't injure yourself.

Files

Files are one of the most widely used of all metalworking hand tools.

Files are often used to clean up rough edges after cutting. There are many different kinds, sizes, and cuts of files available. We will cover only the most common ones.

Files have the following general uses:

- to remove extra material
- to fit material together more accurately
- to correct errors resulting from inaccurate machining
- to file a flat or smooth surface
- to file an edge
- to file a notch, slot, square, or round hole

NOTES

NOTES

You must learn the various parts of a file (Figure 23).

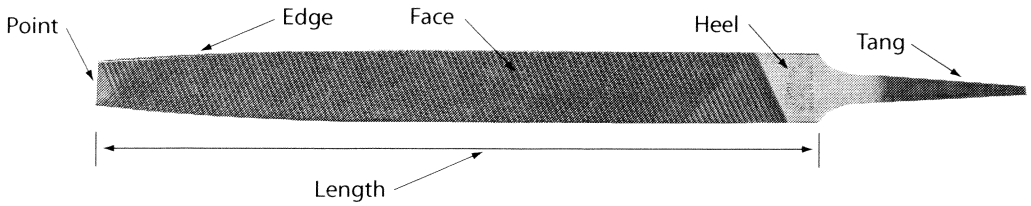

Figure 23. Parts of a File

Follow these safety tips when using a file:

- Using the right kind of file for the job will prevent injuries and increase the life of the file.
- Clean a file only with a cleaning card or brush.
- Never clean a file by striking it against a vise or other metal object. (The extremely hard and brittle steel chips and breaks easily.)
- Never use a piece of hardened steel (such as a pointed punch or chisel) to pick file teeth clean. The tempered steel can damage the teeth.
- Never hammer a file or use it as a pry bar. Such abuse can chip or break the file, leading to injury.
- Never use a file as a centre punch, chisel, or any other type of tool. (The hardened steel can fracture.)
- Never use a file that does not have a smooth, crack-free handle. If a file without a handle should bind, the tang could puncture the palm of the hand, wrist, or another part of your body.
- Do not use files on lathe stock turning at high speed (faster than three turns per file stroke). The end of the file could strike the chuck, dog, or face plate and throw the file (or metal chips) back at you.

Types of Files

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

Shape

The most commonly used shapes are the half-round file and the flat file (Figure 24). When welding pipe, you can use the half-round file to put the root face on the pipe and to remove slag and burrs. Flat files are for general-purpose and draw filing. The flat file normally tapers at the point with teeth on both edges.

NOTES

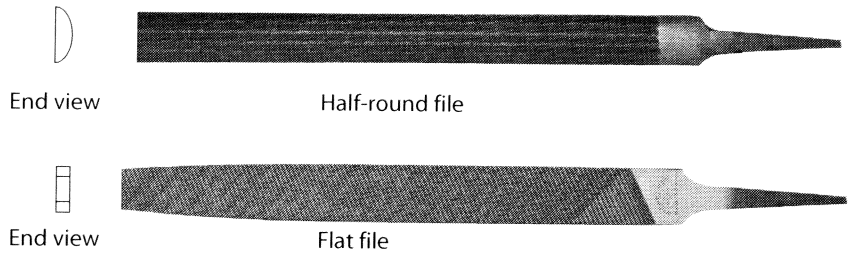

Figure 24. Half-round and Flat Files

Cutting Face

The cutting face of a file is classified according to two elements:

- the design of the cutting face
- the grade of the teeth

Cutting faces come in three designs (Figure 25):

- The single-cut file has one unbroken course of teeth running across the face of the file. It produces a smooth finish.
- The double-cut file has two broken courses of teeth crossing each other. Use this file for rough, fast metal cutting, or where you must file off large amounts of material.
- The curved tooth file is for filing soft metals such as lead or aluminum. It removes material very quickly and produces a smooth surface after each filing stroke.

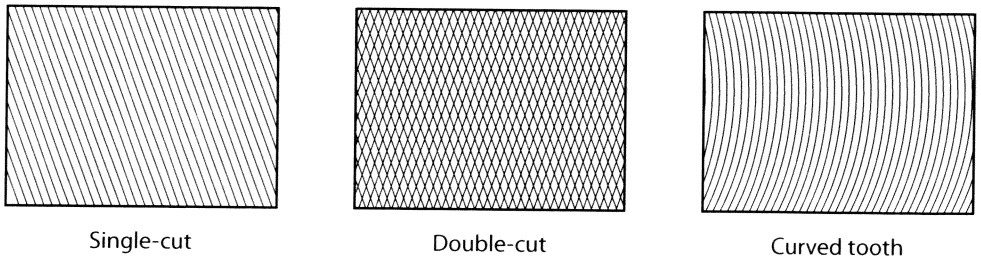

Figure 25. File Faces

Both single- and double-cut files come in six grades of teeth:

- rough-cut
- coarse-cut
- bastard-cut
- second-cut
- smooth-cut
- dead-smooth-cut

NOTES

The curved tooth file comes in only three grades:

- bastard-cut
- second-cut
- smooth-cut

The difference is the spacing between the teeth. The rough-cut file has the largest space between the teeth; the dead-smooth-cut has the smallest. The smaller the spacing is, the smoother the cut. However, the spacing is in relation to the overall size of the file. A large bastard-cut file has more space between the teeth and larger teeth than a small bastard-cut file. Figure 26 shows different grades of a single-cut file.

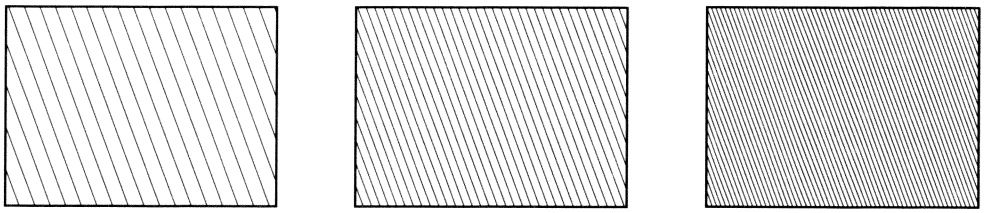

Figure 26. Single-cut File Grades

File Handles

Files are sold without handles, so the first step in using a file is to fit it with the proper handle. Always choose a handle that fits the file—neither too large nor too small. Wooden file handles should have a strong ferrule, or metal collar (Figure 27).

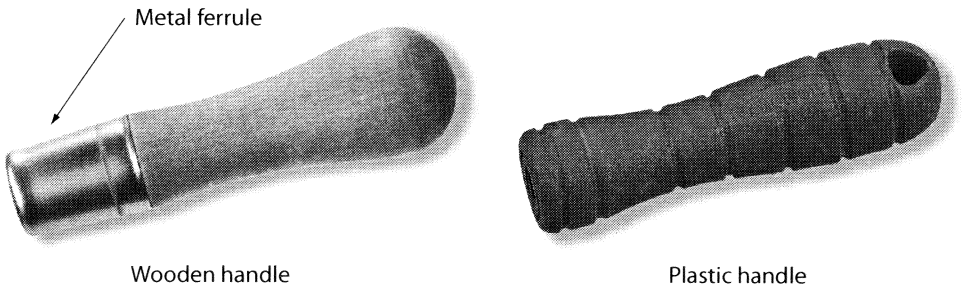

Figure 27. File Handles

NOTES

There are two main reasons for using a file handle on all files. The first and most important is your safety. The tang of a file is usually pointed. If you hit an obstruction while filing and the file stops suddenly, the tang could severely puncture your hand (Figure 28). Second, the handle helps guide the file, so the work can be done more accurately and quickly.

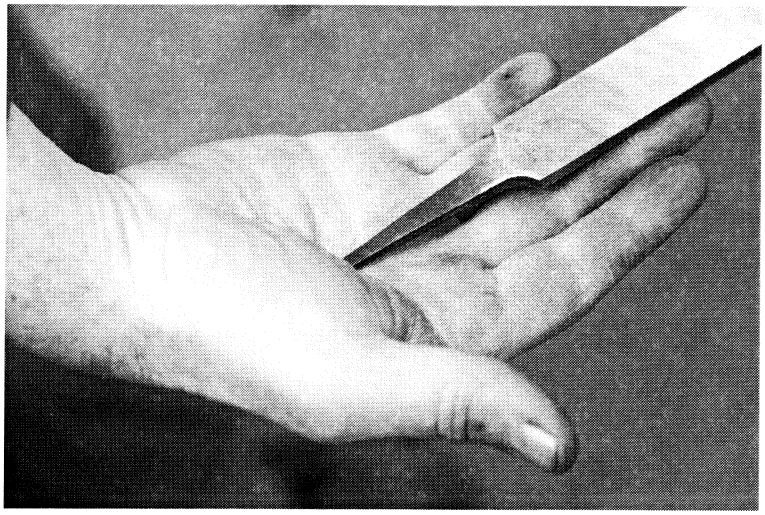

Figure 28. Severely Punctured Hand

Filing Technique

When first working with files, you must work slowly and check your work frequently in order to do the job correctly.

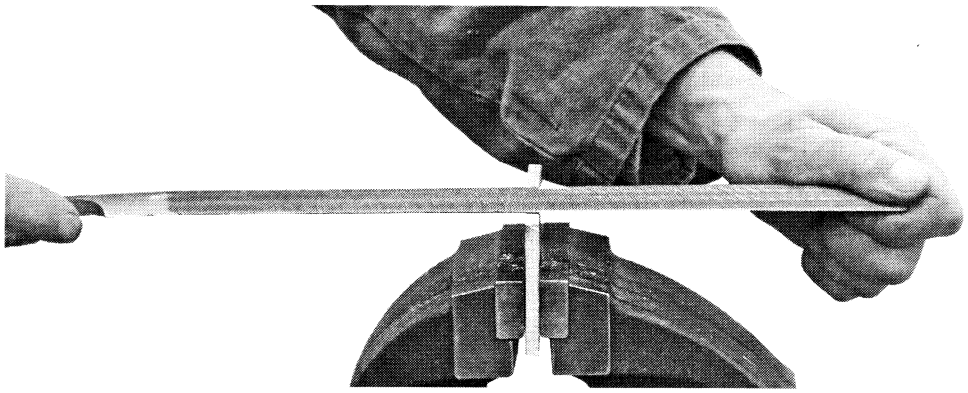

Figure 29. Good Filing Technique

NOTES

The following examples of poor technique **should be avoided**:

- Do not rock the file from left to right as you file the material. This will create a curved surface rather than a flat one.
- Do not bear down too hard in the middle of long cuts. This will create a low spot in the middle of the filed surface.
- Do not file without regularly checking the material. Frequent checks will help detect incorrect filing methods and prevent you from removing too much material.

The following are good techniques that you should follow:

- Clamp the work in a bench vise. If the work is a soft material, such as aluminum, protect it by using soft-jaw caps or placing pieces of wood, plastic, or soft metal between the vise jaws and the work.
- When moving the file across any work, hold the file as shown in Figure 29 and move it straight ahead or at a slight angle.
- Hold the file so that the handle end fits into the heel of your hand, with your thumb lying along the side of the file.
- Your forearm and the file should form a straight line.
- Hold the point of the file with your thumb and first two fingers of your other hand.
- For heavy filing strokes, the whole underside of your thumb should press down.
- On lighter strokes, place your thumb more at a right angle to the file.
- When filing a piece of material, frequently stop and check your work for even cutting and squareness. If you are filing incorrectly or at the wrong angle, you'll discover the problem before the material has been ruined.
- Use a steel square to get an accurate check of your work for even filing and squareness (Figure 30). Hold the body of the square firmly against one edge of the material and check that no clearance is visible between the bottom of the blade and the top edge of the material. If clearance is visible, your filing methods are incorrect.
- Filing with arm movement only will give you better control of the file. Moving your body back and forth while filing will give your work a rounded surface.
- The body should lean forward slightly during the forward stroke, then return to an upright position during the backward stroke.

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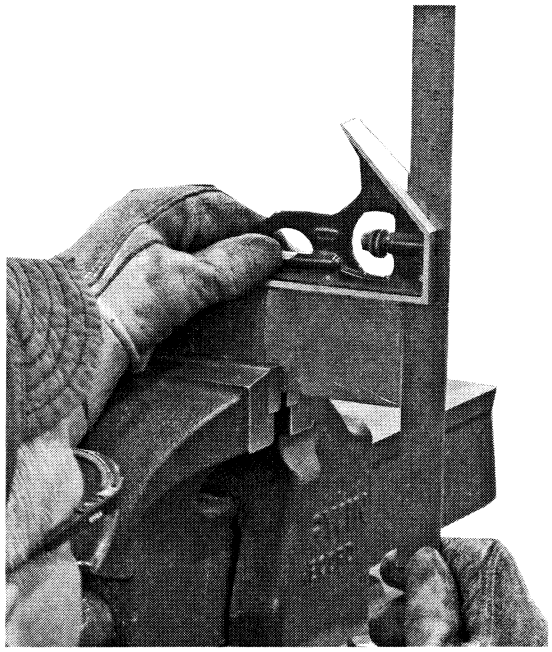

Figure 30. Checking for Square

Draw filing is a technique used to finish a smooth surface by removing only small amounts of material at a time (Figure 31). Generally, you should use a single-cut file for this. To draw file, hold the file in both hands with your thumbs no closer than 13–38 mm (½–1 in.) from each side of the material being cut. Then either push or pull the file straight across. Raise the file slightly on the back stroke as with ordinary filing. With soft metals such as aluminum, brass, copper, or lead, you can apply pressure on the backstroke without damaging the file. With different grades of files, and depending on the type of material you are cutting, the angle at which the file is moved across the material will vary slightly.

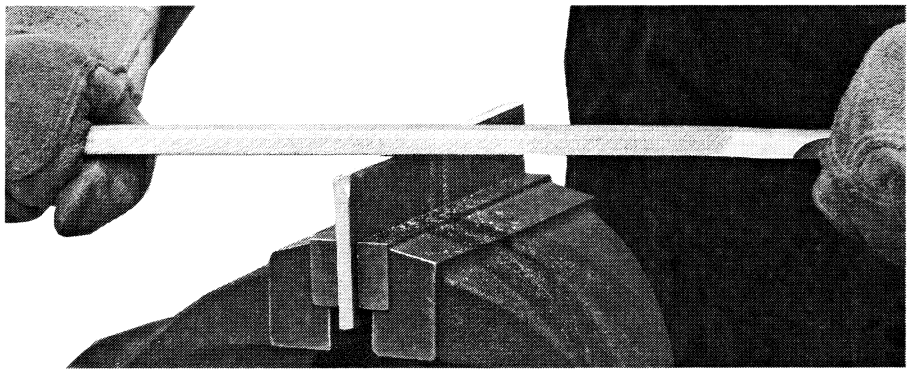

Figure 31. Draw Filing

NOTES

Maintenance of Files

Before starting any filing operation, especially the filing of low-carbon steel or soft non-ferrous metals, you should coat the file with soapstone. Soapstone acts as a dry lubricant and prevents metal cuttings from becoming pinned or trapped in the teeth of the file. These particles reduce the file's ability to remove metal and can damage the surface of the work. When you notice a buildup of particles on your file, brush them off with a file card. A file card has wire bristles on one side and fibre bristles on the other (Figure 32). Begin cleaning the file with the fibre bristles. If particles remain, remove them with the wire bristles. Soft metals such as aluminum, copper, or lead can leave filings between the teeth even after using a file card. If this happens, use a sharp, pointed piece of hard wood or soft iron to remove the remaining filings.

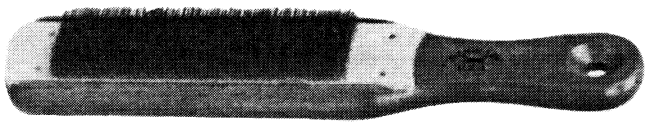

Figure 32. File Card

More files wear out from abuse than from use. To prevent damage to the file teeth while the files are not being used, keep them separated from each other and from other tools. A simple method for safely carrying your files in a tool box (or anyplace, for that matter) is to fold a piece of cardboard into an accordion shape (Figure 33). Each fold should be just wide enough to entirely cover the file blade. Place a file in each fold of the cardboard and fold the accordion together. Secure the folds of cardboard with rubber bands or, preferably, a 13 mm (½ in.) wide strip of old inner tube. Inner tube is preferred as it does not deteriorate as quickly as rubber bands. Once your files have been securely wrapped, store them in a dry place. Rust will damage the cutting edge of file teeth.

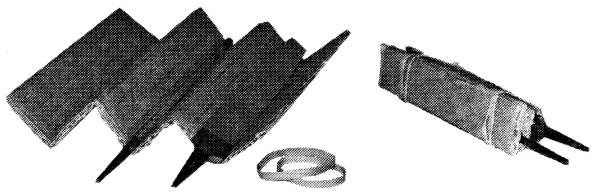

Figure 33. File Compartments

Shears

Bench shears can be used to make straight cuts or unlimited length and width. The blades are adjustable and detachable for regrinding. They're suitable for cutting plate up to about 3 mm (⅛ in.) thick. Heavy-duty models can cut 6 mm (¼ in.) plate.

Follow these safety tips when using bench shears:

- Do not use shears unless you have been trained in their proper and safe use.
- Wear safety glasses or a face-shield and protective gloves.
- Choose the proper tool for the job. Shears are designed for a specific type, hardness, and size of material.
- Cut materials straight across. Keep the material being cut at right angles to the cutting edges of jaws.
- Be aware that metal can fly when cut. The harder the metal, the farther it will fly.
- Warn others in the area to take precautionary measures to avoid possible injury from flying metal pieces.
- Keep shears in good repair.
- Adjust and lubricate shears and moving parts daily if heavily used.
- Sharpen shears according to manufacturer's instructions.
- Do not use cushion-grip handles for jobs requiring insulated handles. Cushion grips are mainly for comfort, they do not protect against electric shock.
- Do not use shears that are cracked, broken, or loose.
- Do not exceed the recommended capacity of the tool.
- Do not cut diagonally.
- Do not rock shears from side to side when cutting wire.
- Do not pry or twist with shears when cutting.
- Do not hammer on shears or extend the handle length to increase cutting power.
- Do not expose shears to excessive heat.

Hand shears are also called "tin snips," "metal masters," or "aviation shears" (Figure 34). They will generally cut sheet metal up to 1.5 mm (1/16 in.) thick. The construction of hand shears varies greatly. Some are made to cut straight only, while others are made to cut left or right curves. Most hand shears can be sharpened by filing.

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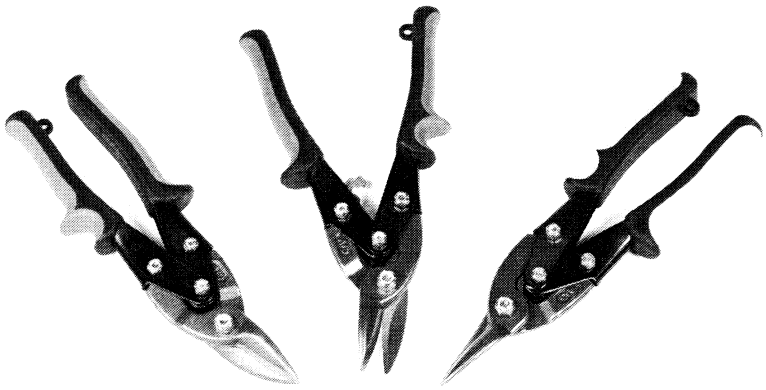


Figure 34. Hand Shears

Follow these safety tips when using hand shears:

- Tin snips should be heavy enough to cut the material with only a single hand. (Use your other hand to keep the material steady)
- Before you make the final cut, support the material so that the cut edges do not press against your hands.
- Keep the jaws of snips tight and well-lubricated.
- Wear approved eye protection when using shears.
- Always wear gloves.
- Do not use shears as nail pullers or pry bars.
- Use jaws that have a hardness specified by the manufacturer for the particular material to be cut.
- Set cutting edges to have a clearance of 0.076 mm (0.003 in.) when closed.

Hammers

There are many kinds of hammers. The two main types are the steel-face and the soft-face. Mechanics usually use steel-face hammers, most frequently the ball-peen and cross-peen varieties (Figure 35).

Ball-peen and Cross-peen Hammers

Steel-face hammers such as the ball-peen and cross-peen have heads made from high-grade alloy steel that has been drop-forged and heat-treated to a suitable degree of hardness. The ball-peen hammer commonly has a slightly rounded striking surface. The end opposite the face is a full half-sphere, called a "peen." Both hammers are available in weights ranging from 57 g–1.36 kg (2 oz.–3 lb.). The most popular weights for ball-peen hammers are 113 g, 340 g, and 1 kg (4oz., 12 oz., and 2 lb.).

NOTES

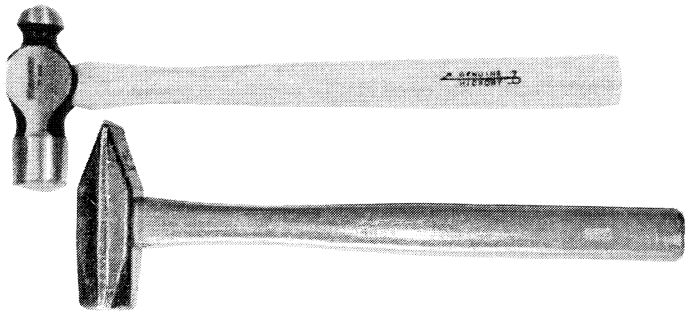


Figure 35. Ball-peen and Cross-peen Hammers

Sledgehammer/Club Hammer

Mechanics use sledgehammers for heavy work driving pins or breaking pieces apart or to help align components for assembly. A sledgehammer consists of a large, flat-faced, double-ended head attached to a handle (Figure 36). The head is usually made of metal and weighs from 1–9 kg (2–20 lb.) or more. The sledgehammer handle ranges from 250 mm–1 m (10–39 in.). Smaller versions are called "club hammers."

Sledgehammers usually require two hands and a swinging motion involving the entire torso. The combination of a long swinging range and a heavy head increases the momentum driving the hammer's impact.

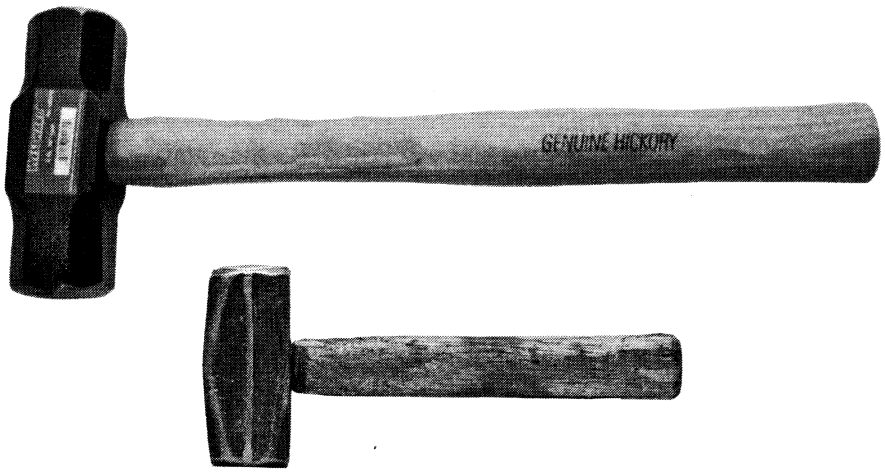


Figure 36. Sledgehammers

NOTES

Soft-face Hammers

Mechanics use soft-face hammers when assembling or disassembling equipment. Soft-face hammers are used when working on machined surfaces and precision parts to avoid marring the finish. Soft-face hammers can be faced with plastic, rubber, brass, lead, wood, or leather.

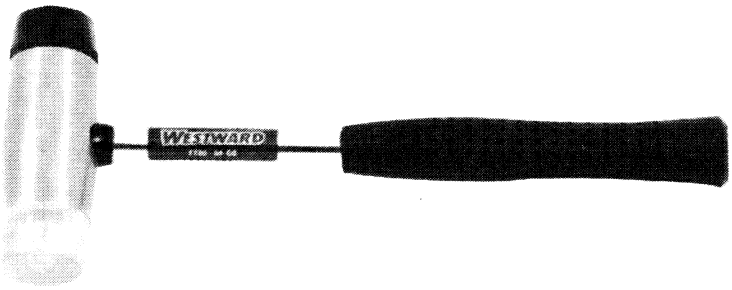


Figure 37. Soft-face Hammer

Dead Blow Hammer

A dead blow hammer is a rubber or plastic soft hammer with a hammer head filled with lead or steel shot (Figure 38). The shot adds weight and eliminates hammer bounce. Mechanics use the dead blow hammer when they need a soft face and definite blow, such as during the assembly and disassembly of painted or finely finished components.

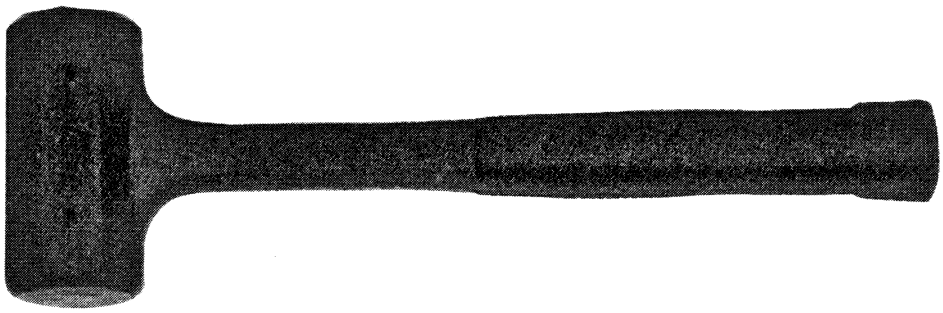


Figure 38. Dead Blow Hammer

NOTES

Chipping Hammers

Chipping hammers are used when welding with an arc welder. They're used after every weld deposit to chip the slag from the weld. The heads of chipping hammers are made of forged alloy steel that has been hardened and drawn for maximum toughness. The types available differ only slightly in design. The most popular is the cone and straight chisel with either a wire or a hardwood handle. The point of the slender cone and the thin, tapered chisel edge can reach slag in even the most confined area. Since they are used so frequently, chipping hammers need to be maintained regularly. You can sharpen them on a bench grinder or with a file. Be careful not to overheat.

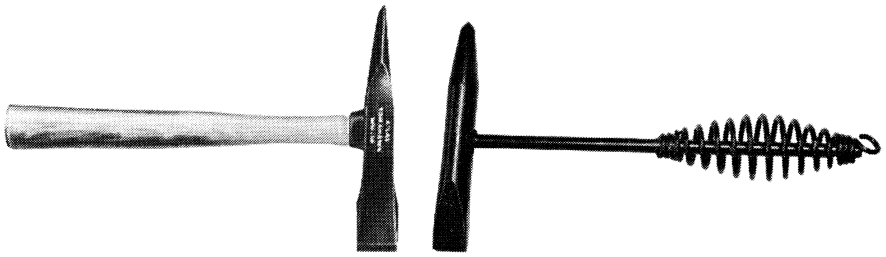


Figure 39. Chipping Hammers

Hammer Safety

Follow these safety tips when using a hammer:

- The handle of the hammer should be smooth, without cracks or splinters, free of oil, shaped to fit the hand, and of the specified size and length needed to support the head.
- The handle must be securely fitted to the head of the hammer.
- Never use a hammer with a loose head or a damaged handle. You can be injured if the head flies off or if the handle breaks.
- Wear approved safety eyewear to protect against flying chips, nails, or scale.
- Use the right hammer for the job.
- Grip the hammer firmly by the handle.
- Keep your wrist straight and use your whole forearm to lift and drop the tool.
- Let the hammer do most of the work. Use its weight to strike the blow rather than pounding with your full force.
- Never use a steel hammer on hardened steel surfaces.

NOTES

Figure 40 shows the correct way to hold and use a hammer. To strike a heavy blow with the least effort, grip the hammer firmly, but not rigidly, near the end of the handle. Gripping the handle near the head reduces the force of the blow. Always strike the object with the centre of the face of the hammer. This spreads the force of the blow over a larger area, protecting the work from indentation and the hammer from chipping. Always start hammering with light blows and follow with heavier blows if necessary.

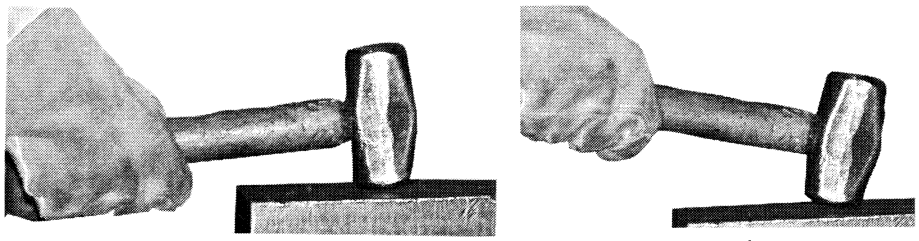


Figure 40. Correct Use of Hammer

Chisels

Mechanics generally use chisels to remove rusted machine parts and to shear off bolts or cotter pins. Chisels are forged from square, rectangular, hexagonal, and octagonal high-carbon steel stock. The steel is machined and then hardened and tempered. The body and head are softer than the cutting edge so that they can withstand a striking force without chipping. The upper end of a chisel has a slight taper (chamfer) to compensate for the mushrooming caused by repeated hammer blows.

Different types of chisels are used for different applications. These include:

- diamond-point
- side
- round nose
- cold
- cape

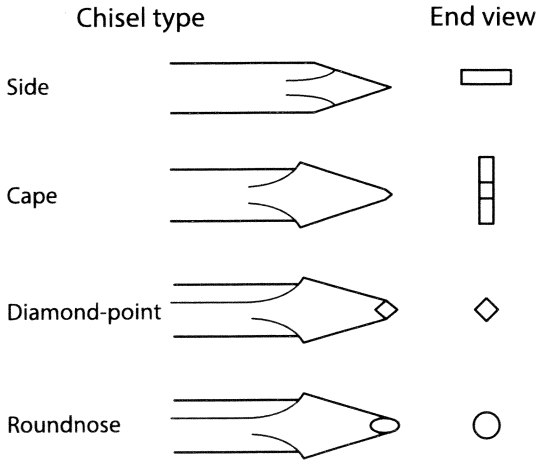


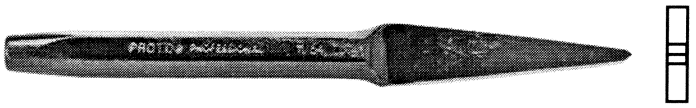
Figure 41. Types of Chisels

NOTES

Flat Cold Chisels

Mechanics use the flat chisel for general cutting work (Figure 42). The cutting edge is beveled (tapered) from both sides toward the centre. The angle of the bevel is generally between 60° and 70°. For soft metals, the angle should be reduced and for very hard metals, it should be increased. Flat cold chisels have cutting edges that vary in width from 6–25 mm (¼–1 in.). They are usually from 150–200 mm (6–8 in.) long. Figure 43 shows other types of chisels. These types are mainly for cutting narrow grooves of various shapes.

Figure 42. Flat Chisel



Cape chisel End view

Diamond-point chisel End view

Figure 43. Other Types of Chisels

NOTES

Cutting with a Cold Chisel

Cutting with a cold chisel is a quick and efficient method of removing surplus metal on low-carbon steel up to 3 mm (⅛ in.) thick. When performing this type of cutting, hold the work piece in a vise and shear the metal between the sharpened edge of the chisel and the edge of the stationary jaw of the vise (Figure 44).

It's important that you hold the chisel correctly. Otherwise, the job will be rough or badly twisted, and both the chisel and the vise could be damaged. To get a clean shearing action, place the bevel of the cutting edge of the chisel flat against the jaw of the vise and angle the chisel. This will duplicate the action of a hand or power shear.

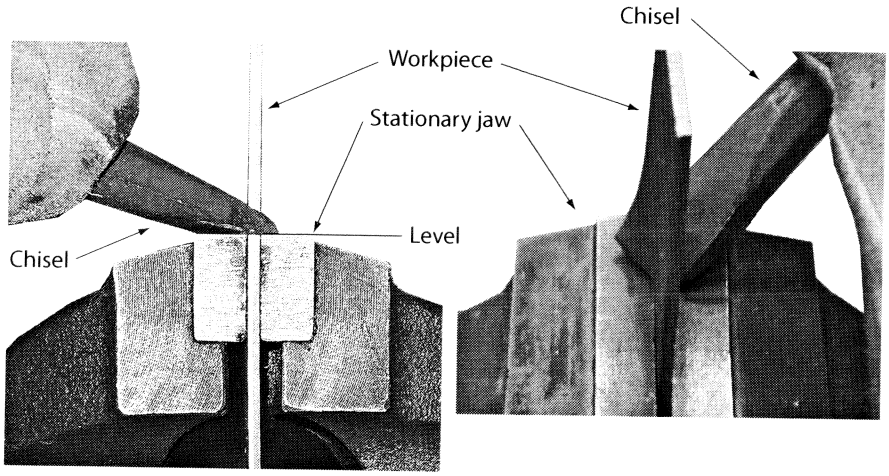


Figure 44. Correct Position of Chisel

Never try to cut from the end of the metal (Figure 45).

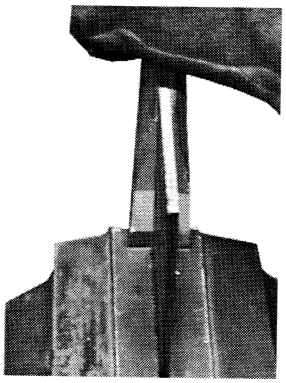


Figure 45. Incorrect Position of Chisel

Chisel Safety

Follow these safety tips when using chisels:

- Always wear safety glasses or a face-shield and hand protection.
- Choose chisels that come with hand protectors designed for that tool.
- Set up a shield or screen to prevent injury to other workers from flying debris. If a shield does not provide complete protection for all exposed workers, then they should wear approved safety glasses.
- Choose your chisel based upon the material to be cut, the size and shape of the tool, and the depth of the cut to be made.
- The chisel should be heavy enough so that it will not buckle or spring when struck.
- Choose a chisel that is the right size for the job. If the chisel is too large, the point or corner of the chisel will be doing the cutting, rather than the blade. If the chisel is too small, you will need more effort to complete the task.
- Use a hammer heavy enough to do the job. The usual weight of hammers for chiseling range from 340–900 g (12 oz.–2 lb.). Use a large hammer with a large chisel.
- Do not use a chisel that's in poor condition. Ensure that the cutting edges are sharp, and the struck head is not mushroomed or chipped.
- For shearing and chipping, hold the chisel at an angle so the bevel of the cutting edge lies flat against the shearing plane.
- Throw away chisels that are bent, cracked, or chipped.
- Redress chisels with burred or mushroomed heads. Redress the point or cutting edge to its original shape. Grind to a slightly convex cutting edge. The point angle of the chisel should be 70° for hard metals, 60° for soft (Figure 46).
- Never grip the chisel too tightly. A poorly aimed blow that misses the chisel could seriously injure your hand.
- Do not use struck tools if the struck end is chipped or mushroomed.
- Do not use struck tools if the cutting edge is dull or chipped or if the point of a punch is slanted or damaged.
- Do not apply too much pressure to the head when grinding a chisel. The heat generated can remove the temper. Immerse the chisel in cold water every so often when grinding.
- Do not use cold chisels to cut or split stone or concrete.

Maintenance of Chisels

A damaged chisel will have a mushroomed head and/or a cutting edge that is nicked or dull (Figure 47). When this happens, you must dress the chisel (clean up or repair it) before using it again.

NOTES

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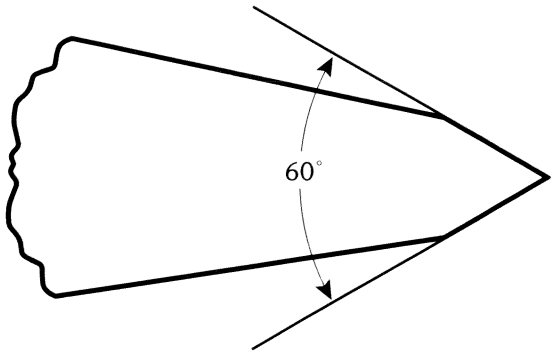

Figure 46. Proper Angle for General Use Cold Chisel

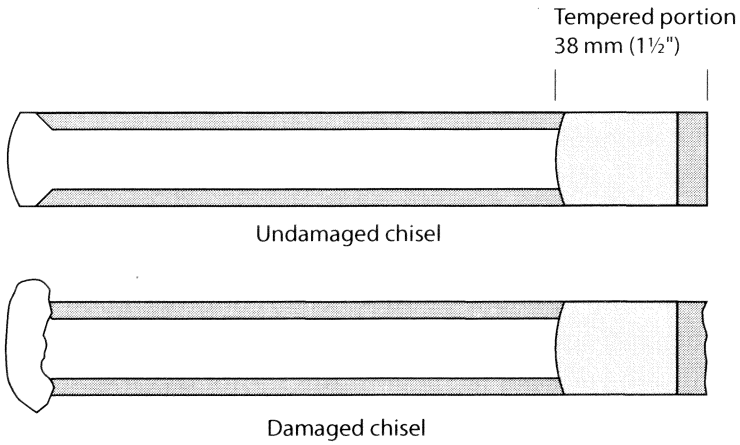

Figure 47. Undamaged and Damaged Chisels

Five rules for dressing chisels:

- The chisel must be returned to its original shape. Check an undamaged chisel to determine the original shape.
- Remove all cracks and spalls (chipped areas). Some cracks cannot be seen with the naked eye. Use a magnifying glass for a closer look.
- The grinding temperature must be controlled during dressing. Chisels are made from heat-treated hardenable steel. Approximately 38 mm (1½ in.) of the cutting end is hardened and tempered for toughness, and the striking end is made soft and ductile. If either end is overheated, then rapidly cooled, it will become hard, brittle, and easily fractured. If the cutting end is overheated and allowed to cool slowly, it will become soft and unable to hold an edge.
- Use a medium- or fine-grit grinding wheel.
- The wheel rotation should always be away from the cutting edge, toward the body of the tool. This positioning of the tool directs heat away from the cutting edge.

NOTES

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

A durable bronze head can be added to a cold chisel to increase its working life considerably (Figure 48). Here are the steps:

1. Grind the head of the tool to remove the mushrooming. The grinding must be done in stages.

2. Grind a small shoulder all around the cut end, about 6 mm (1/4 in.) down the handle and 1.5 mm (1/16 in.) deep.

3. Braze weld on about 3 mm (1/8 in.) of bronze.

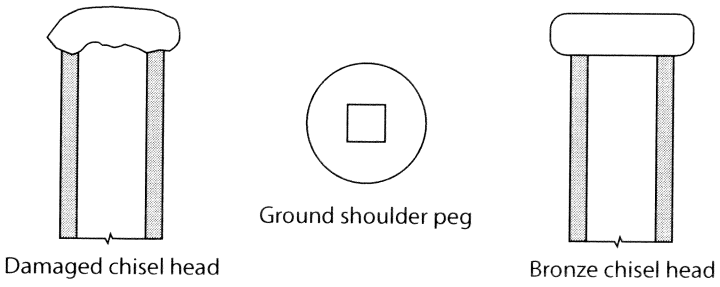

Figure 48. Bronze Head Added to Chisel

Punches

There are a wide variety of punches used in the mechanical trade. Pin, tapered, alignment, centre, prick, brass drift, and mild steel punches are just a few you may use regularly. They can be used to remove pins, align parts, mark steel, or drive components without damaging the component. They come in all sizes depending on what function they are performing.

Centre Punch

The centre punch has a tapered tip with a broad, sharp point. The tips of centre punches are ground to an included angle of 60–90°. This makes them durable tools, but they are difficult to position accurately on a smooth work surface. Centre punches are mainly used to punch indentations in metal as a guide for drill bits. For this procedure, you first mark the material to be drilled with a scriber or pencil, then place the centre punch directly on the mark and strike the head of the punch with a hammer. The large 60–90° indentation helps prevent the tip of the drill bit from slipping out of position.

NOTES

Figure 49. Centre Punch

Taper Punch

A taper punch, or taper pin, is used to:

- align bolt or rivet holes before inserting a fastener
- move stuck, jammed, or rusted-in bolts or pins in a tight spot

A taper punch is made of hard or tempered steel in the shape of a tapered rod. To align holes, place the tapered end of the taper punch into the semi-aligned bolt holes of two separate components, and then drive it into the hole. As it is driven in, the taper forces the two components into alignment, allowing for easy insertion of the fastener. When the taper punch is used to move stuck components, the tapered end is applied to the jammed bolt or pin and the other end is struck with a hammer. In this case, the taper punch concentrates or pinpoints the force of the hammer blow in order to move the stuck part.

Figure 50. Taper Punch

Pin Punch

The pin punch is necessary because the taper on the taper punch will not allow it to completely follow the object through the hole during removal. Pin punches also come in various punch shaft diameters. Large pin punches are called drift punches and are used for applications where considerable force is required.

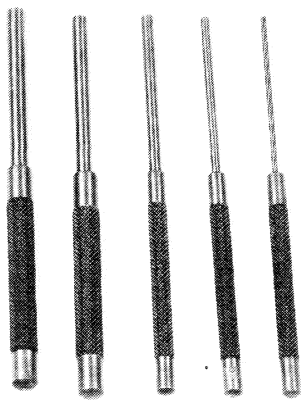

Figure 51. Pin Punches

NOTES

Brass Drift Punch

The brass drift punch is made of solid brass. The shaft is usually knurled so you have a better grip. They're used in applications where you don't want a spark, or when you don't want to damage the component you are driving.

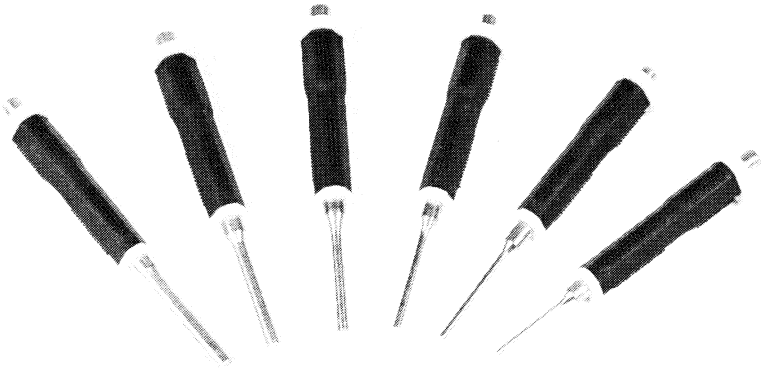

Figure 52. Brass Drift Punches

How to Use a Punch

When using a punch and hammer, strike the punch squarely (Figure 53). A glancing blow could damage the material or your fingers. Never use the side of the hammer to strike a punch. Punches become dull in time and need to be ground on a grinding wheel. When doing so, you must take care not to overheat them because this will remove the temper of the metal.

Figure 53. Correct Use of a Punch

NOTES

Aligning/Pry Bars

Mechanics regularly use alignment/pry bars. A pry bar is used when separating the transmission from the engine, or lifting a heavy component. One end is normally flattened and curved and the other is round and tapered. Pry bars are normally made of heat-treated, high-grade alloy steel. Aligning bars are made from aluminum or titanium, which have the advantage of being lighter and non-magnetic. Less expensive aligning bars are forged from hexagonal stock. This shape makes them more resistant to bending. Pry bars come in different lengths depending on what you need to move or lift. Some pry bars have a foot or heel on the end.

Figure 54. Pry Bars

Figure 55. Footed or Heeled Pry Bars

Pliers

Pliers are used for holding, gripping, cutting, and crimping. They're forged from hardened steel and machined to close tolerances. Some have honed cutting edges and are polished. Pliers are classified by their type and by their overall length, which can vary from 10–50 cm (4–20 in.). Common types of pliers include:

- combination slip-joint
- interlocking slip-joint
- needle-nose and round-nose
- diagonal or side-cutting
- locking
- specialized application

NOTES

Combination Slip-joint Pliers

Combination slip-joint pliers are the most common general-purpose pliers. The size of pliers is measured by their overall length. Combination pliers normally come in 125, 150, and 200 mm (5, 6, and 8 in.) sizes. They can be adjusted with a sliding pivot that allows the jaws to open to grip larger items. The jaws have sharp, hardened cross teeth to allow a more secure hold.

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

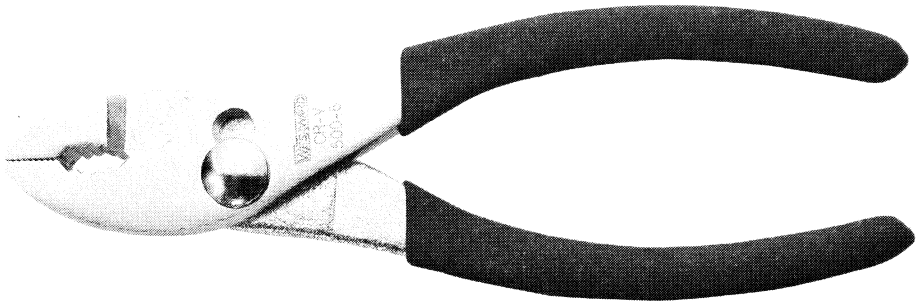

Figure 56. Combination Slip-joint Pliers

Interlocking Slip-joint Pliers

Interlocking slip-joint pliers or water pump pliers are a variation of the combination slip-joint pliers. These pliers are very useful for gripping large or hard-to-get-at objects. They can be opened to a number of positions while the jaws remain parallel to each other. Because of the large bite available, the handles are made longer to provide greater leverage.

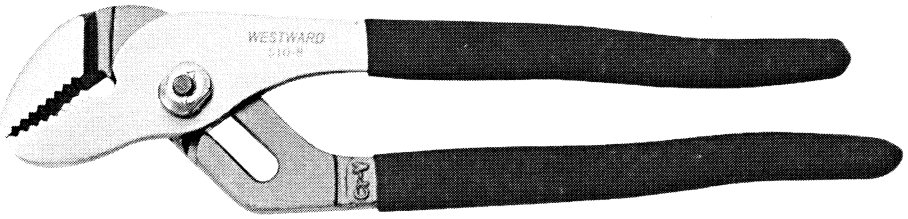

Figure 57. Interlocking Slip-joint Pliers

NOTES

Needle-nose and Round-nose Pliers

These pliers come in a variety of sizes and styles, some incorporating a cutting surface. Round-nose pliers have rounded jaws that are useful for bending wire into curves and circles.

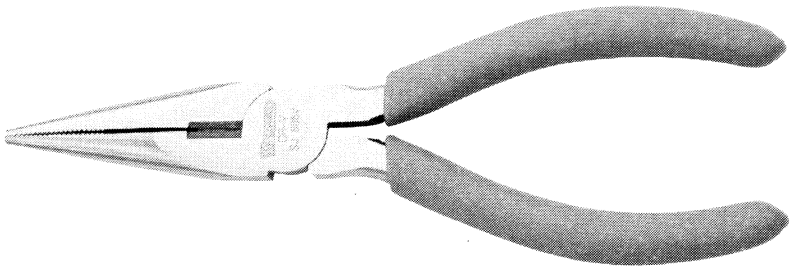

Figure 58. Needle-nose Pliers

Diagonal or Side-cutting Pliers

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

Figure 59. Side-cutting Pliers

Locking Pliers

Locking pliers, often called Vise-grips®, are useful for holding parts together or locking onto a rounded nut head. They have a built-in spring-type mechanism which can be locked into position and is released by pulling or squeezing a lever. Locking pliers come in many sizes and styles and are available with either straight, cutting, or curved jaws (Figure 60).

NOTES

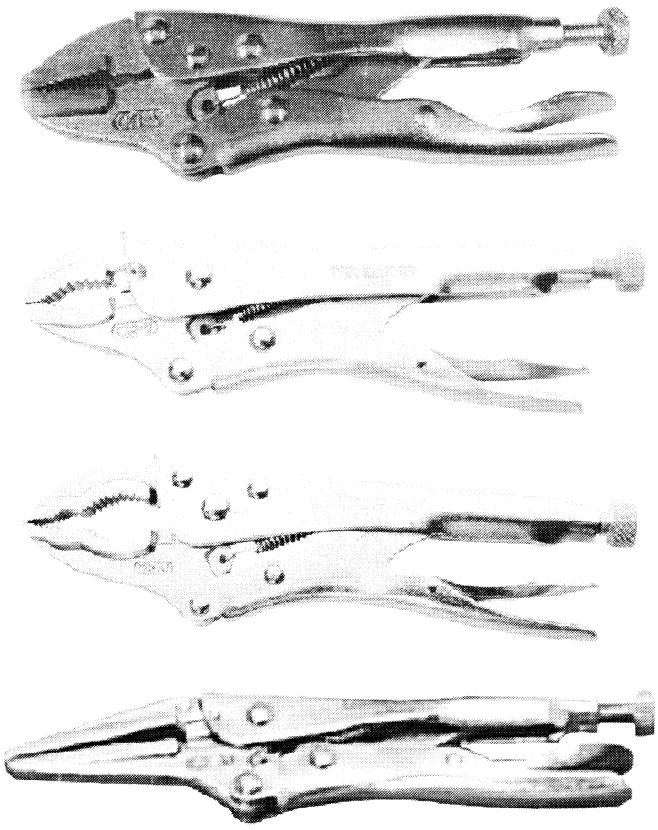

Figure 60. Locking or Vise-grip® Pliers

Specialized Pliers

There are many different types of pliers designed for specific applications:

- battery terminal pliers to spread battery terminals
- right angle pliers
- ignition pliers
- snap-ring pliers
- wire crimping pliers
- wire stripping pliers

Follow these safety tips when using pliers:

- Pliers are meant for gripping and cutting. Do not use them as a substitute for wrenches.
- Wear safety glasses or a face-shield when there is a hazard of flying particles, pieces of wire, etc.
- Pliers used on or around electrical equipment must have insulated handles.

NOTES

- Do not use cushion-grip handles for jobs requiring tools with electrically insulated handles. Cushion grips are mainly for comfort and do not protect against electric shock.
- Cut at right angles. Never rock the cutting tool from side to side or bend wire back and forth against the cutting edges.
- Choose pliers or wire cutters that have a grip span of 60–90 mm (2–3 in.) to prevent your palm or fingers from being pinched when the tool is closed.
- Use adjustable pliers that allow you to grip the work piece firmly and comfortably—in other words, don't spread the handles so far apart that they're difficult to grasp.
- Make sure that the cutting edges of pliers are sharp. Dull and worn cutting edges are dangerous and require many times more force for cutting.
- Make sure that the toothed jaws of pliers are clean and sharp. Greasy or worn-down jaws can be unsafe. Such tools also require increased force to hold the work piece. This increases the risk of muscular fatigue and repetitive strain injuries.
- Oil pliers and wire cutters regularly. A drop of oil on the hinge will make the tool easier to use.

Abrasives

Emery Cloth

Emery cloth is used to finish and polish metals. The grit on emery cloth is a natural abrasive, an impure form of crystalline alumina. The emery grit is bonded to either paper or cloth backing (Figure 61). Cloth is more widely used.

Emery cloth usually comes in three grades: fine (100–140), medium (80–100) and coarse (60–80). It can be used wet (with oil) or dry. The longer the emery cloth is used, the finer the crystalline structure becomes. Therefore, as you polish the metal, your surface finish will become smoother and finer.

NOTES

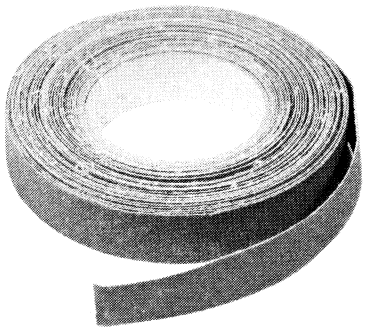

Figure 61. Emery Cloth Roll, 100 Grit

Clamping Tools

Bench Vise

A standard metal or bench vise is available in many sizes and variations (Figure 62). A good quality vise is a very rugged piece of equipment. Vises hold materials while performing work such as assembly, disassembly, welding, or filing. The size of a vise is usually measured by jaw width, but the maximum jaw opening should also be measured and considered when sizing a vise. Most vises are available with a variety of jaw widths and the jaws may be replaceable.

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

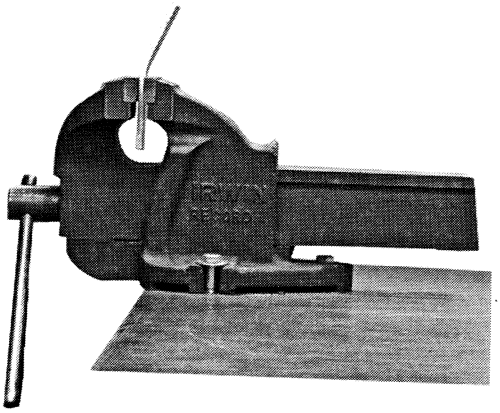

Figure 62. Bench Vise

NOTES

Soft vise jaw-caps are available to protect the work piece (Figure 63). They come in pairs and slip over the jaw facings. The tabs are bent around the front and back jaws to hold them in place.

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

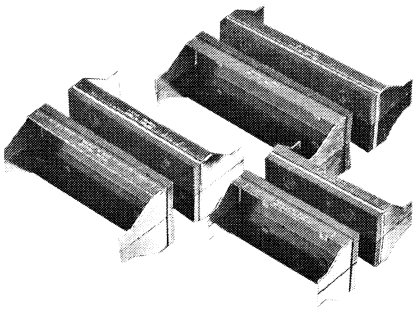

Figure 63. Soft Vise Jaw-caps

For a hard or tough work piece that is to be hammered or chiselled, you must ensure that the vise is tight enough to prevent the work piece from slipping. You should also place the work piece in such a position that you will be hammering or chiselling toward the stationary jaw (Figure 64).

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

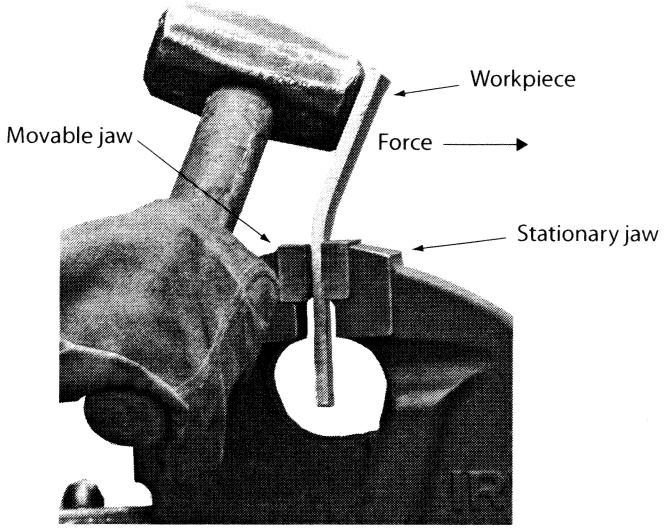

Figure 64. Hammering Toward Stationary Jaw

NOTES

Machine Vise

A machine vise is used to hold a work piece for a machining operation (Figure 65). For example, a machine vise is used to hold a work piece for drilling with a drill press. The vise can be bolted to the drill press table. Machine vise jaws are replaceable. The jaw face is usually smooth to prevent the work piece from becoming marred. The jaws may also have vertical and horizontal grooves to provide a gripping surface for round or irregularly shaped objects.

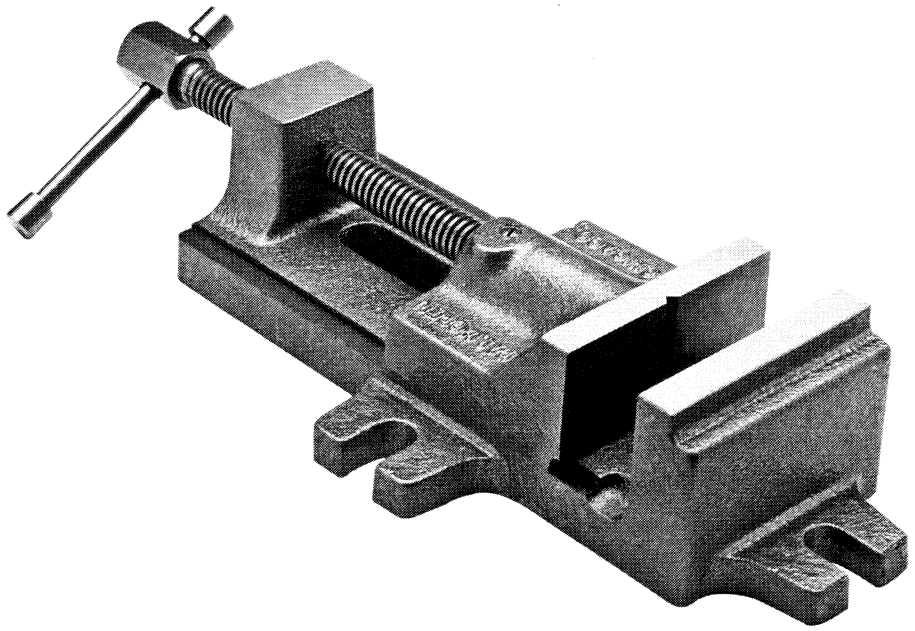

Figure 65. Machine Vise

C-clamps

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

C-clamps have many different uses. They can clamp an oddly-shaped item to a drill press table and often used to hold a work piece during welding. When welding, you must be careful to protect the screws of the clamp from weld spatter.

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

NOTES

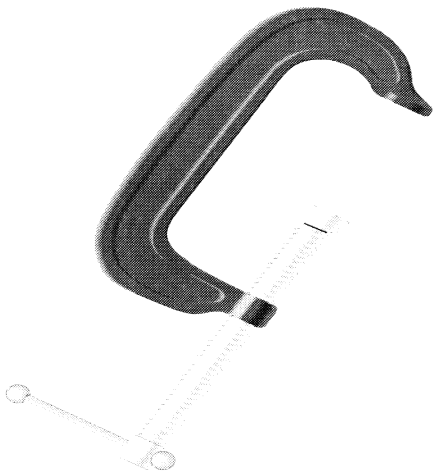

Figure 66. C-clamps

Follow these safety tips when using C-clamps:

- Wear safety glasses or a face-shield.
- Choose the proper clamp style and size by matching the work-holding requirements of the job with the following clamp features: strength and weight, opening (length of reach), throat depth (depth of reach), ease of adjusting clamping surfaces (material used and size).
- Ensure that the swivel at the end of the screw turns freely.
- Do not use any clamps that have a bent frame or spindle. Dispose of clamps with bent frames. Replace bent spindles, if possible.
- Ensure that the pressure plate and anvil parts of the clamp are in full contact with the work piece before tightening.
- Use pads with C-clamps to avoid marking the work.
- When you use clamps to hold material for welding, you must be careful to avoid damaging the threads with weld spatter.
- Remove clamps as soon as the job is finished. Clamps are only for temporarily holding work securely in place.
- Keep all moving parts of clamps lightly oiled.
- Keep tools clean to prevent slippage. Also make sure there is no dirt or oil on any part that will come into contact with the work.
- Store C-clamps by clamping them in a rack.
- Do not use extra-large clamps just for the sake of their large throats. Use deep-throat clamps instead.
- Do not use wrenches, pipes, hammers, or pliers to tighten clamps.
- Do not hoist or pull with C-clamps. Use special lifting clamps.
- Do not use C-clamps to secure scaffolds or platforms for workers.

NOTES

Pullers

Pullers are used to pull:

- something off a shaft, such as a bearing, in order to replace the part or access another component
- something out of a hole, such as an oil seal, to replace seal or to access another part
- a shaft, such as a transmission shaft, so that a repair can be undertaken

Slide Hammer

A slide hammer uses the inertia of a heavy slide to hammer a part out of its location. Adapters or jaws for the slide hammer are often the same as for the pressure screw pullers. Two examples of these pullers and their attachments are shown in Figure 67.

If the part to be removed involves a ball or roller-type bearing, you must remember that hammering usually results in the destruction of the bearing. Since the slide hammer is easy to set-up and use, the tendency is to choose it first. This may not be the best choice. Examine the job closely and select the correct puller.

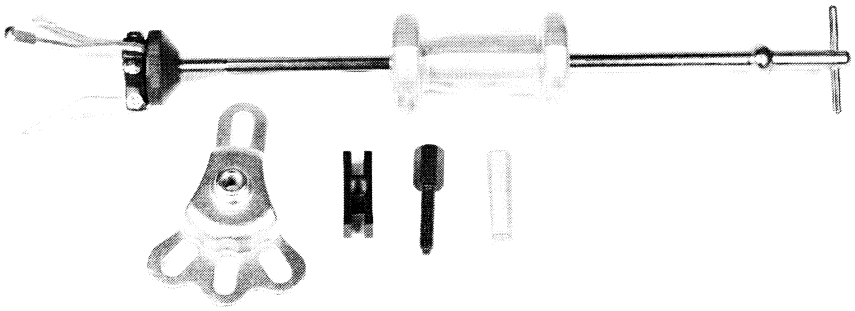

Figure 67. Slide Hammer/Puller Set

Jaw Puller

Jaw pullers are designed to hold or grab one part of the component while pressure is being placed on the other piece to separate them. There are two main types: two-jaw and three-jaw pullers. Jaw pullers are measured for the diameter they can grab and length of their jaws. The jaws can be adjusted for length and for inside or outside grabbing.

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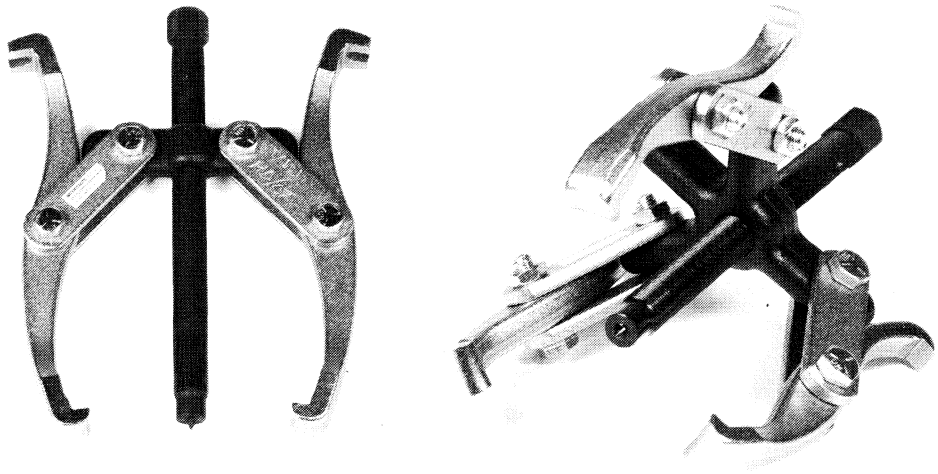

Figure 68. Two-jaw and Three-jaw Pullers

Bearing Separator

The bearing separator or splitter is usually used to pull a bearing off a shaft. It is adjustable to open the jaws so that it can go over the bearing and then close up again to lock underneath the bearing. It is then attached to a strong back which puts pressure on the shaft to pull the bearing off the shaft. The shaft may also be pushed off in a press. The bearing separator comes in varying sizes for different bearing sizes.

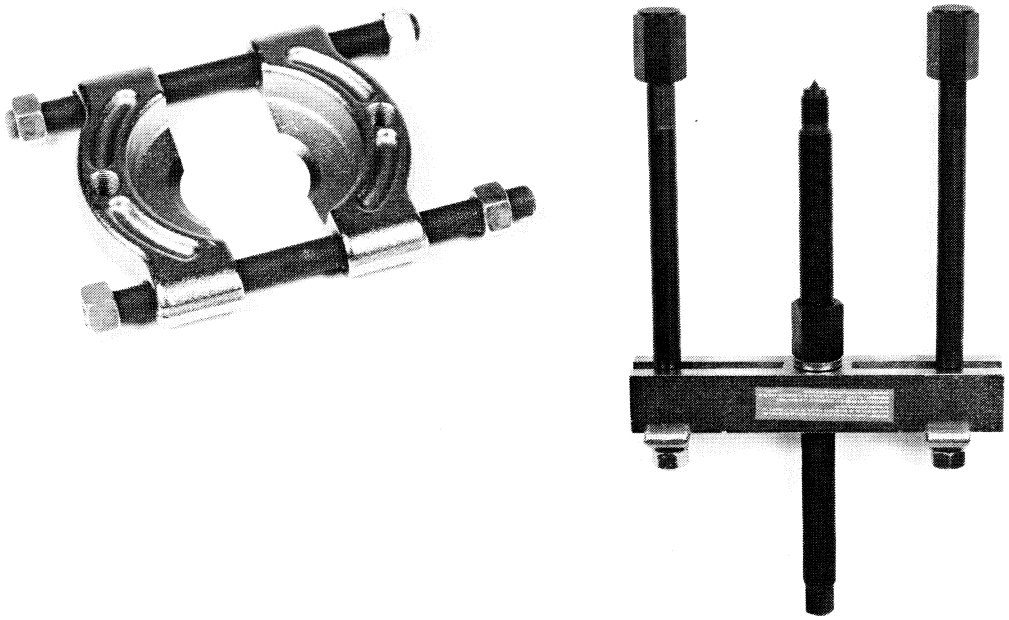

Figure 69. Bearing Separators

NOTES

There are other specialty pullers used for specific applications:

- steering wheel
- battery post
- tie rod end
- pulleys

Puller Safety

Pullers (especially hydraulic pullers) can exert a tremendous amount of force, often up to 100 tons. Careful attention must be given to the correct choice of puller and to the safe use of that puller.

Select the right size puller with the correct reach and spread for the job. Do not overload a puller. For manual, screw-powered pullers, the screw must be at least half as large (in diameter) as the shaft of the pulling job.

The tonnage capacity of a puller is reduced as the legs get longer. Long legs also increase the chances of the legs bending, breaking, or misaligning. Always use the shortest legs possible to do the job.

For hydraulic pullers, the maximum force exerted in tons should be 7 to 10 times the diameter of the shaft in inches (Table 1).

For Shaft Diameter	Use Hydraulic Puller With
0–2 in.	17½-ton ram
2–3½ in.	30-ton ram
3½–5½ in.	50-ton ram

Table 1.

Place a shaft protector over the end of shaft before installing a puller. When the puller is installed, be sure the set-up is rigid and the puller is square with the work. Apply force gradually. The component should give a little at a time. Do not try to speed the removal by using an impact wrench on the screw. If you have applied maximum force and the part does not move, use a larger capacity puller.

Always wear safety glasses when using a puller.

Tools that are in contact with hard metal surfaces and subject to high loads should be inspected on a regular basis. Pullers receive a great deal of abuse when used under certain circumstances. The points or hooks on the jaws may become rounded and worn and could require replacement or repair.

NOTES

The pressure screw threads should be lightly oiled, clean, and free of burrs. The screw end should have a clean point so that it will seat properly into the recess on the adapter plates. Jaw pins should be kept in good condition and properly maintained.

Torque Wrench and Torque Multiplier

Torque is the amount of twisting action at a given point. A torque wrench allows you to tighten bolts, nuts, or screws to an exact, predetermined tension.

Torquing of bolts, nuts, and screws is a critical operation. Applying too little or too much torque can cause leaks. Applying too much torque will also cause distortion and major damage to expensive parts. Torque wrenches are designed to measure the amount of torque being applied.

The audible-click type and the dial-indicating type are preferable to the deflecting-beam type. The audible-click torque wrench can be used in applications where it would be difficult to read a dial or scale while performing the tightening sequences.

Some torque wrenches have a ratchet drive. Torque wrench square drives vary from ¼–1 in. in size for standard uses and in larger sizes for heavy industrial applications. Some ratchet drivers will operate in both directions, while others may operate only in a right-hand rotation.

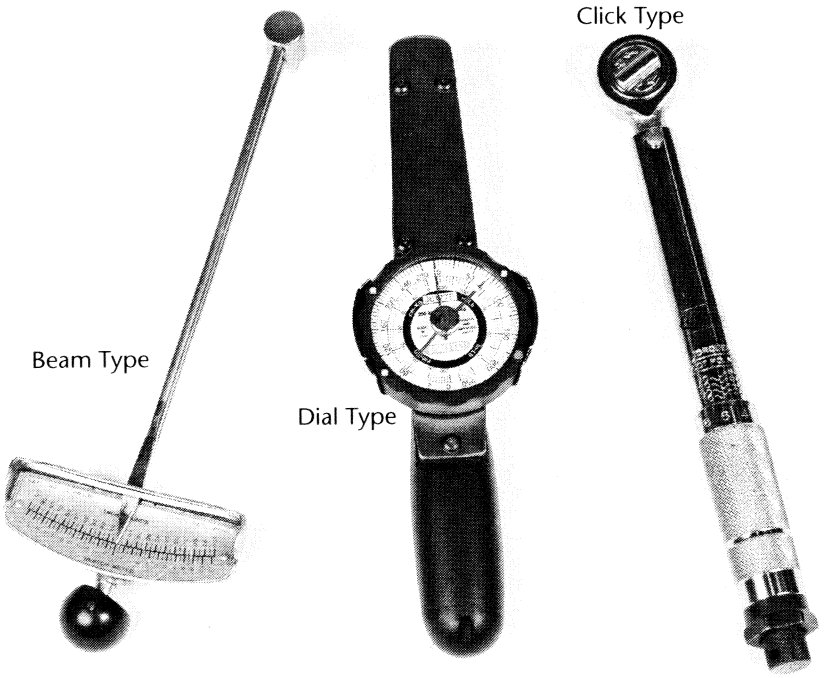

Figure 70. Different Types of Torque Wrenches

NOTES

Deflecting-beam Torque Wrench

The deflecting beam on this type of wrench is a lever that is attached to the handle. When used, the lever deflects (bends) when a load is applied to the handle. A pointer attached to the square drive remains straight when the beam deflects and shows the applied load as torque on an indicator plate attached to the torque wrench (Figure 71).

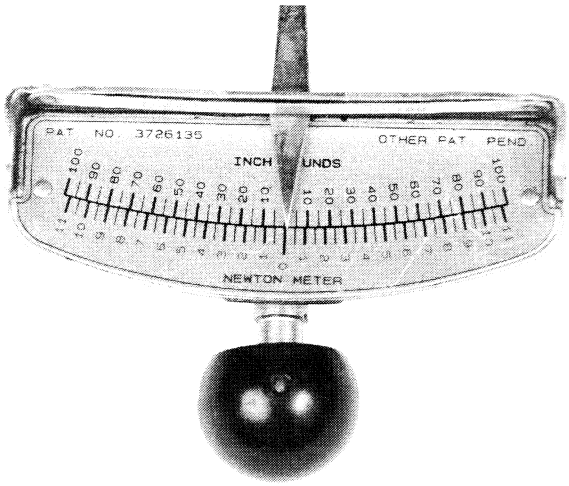

Figure 71. Torque Indication

Dial-indicator Torque Wrench

The dial-indicator torque wrench operates like the deflecting-beam type, except that it is encased in a rigid frame. The deflecting element inside the rigid frame actuates a pointer in the indicator dial, which shows the applied load as torque (Figure 72).

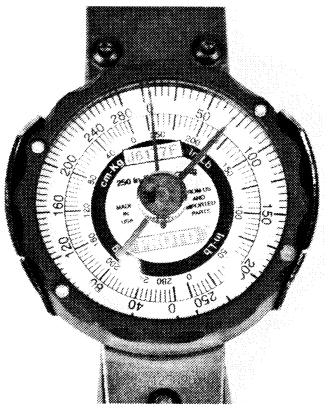

Figure 72. Dial Indicator

NOTES

Some features of dial-indicator torque wrenches include oversized indicator dials for easier reading and a light signal feature—when the desired torque is reached, the light illuminates. Some have follow-up pointers. The dial is set for zero torque. As the torque load is applied, two indicator pointers follow the scale up to the desired torque. When the load is released, one pointer remains at the exact point of release. This lets you verify torque accurately. Many dial indicator wrenches have dual-direction dials which allow you to torque right- or left-hand threaded fasteners.

Audible-click Torque Wrench

The audible-click torque wrench has a micrometer-type barrel for pre-setting the desired torque (Figure 73). The deflecting element inside the torque wrench is a compression spring that applies pressure to a lever in a detent (notch). When the pre-set torque is reached, the lever slips out of the detent with an audible click and sends noticeable vibration to the handle, informing you that the desired torque has been reached.

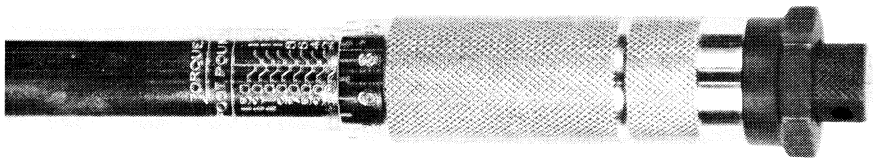

Figure 73. Audible-click Torque Wrench

This torque wrench is excellent for a variety of uses. The ratchet head is dual-purpose. It can be used as a ratchet for tightening fasteners before applying the final torque. By changing the ratchet selector, fasteners with left- and right-hand threads can be torqued without resetting the micrometer barrel (if the wrench will torque in both directions).

Never use any torque wrench, especially the audible-click type, as a tool to loosen fasteners. This can cause permanent damage to your precision instrument.

Units of Torque

Torque is expressed in several different units. The most common units of torque are pound-inches (lb•in), pound-feet (lb•ft), and newton-metres (N•m). A torque wrench is often rated in both metric and imperial units. Older wrenches may be rated only in imperial. It is best to use a torque wrench that is rated in the same units as those required for the job.

Choosing the Correct Torque Wrench

When you're selecting a torque wrench for a particular application, the range of the wrench must be considered. Some companies guarantee the precision of their torque wrenches no more than a 1% or 2% degree of error through the full range of their scale (i.e., 0–150 lb•ft). However, the accuracy of most torque wrenches tends to decrease at the extreme ends of their range. The greatest accuracy is obtained in the range above 10% and below 90%.

For example, for a torque wrench with a range of 0–150 lb•ft, the actual accurate range is 15–135 lb•ft. For accurate readings outside of this range, select a different torque wrench.

The torque wrench should be calibrated in the same units (lb•ft or N•m) as you're using for that specific fastener. For example, if the repair manual tells you to torque a fastener to 4 lb•ft, then use a pound-feet torque wrench.

Torque wrenches are made in different sizes or ranges as well as in different calibrations, such as 0–200 lb•in (0–22.60 N•m), 0–50 lb•ft (0–67.79 N•m), 0–100 lb•ft (0–135.58 N•m), and higher. The larger the drive size, the greater the capacity of the torque wrench.

Using the Torque Wrench

Always grasp the torque wrench handle with the palm of your hand at the centre of the handle. Placing your hand too far back or too far forward alters the applied torque because this changes the lever length. Similarly, adding an extension to the handle to acquire extra leverage also produces inaccurate torque readings. A smooth, steady force must be applied to the handle to obtain accurate torque values. Exerting rapid or jerky force can result in considerable error in the applied torque.

With a deflecting-beam torque wrench, the torque value is read on the scale as the force is applied to the handle. Always ensure that the pointer is on zero before using the wrench.

With a dial-indicating torque wrench, the dial must be rotated and placed on zero before applying any force to the torque wrench handle. Sometimes the dial will then be in a poor position to be read, so if your torque wrench has a dial that rotates, you can set the dial at your predetermined torque value rather than zero and apply force to the handle. The indicator pointer will then travel from your pre-determined torque value back to zero.

NOTES

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With an audible-click torque wrench, you pre-set the torque value on the wrench by releasing the lock on the handle and rotating the micrometer barrel clockwise or counter-clockwise to the desired torque setting. The lock must be reset once the setting has been made. These wrenches must have the micrometer barrel set to the lowest setting when stored to maintain their accuracy. This type of wrench must also be regularly checked for calibration accuracy.

Torque-turn Method of Tightening

Torque-turn tightening (degree torque) is a reliable method for tightening a stud or nut. It provides more consistent clamping than merely tightening to recommended settings. This method is used in the assembly of cylinder heads, connecting rods, main bearings, flywheels, and other components.

Each rotation of a fastener will advance it a distance equal to one thread pitch. For example, if a bolt is turned and is restrained from advancing, it must elongate. Degrees of fastener rotation relate to elongation and the amount of pre-load that will develop.

An example from one manufacturing service manual for tightening main bearing bolts states to tighten the bolts to "x" lb•ft with a torque wrench, mark the head of the bolt and advance it 120°.

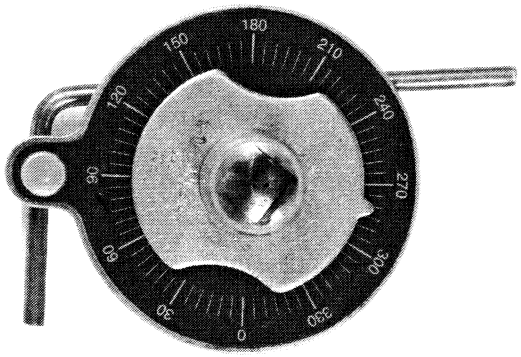

Figure 74. Dial and Torque Wrench

Use of Torque Wrench with Adapters

NOTES

Many torque wrench applications require the use of extensions and adapters to reach fasteners in places of limited accessibility or to position the torque wrench so that the dial can be read more easily.

Straight Vertical Adapter

An adapter or extension can extend the square drive vertically. This vertical extension presents no particular problem, since the effective length of the torque wrench has not been changed.

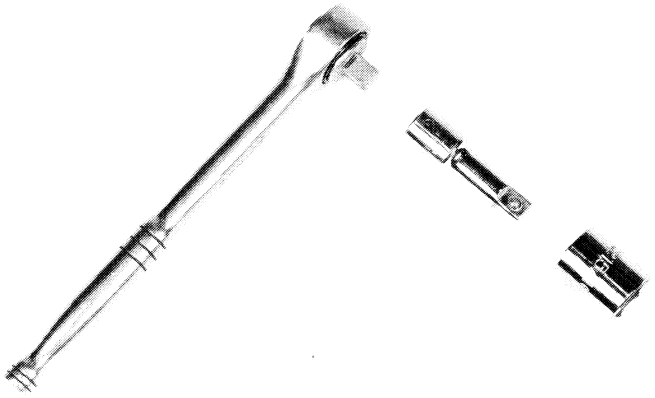

Figure 75. Vertical Extension

Horizontal Adapter

For some applications, an adapter must be used on the torque wrench that operates not vertically but horizontally with the square drive (Figure 76).

An adapter of this type has the effect of lengthening or shortening the torque wrench. The torque value shown on the torque wrench indicator is not the torque that will be applied to the fastener. To make sure you are applying the correct amount of torque, you have to do some simple calculations.

Referring to the Figure 76 you will see A is the new total length of the torque wrench and B is the original length. Divide measurement A by measurement B. So if A is 60 cm and B is 50 cm, you get 60/50 = 1.2 quotient. If the torque applied to the wrench is 100 N•m the torque on the bolt will be 100 N•m x 1.2 = 120 N•m. If you only want 100 N•m, divide the torque specification by the 1.2 quotient. 100 N•m / 1.2 = 83 N•m. Applying 83 N•m to the torque wrench will result in 100 N•m being applied to the bolt.

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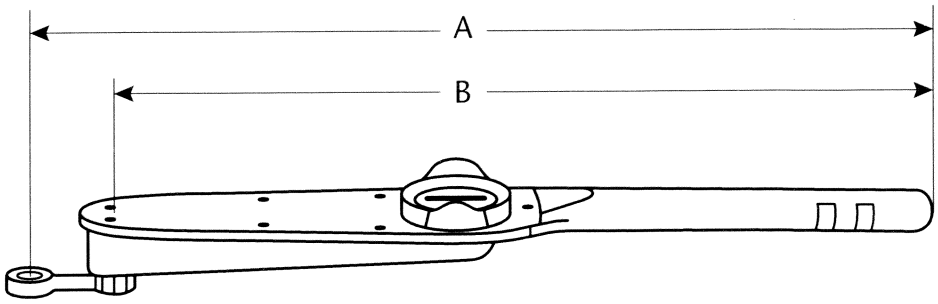


Figure 76. Horizontal Adapter Lengthening the Torque Wrench

Torque Multiplier

There will be times when you will need to tighten a bolt extremely tightly. For example, some U-bolts need to be torqued to 1890 N•m. No torque wrench will be able to deliver that amount of torque accurately. A torque multiplier is an adapter that goes between your torque wrench and the socket on the bolt. It will multiply the torque you apply. Some may multiply at a rate of 4-1, others may go as high as 25-1. With a 4-1 multiplier, applying 400 N•m of torque will result in 1600 N•m torque at the bolt head.

Figure 77. Torque Multiplier

Learning Task 4

Select, Use, and Maintain Measuring Instruments

NOTES

Layout Tools

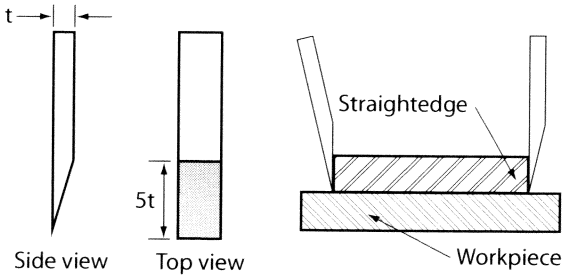
Layout is the procedure by which you measure and mark lines on materials. Since these lines are taken from plans, blueprints, or drawings, layout involves the skill of transferring measurements or dimensions to the materials accurately and clearly.

Marking Tools

When you fabricate a component, you have to lay out where holes are drilled, where it is cut and at what angle, how long the piece is, and its final shape. Marking tools allow you to accomplish this.

Soapstone

Soapstone is a chalk-like substance that you use to mark layout lines on steel (Figure 1). Its disadvantage is that it wipes off easily. Soapstone is kept in a soapstone holder, which is usually either round or flat.



When sharpening soapstone, taper 4 to 5 times thickness.

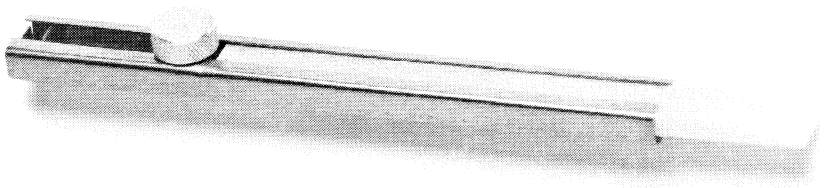


Figure 1. Soapstone and Holder

NOTES

Scriber or Awl

The scriber or awl creates layout lines that are accurate and last longer than lines made with soapstone (Figure 2). Scribers come in different sizes and forms. Maintain the sharpness of the fine point by grinding the scriber regularly. Use only light pressure to prevent overheating. Overheating will draw or remove the temper (hardness) from the point. Some scribers have tungsten carbide tips which last longer than regular tips, but can only be ground on diamond wheels.

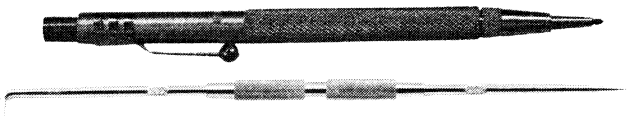


Figure 2. Scriber

Chalk Line

A chalk line is a string that has been coated with chalk powder (Figure 3). They are available in white, blue, and red. Choose the colour that has the highest contrast with the surface you're marking. Chalk lines are used to lay out true vertical and horizontal lines in the same way as a plumb bob. Stretch the line tightly between two points on a surface, raise the line and allow it to snap back. The snapping action deposits a straight line of chalk.

Figure 3. Chalk Line

Divider

Another tool used in layout and metal fabrication is the divider (Figure 4). You can use the divider to scribe circles and arcs or to locate one centre point in relation to another. As with the scriber, the hard, slender point has to be ground frequently. Do this gently to avoid overheating.

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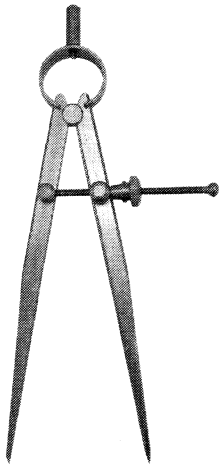

Figure 4. Divider

Prick Punch

You can use a prick punch to make a dimple in metal before drilling a hole. Its tip tapers to a very narrow, sharp point that is ground to an angle of 30–60°. This gives the prick punch a very thin point, which makes it easy to make an exact placement on the work piece. Use the prick punch before drilling to make a small, accurate indentation at the intersection of two layout lines. Once you've accurately placed this indentation, use a centre punch to enlarge it to the size appropriate for the drill bit.

Figure 5. Prick Punch

Spring-loaded Prick Punch

A spring-loaded prick punch (Figure 6) can be used to make a small, accurate indentation at the intersection of two layout lines. Push the punch into the work piece, compressing the spring until you reach the release point. Then the spring shoots the tip into the work.

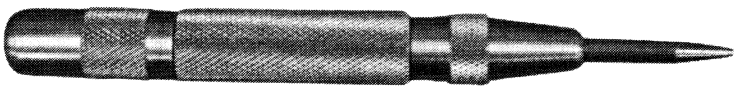

Figure 6. Spring-loaded Prick Punch

NOTES

Centre Punch

The centre punch has a tapered tip with a broad, sharp point (Figure 7). The tips of centre punches are ground to an angle of 60–90°. This makes them durable tools, but also difficult to position accurately on a smooth work surface such as plate.

You will use the centre punch mainly to punch indentations in metal as a guide for starting a drill bit. For this procedure, you first mark the material to be drilled with a scriber or pencil, then place the centre punch directly on the mark and strike the punch with a hammer. The larger 60–90° indentation helps prevent the tip of the drill bit from slipping out of position.

Figure 7. Centre Punch

Precision Measuring

You will often have to measure components with great accuracy. This is necessary to determine if a part is serviceable, can be reconditioned, or must be replaced. There are many tools and measuring instruments you'll use depending on what needs to be measured. There are also two systems of measure: metric and imperial.

Metric

The base unit in metric measurement is the metre. The metre is divided into 100 centimetres (cm) or 1000 millimetres (mm). A millimetre is one-tenth of a centimetre. Millimetres and centimetres are the common units of metric measurement.

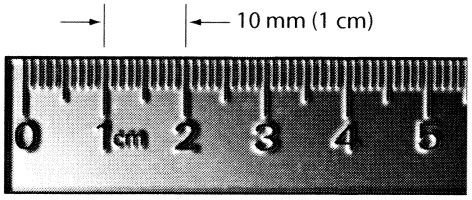

Figure 8. Relationship Between Millimetres and Centimetres

NOTES

Imperial

Feet (') are divided into 12 equal parts called inches ("). Inches are divided into equal parts. The parts of an inch are referred to in fractions. The fractions can be as large as ½, but greater accuracy is achieved by dividing these parts of an inch into quarters, eighths, sixteenths, or thirty-seconds of an inch.

Whenever a degree of accuracy greater than one thirty-second of an inch is required, mechanics measure by thousandths or ten-thousandths of an inch.

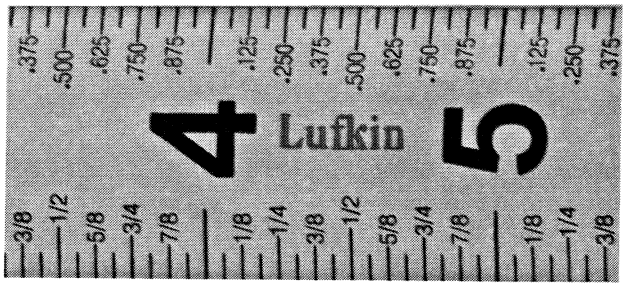

Figure 9. Quick Read Tape

Basic Measuring Devices

Mechanics use a wide range of measuring instruments for checking clearances and tolerances. These include:

- measuring tape
- steel rule
- calipers
- combination square

Measuring Tape

Tapes are used to measure large layouts (Figure 10). The steel tape is spring loaded to retract into its carrying case when released. Metric tapes are marked in one millimetre graduations. Some imperial tapes are graduated at thirty-seconds of an inch for the first 6 or 12 in., then at sixteenths for the balance of the tape.

NOTES

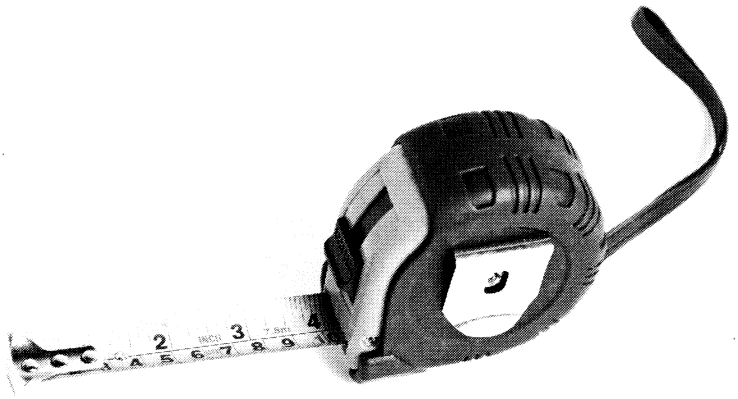

Figure 10. Pocket Tape

Steel Rule

Steel rules are usually 15 or 30 cm (6 or 12 in.) in length. They are used as straight edges and for measurements shorter than the length of the rule.

Imperial steel rules can be graduated as finely as 1/100 in. Metric rules may have graduations of 0.5 mm.

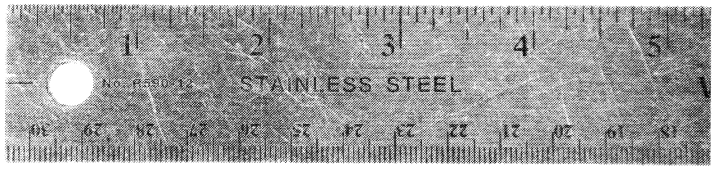

Figure 11. Steel Rule

Calipers

There are several styles of calipers (Figure 12). They can be used to compare measurements of one item to another, or to transfer a measurement to a steel rule or tape. Inside calipers are used to compare inside measurements such as the diameters of holes or the distance between two faces. Outside calipers are used for checking the diameter of cylindrical objects such as spindles, axles, and shafts. Dividers are used for layout only. They are never used to compare the inside measurement of one object to the outside measurement of another object.

NOTES

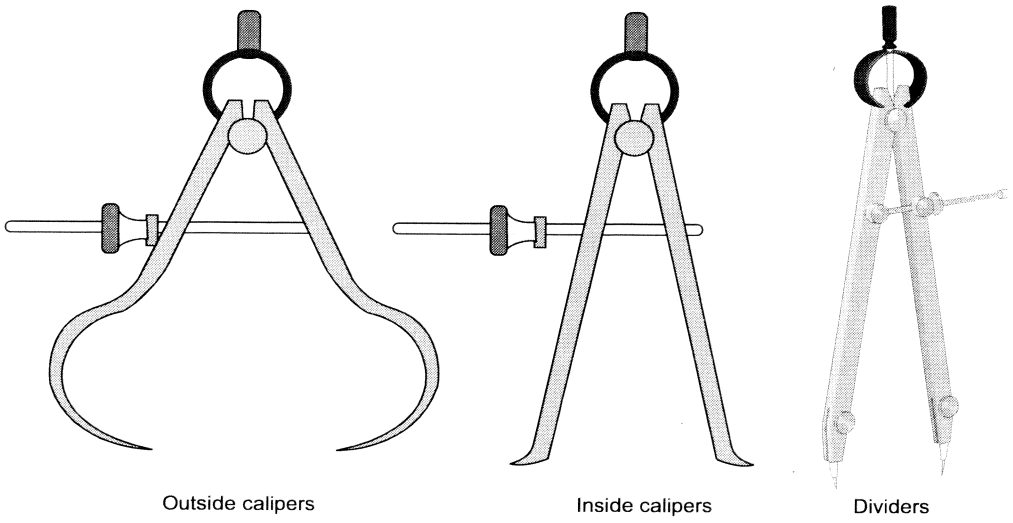

Figure 12. Calipers

Combination Square

A combination square has a tempered steel blade with four engraved scales (Figure 13). There are three interchangeable heads which slide in a central groove on the blade. The three heads are the square head, the protractor head, and the centre head. They can be adjusted to any position along the blade or removed to allow the blade to be used as a rule. Combination squares have a large number of applications.

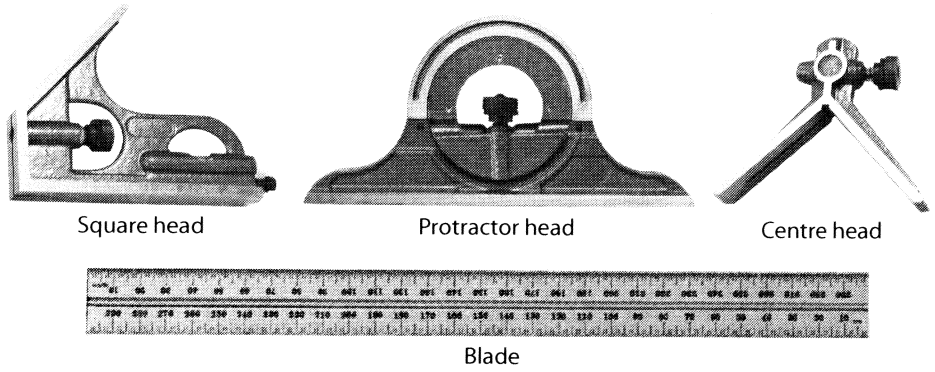

Figure 13. Combination Square

Square heads have a 90° square face and a 45° mitred face. They can also have a spirit level and a scriber and can be used separately as a level. Protractor heads have a revolving turret with graduations from 0–180°. Centre heads have two equal arms that enable you to find the centre of round stock.

NOTES

Some of the practical applications of combination sets are squaring work, transferring measurements, laying out work, levelling surfaces, determining plumb, establishing centres, and laying out and checking angles. They can also be used as a depth gauge for measuring recesses.

Precision Measuring Devices

Many components will need to be measured to a greater accuracy than can be achieved with a tape measure. When you need to measure to a tenth of a millimetre or a thousandth of an inch, you will use one of the following instruments:

- micrometer
- vernier caliper
- dial indicator
- thickness gauge
- small bore gauge

Micrometer

Micrometers are available in many shapes and sizes to suit a variety of purposes. Micrometers which are used to measure the outside dimension of an object are called outside micrometers. Inside micrometers measure the diameter of a hole or distances between two surfaces. Depth micrometers measure the depth of a hole or the step on a counter-bore.

Most micrometers are available with a digital display which provides the total measurement, so you don't need to know how to read micrometer markings. The accuracy of digital micrometers can be as high as 0.001 mm (0.00005 in.). Many digital micrometers can be set to display in millimetres or in decimal inches. Digital micrometers may have additional features such as "hold on readings" which keeps the measurement displayed even after the tool is adjusted.

Outside Micrometer

Outside micrometers have a rounded frame to fit around the object being measured (Figure 14). The anvil is a smooth, fixed contact face which you place against the object to be measured. The spindle also has a smooth contact face. The sleeve (also called a "hub" or "barrel") is fixed to the frame and does not move. The major and minor scale measurements are on the central line of the sleeve. These numbers are usually scribed into the metal of the sleeve. A line scribed under the numbers is called the zero line (or "datum line").

The thimble rotates. Threads inside the thimble are connected to threads on the spindle, so rotating the thimble moves the spindle back and forth.

NOTES

Around the circumference of the thimble are the thimble graduations which represent units of measurement smaller than those on the sleeve. One complete revolution of the thimble equals one sleeve minor scale increment. The thimble is tapered at the upper end so that the lines on the thimble and the zero line on the sleeve meet on the same plane.

The ratchet stop or friction device is used to rotate the spindle when you are making very fine measurements. The ratchet stop limits the spindle pressure on the part being measured to a finite amount. The ratchet stop begins to slip when too much pressure is applied, indicated by a clicking sound. It is advisable to count the number of ratchet clicks and use the same number of clicks each time a measurement is taken.

A lock nut or clamping ring is used to lock the spindle at the desired setting. This allows the part being measured to be removed without accidentally changing the measurement.

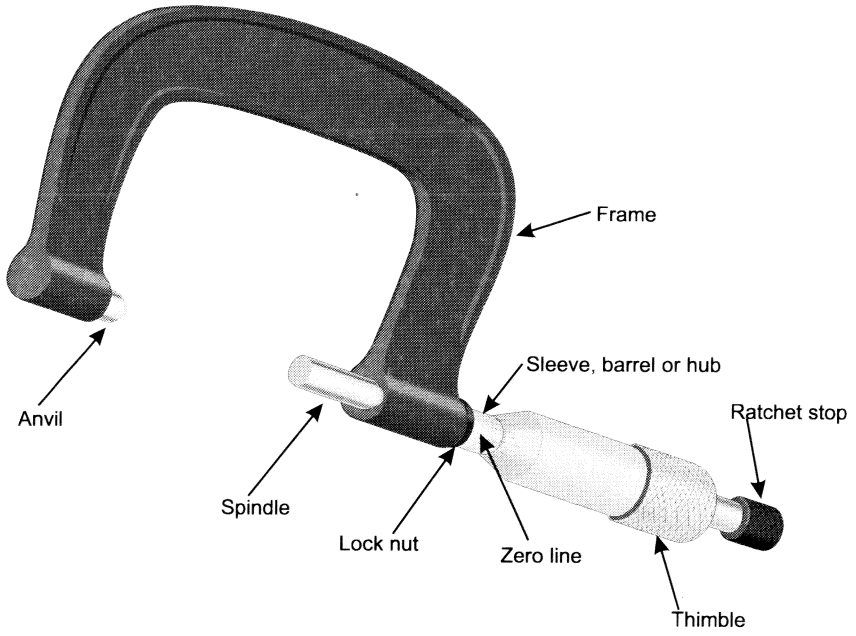

Figure 14. Outside Micrometer

To read a metric outside micrometer, the sleeve major scale graduations mark millimetres. The numbers 2 and 3 on this scale correspond to 2 mm and 3 mm respectively. Some metric micrometers do not have a number to mark every millimetre line, but only mark every 5 mm.

The sleeve minor scale is represented by lines, not numbers. This minor scale marks halves of the major scale, so there is one line between each major scale line. The minor scale marks equal 0.50 mm.

NOTES

The thimble graduations are marked by lines and numbers scribed onto the thimble. These numbers marks hundredths of a millimetre (0.01 mm). The numbers 2 and 3 on this scale correspond to 0.02 mm and 0.03 mm respectively. Some metric micrometers do not have numbers to mark every 0.01 mm; but only mark every 0.05 mm.

To read the metric micrometer:

1. Write down the minimum size of the micrometer.

2. Locate the highest sleeve major scale graduation that is visible on the sleeve, multiply this number by 1.00 mm and write it down below the first number.

3. Count how many sleeve minor scale graduations are visible between the major scale graduation and the thimble, multiply this number by 0.50 mm and write it down below the other numbers.

4. Locate the thimble graduation that is nearest to the zero line, multiply this number by 0.01 mm and write it down below the other numbers. (Often the lines will not line up exactly as long as you only need a measurement accurate to 0.01 mm, use the lower number for your reading.)

5. Add up the numbers.

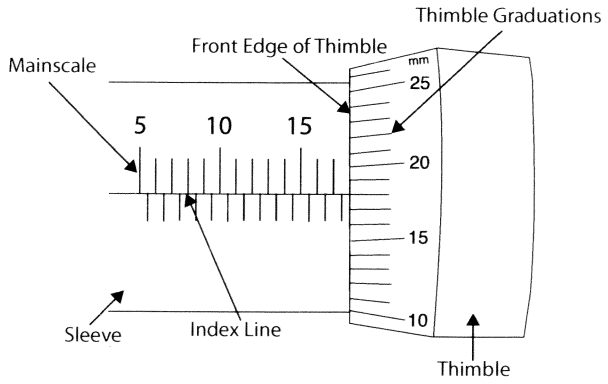

Figure 15. Metric Micrometer

In Figure 16, the reading will be 11 mm on the sleeve, plus 0.50 mm on the thimble, which equals 11.50 mm.

NOTES

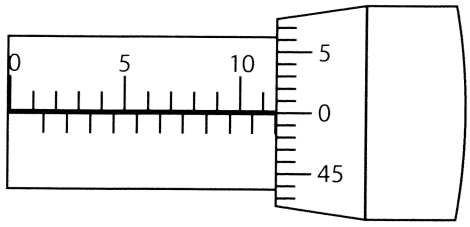

Figure 16. Reading a Metric Micrometer

Some micrometers called vernier micrometers measure to an accuracy of 1/100 000 of an inch.

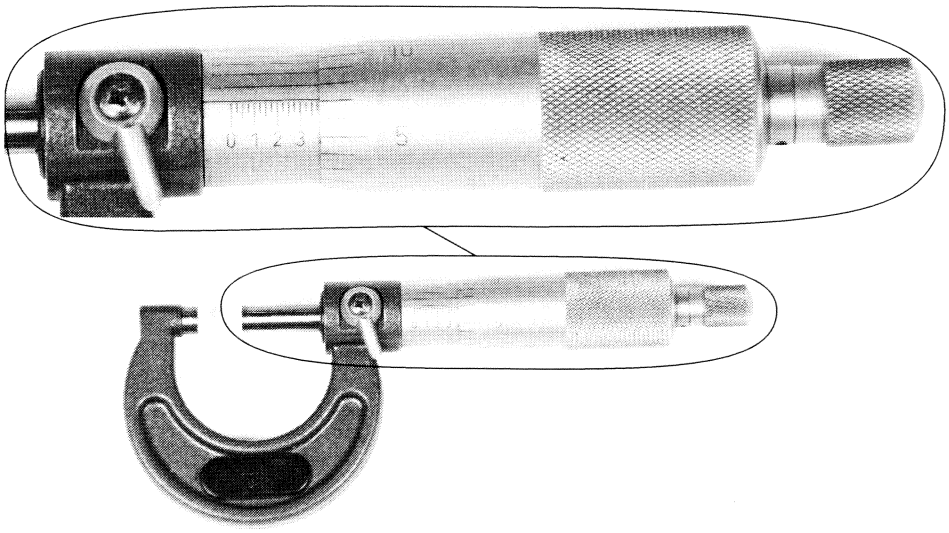

Figure 17. Vernier Micrometer

On imperial outside micrometers, the sleeve major scale graduations mark tenths of an inch. The numbers 2 and 3 on this scale correspond to 0.200 in. and 0.300 in. respectively. The sleeve minor scale is represented by lines only, not numbers. The minor scale graduations mark 0.025 in., therefore there are three lines between each major scale line and number. The minor scale graduations equal 0.025 in., 0.050 in, and 0.075 in.

The thimble graduations are marked by lines and numbers scribed onto the thimble. These numbers mark thousandths of an inch. The numbers 2 and 3 on this scale correspond to 0.002 in. and 0.003 in. respectively.

NOTES

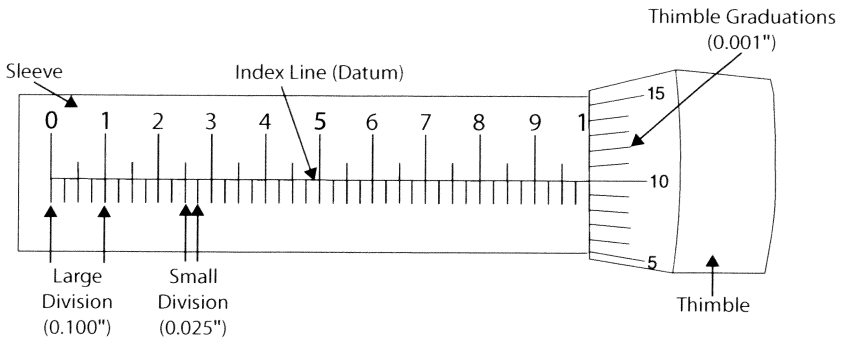

Figure 18. Imperial Micrometer

To read the imperial micrometer:

1. Write down the minimum size of the micrometer.

2. Locate the highest sleeve major scale graduation that is visible on the sleeve, multiply this number by 0.100 in. and write it down below your first number.

3. Count how many sleeve minor scale graduations are visible between the major scale graduation and the thimble, multiply this number by 0.025 in. and write it down below the other numbers.

4. Locate the thimble graduation line that is either on the zero line or below it, multiply this number by 0.001 in. and write it down below the other number. (Often the lines will not line up exactly; as long as you only need a measurement accurate to 0.001 in., use the lower number for your reading.)

5. Add up the numbers.

For the example in Figure 19, there are six major divisions which equal 0.600 in., then there are three minor division which equals 0.075 in. and then the thimble has 0.015 in. When you add them up, the measurement is 0.690 in.

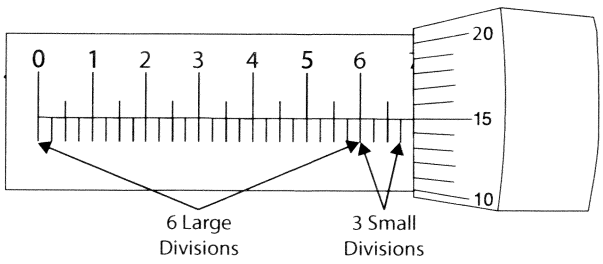

Figure 19. Reading a Imperial Micrometer

NOTES

With practice, you'll be able to do these calculations in your head but while learning how to read a micrometer, it's best to write down your calculations.

Some standard imperial micrometers are capable of measurements that are accurate to one-thousandth of an inch (0.001 in.). In many cases it's necessary to make measurements to one ten-thousandth of an inch (0.0001 in.). The vernier micrometer has the capability of measuring this accurately.

A vernier micrometer is similar to a standard imperial micrometer, with the exception of an additional scale located on the sleeve graduated to read in ten-thousandths of an inch. This set of 11 lines or graduations is called the vernier scale.

On a micrometer with a vernier scale on the sleeve, the additional graduations measure a decimal part of a division of the thimble. The vernier scale divides the thousandth of an inch into tenths of a thousandth of an inch. Each vernier graduation is equal to 0.0001 in. The graduation on the vernier scale that lines up perfectly is the number you use. For example the reading for Figure 20 is 0.3821 in.

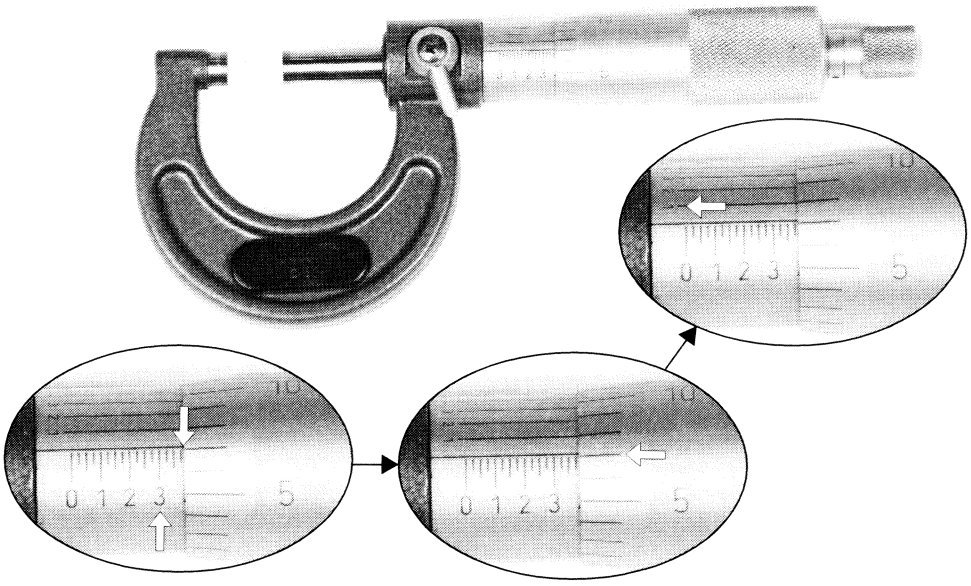

Figure 20. Graduation Reading

The range of an outside micrometer is in increments of 25 mm (1 in.). For example, one micrometer may measure from 0–25 mm (0–1 in.), while another measures from 25–50 mm (1–2 in.). If you need to measure a component that is around 65 mm (2.5 in.), use a 50–75 mm (2–3 in.) micrometer. Some micrometers come in a set from 50–150 mm (2–6 in.). You have to change the spindle to change the range of the micrometer.

NOTES

Every outside micrometer must be calibrated before use. The micrometer calibration is adjustable with a couple of wrenches. You must use the measuring standard for the range of spindle you are using (Figure 21).

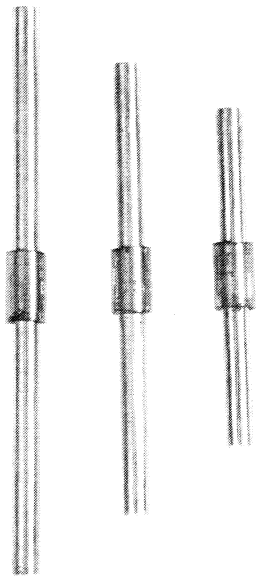

Figure 21. Measuring Standards

Inside Micrometer

An inside micrometer is used when you want to accurately measure a bore. The smallest measurement the inside micrometer is able to take is 25 mm (1 in.). Like the outside micrometer, inside micrometers are available in either imperial or metric scales. The basic parts of the inside micrometer are similar to the conventional outside micrometer, but without a frame. Graduations are etched on the sleeve and thimble. Inside micrometers normally have a range of 12 mm (½ in.). Readings are obtained in the same manner as with the outside micrometer. One end of the anvil is located at the thimble end. The head or holder is used to hold measuring rods. Various lengths of rods are used depending upon the diameter or distance to be measured (Figure 22). Combinations of rods can be used to measure distances from 50–150 mm (2–6 in.). A spacing collar of 12 mm (0.500 in.) can increase the size of the micrometer when placed on the rod between the micrometer head and the rod shoulder.

NOTES

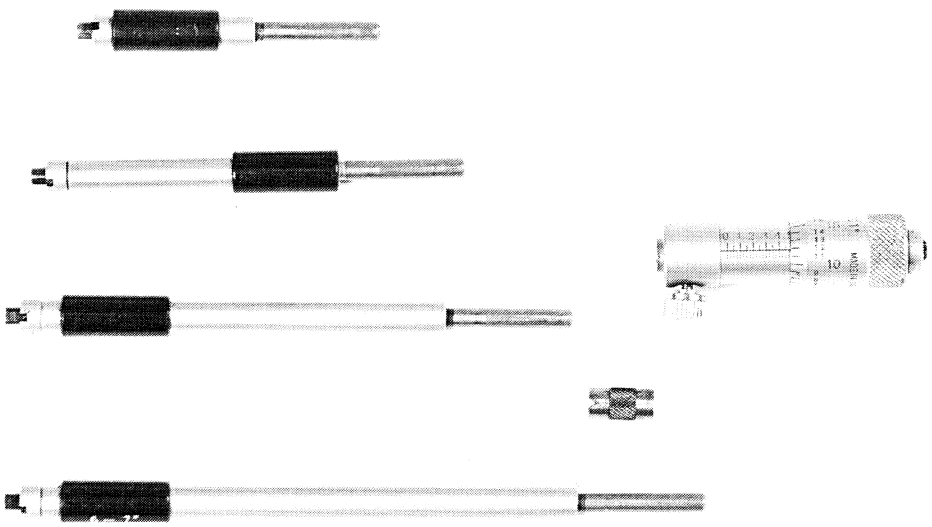

Figure 22. Inside Micrometer Parts

Some inside micrometers use a locking ring or lock nut to hold the rod tight within the head. The zero on the rod should be in line with the zero on the head when the rod is locked in place.

An extension handle and holder can be used when the inside micrometer must be placed down a long cylinder or deep groove to obtain a reading. The handle is usually part of an inside micrometer set.

Before a measurement can be taken, the approximate diameter or distance must be determined in order to know which extension rod to use. Once the approximate size to be measured has been estimated, assemble the correct length measuring rod on the micrometer head. Be sure to wipe down the spindle of the micrometer before assembling.

Hold the assembled tool across the diameter of the work with the rod end held against one of the surfaces. Turn the thimble until the anvil just begins to make contact with the surface directly opposite the rod end. Gently rotate the end of the micrometer in both directions to be sure that you are measuring the true diameter.

Try to move the micrometer from left to right and in and out of the diameter being measured. You have the proper measurement when you feel no left and right movement and when a slight drag is noticeable when you move the instrument in and out.

For large diameters, it's advisable to take several readings and average them to determine a final reading. However, if you're looking for the greatest wear or maximum run-out, take several readings to obtain both the highest and lowest reading (rather than the average). Remember to add the length of the measuring rod to the reading obtained on the sleeve and thimble.

NOTES

Depth Micrometer

The micrometer depth gauge, like the micrometer, can obtain readings accurate to a hundredth of a millimetre or a thousandth of an inch.

The micrometer depth gauge is used to measure slots, depths of holes, recesses, keyholes, etc. The base is hardened for greater accuracy. The hub and thimble are the same as on an outside micrometer, except for the fact that the scale is read from the opposite end. Interchangeable measuring rods are supplied in increments of 25 mm (1 in.). The range of most micrometer depth gauges is from 0–250 mm (0–10 in.).

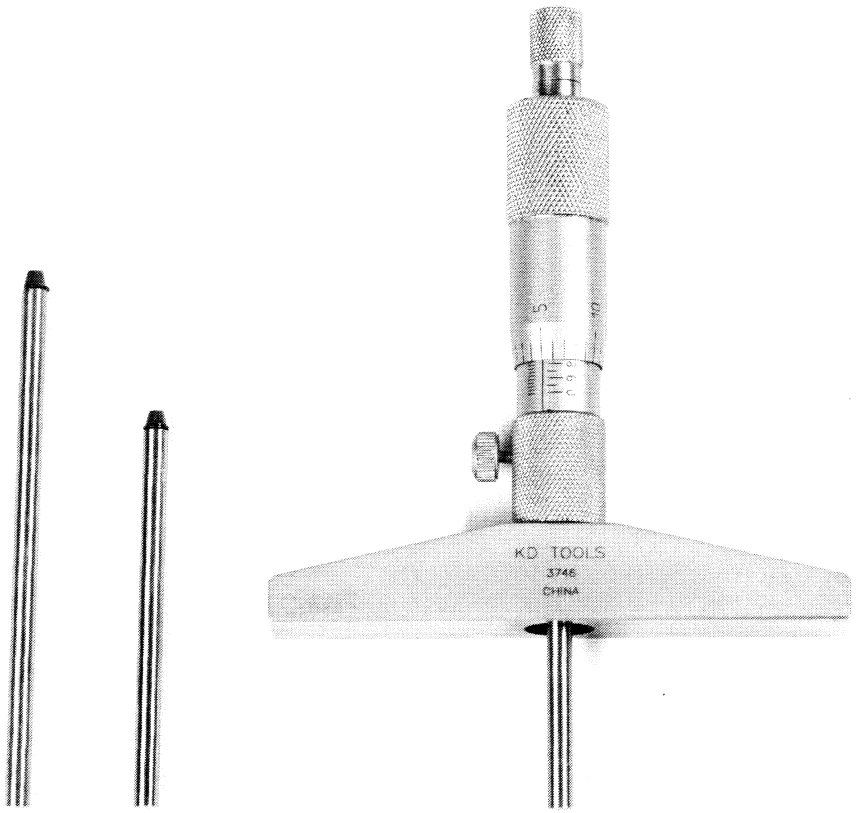

Figure 23. Depth Micrometer

Measuring rods are inserted in the end of the micrometer by removing the knurled nut on the thimble. The desired length rod is passed through the hole and pressed in until it is firmly set in the thimble. The knurled nut is then tightened to prevent the rod from loosening.

Reading Micrometer Depth Gauges

Depth gauge readings are taken in exactly the same way as with an outside micrometer except that the graduations on the hub run in the opposite direction. As the thimble is turned clockwisė, more graduations are covered.

NOTES

When taking a reading using a rod other than the 0–25 mm (0–1 in.) rod, be sure to consider the additional rod length. For example, if the 25–50 mm (1–2 in.) rod is used, 25 mm (1 in.) must be added to the hub and thimble readings. When using a 50–75 mm (2–3 in.) rod, 50 mm (2 in.) must be added to the reading.

Before using a micrometer depth gauge, clean the base, end of the rod, and the part being measured. Be sure that the rod is correctly placed in the micrometer. Hold the base firmly against the part to be measured and turn the thimble until the rod contacts the bottom of the slot, hole, or recess. Be sure to use the ratchet stop for a consistent feel. Tighten the lock nut and remove the tool from the work.

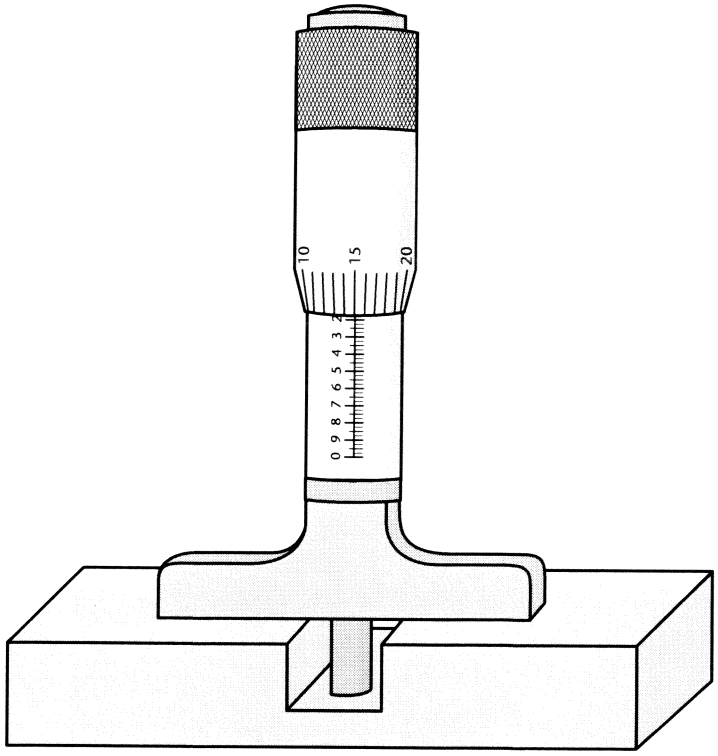

Figure 24. Micrometer Depth Gauge

Vernier Caliper

A vernier caliper (Figure 25) consists of an L-shaped frame with a fixed jaw as one of the legs of the frame. The graduations on the fixed portion of the calipers are called the main scale. The length of the main scale determines the size of the calipers. Standard lengths are 150 mm, 300 mm, 0.9 m, and 1.2 m (6 in., 12 in., 36 in., and 48 in.). The most commonly used sizes are 150 mm and 300 mm (6 in. and 12 in.). A sliding bar with a jaw attached moves along the main scale. The sliding bar has a vernier scale (Figure 26).

NOTES

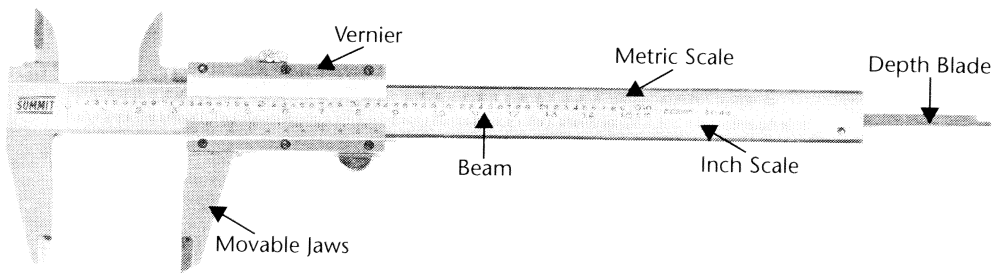

Figure 25. Vernier Caliper

Both inside and outside measurements with vernier calipers are taken in much the same way. To take an outside measurement on a piece of round stock, loosen both lock screws on the movable jaw and the sliding member. Place the calipers over the piece to be measured. Place the stationary jaw against the round stock and push the movable jaw in until it nearly touches the round stock.

Next, tighten the lock screw on the slide member and rotate the fine adjustment nut until the movable jaw contacts the round stock. You have the proper feel when there is a slight resistance to removing the caliper from the round stock. Tighten the lock screw on the movable jaw to prevent any possible change in the setting of the instrument after the calipers are removed. Carefully remove the tool from the round stock and take the reading.

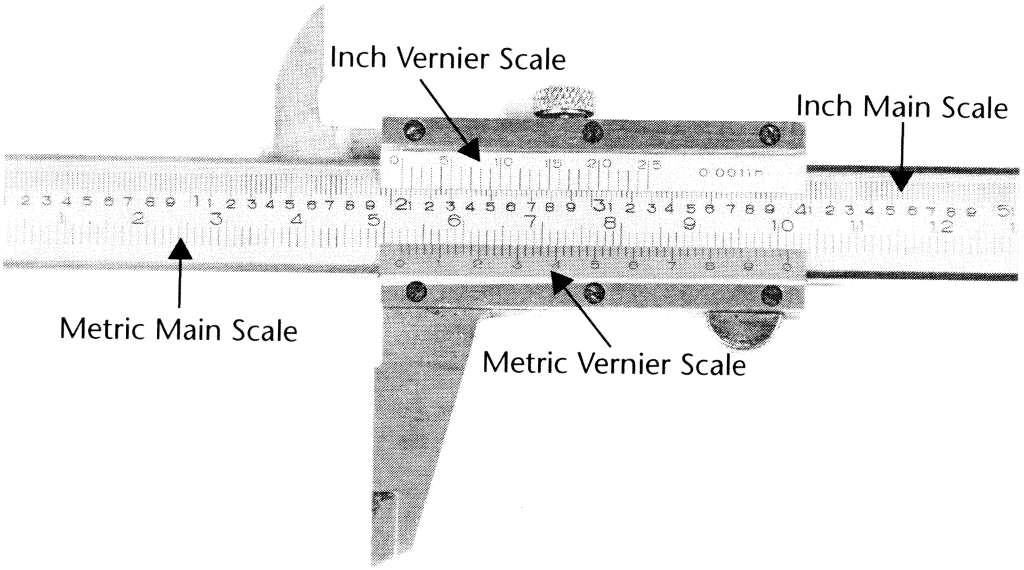

Figure 26. Sliding Bar of a Vernier Caliper

NOTES

To read the metric measurement, you need to find the zero "0" on the vernier scale. That is your starting point. On the top side of the caliper is the Metric Main Scale. The large numbers (10, 20, 30, 40, etc.) are millimeters. The Metric Vernier Scale has large numbers (1, 2, 3, etc.) each of which equals 0.1 mm. It also has a series of small lines, each equal to 0.02 mm.

In Figure 27 the "0" is between 5 and 6 mm, but you can't tell exactly where. To calculate this measurement you add 5 mm to the vernier scale number that lines up perfectly with the numbers on the beam. In this case it is the number 2, which is 0.2 mm. So the measurement equals 5.2 mm.

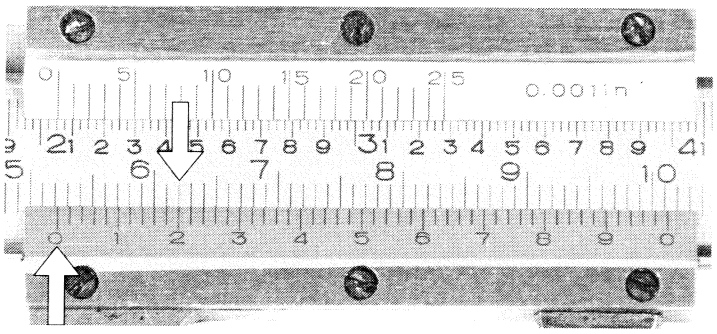

Figure 27. Reading a Metric Vernier Caliper

To read the imperial measurement, you need to find the "0" on the vernier scale. That is your starting point. On the bottom side of the caliper is the Inch Main Scale. The large numbers on the beam are inches, the small numbers are 0.100 in. and each small dash is 0.025 in. The vernier scale has markings of 0–25 which are thousands of an inch.

There are four readings you must sum to find the complete measurement:

1. The position of the 0 on the 1 in. main scale.
2. The position of the 0 on the 0.1 in. main scale.
3. The position of the 0 on the 0.025 in. main scale.
4. The graduation on the vernier scale that most closely aligns with a graduation on the main scale.

NOTES

Referring to Figure 28, you have the following readings:

1. The 0 is between 2 and 3 on the 1 in. scale, so the reading is 2 in.
2. The 0 is between 0 and 1 on the 0.1 in. scale, so the reading is 0.0 in.
3. The 0 is between the second and third dashes on the 0.025 in. scale, so the reading is (2 x 0.025 in.) or 0.050 in.
4. The graduation on the vernier scale that most closely aligns with a graduation on the main scale is 4, so the reading is 0.004 in.

Adding all of these together results in 2" + 0.0" + 0.050" + 0.004" = 2.054".

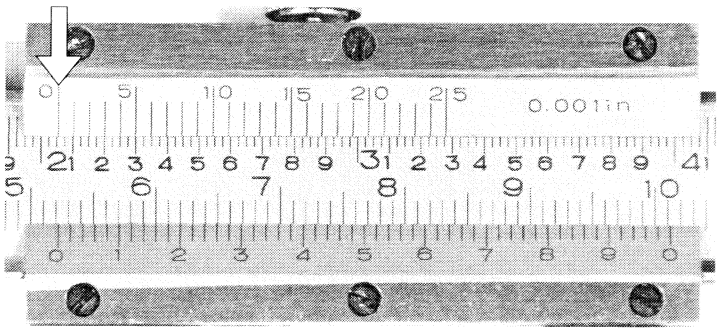

Figure 28. Reading an Imperial Vernier Caliper

Dial Caliper

Dial calipers (Figure 29) are similar to ordinary vernier callipers except for the dial indicator and the graduations on the bar. Each graduation on the bar is equal to 0.100 in., while the dial is calibrated in 0.001 in. graduations. One complete revolution of the dial is equal to 0.100 in. The jaws are constructed to take both inside and outside measurements. A sliding rod is also provided for measuring depth. A thumb roll knob is included so that fine adjustments can be made with one hand.

NOTES

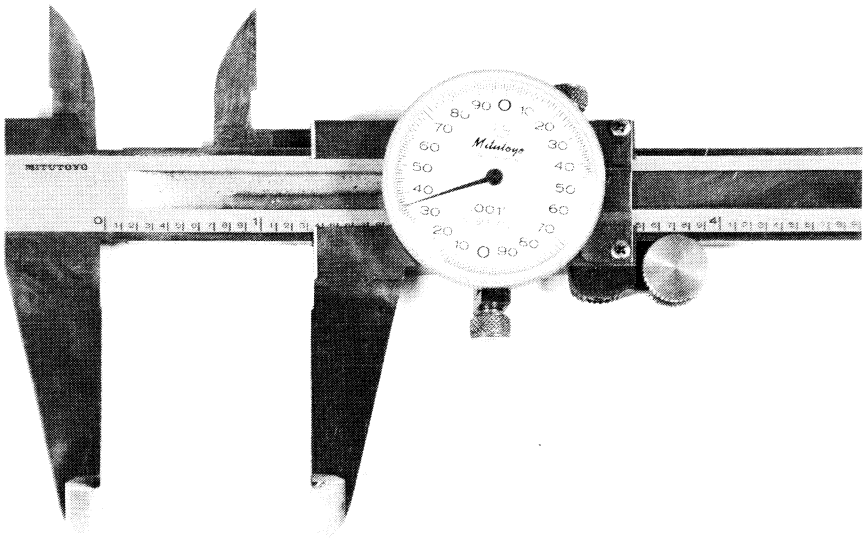

Figure 29. Dial Caliper

Digital Caliper

Digital calipers are very easy to use as the reading is shown digitally. You can change from metric to imperial with a push of a button. You can also hold your reading with a push of a button, so it doesn't change if you bump the caliper.

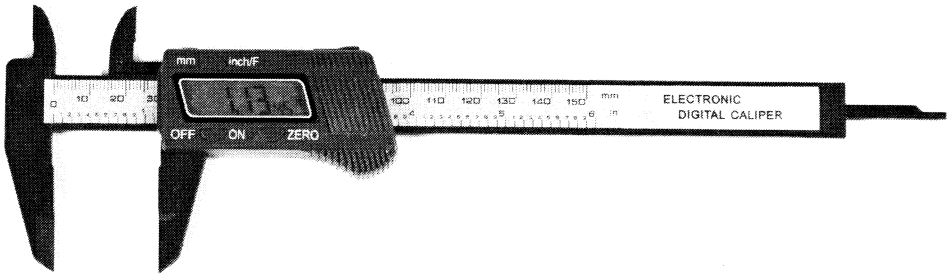

Figure 30. Digital Caliper

NOTES

Dial Indicator

Dial indicators are used to check variations from a desired dimension on machined parts, backlash, and clearances. Dial indicators range in size from approximately 25–114 mm (1–4½ in.) in diameter. Most stems have 1.2 mm (0.5 in.) travel, but some have 25 mm (1 in.). They can be mounted with a magnetic base or clamped to a work piece.

The face of the indicator is called the dial and features equally spaced graduations. Imperial dial indicators are classified as 0.001 in. indicators or 0.0001 in. indicators and this is shown on the dial face. The stem makes contact with the surface to be measured and may also be operated by a lever. The stem moves in and out and is linked to a dial pointer through a system of small gears. These gears multiply the tiny movement of the stem into larger, more easily seen movement of the pointer. This tool is delicate because of its precision. Avoid dropping or rough-handling the indicator in any way.

The dial can be rotated in order to adjust or "zero" the indicator. The dial is connected to an outer ring called a bezel. A bezel clamp screw locks the bezel and dial at any desired location.

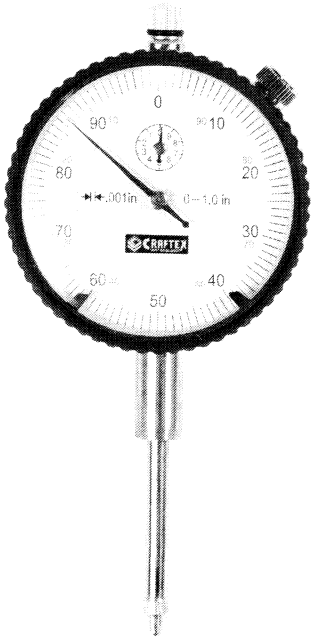

Figure 31. Dial Indicator

Dial Types

The most common type of dial indicator is the balanced type. A balanced dial has an equal number of graduations on both sides of zero. This kind of dial is used to check the plus and minus tolerance variations of a particular part. Some balanced indicators may have double rows of figures on the dial. There are two sets of numbers that sweep completely around the dial in opposite directions. This arrangement allows the pointer to move in a complete circle and have twice the range.

Continuous dials have their graduations numbered continuously around the face of the dial. The range of these dials is usually two and a half revolutions of the pointer. Some indicators have a revolution counter built into the face of the dial that tells how many revolutions the pointer has made.

Digital dial indicators display the measurement on a liquid crystal display. They can be set to display in metric or imperial.

NOTES

How to Use Dial Indicators

The stem of the indicator operates the pointer on the dial. When the stem is pushed into the bushing, the pointer moves clockwise, or to the right, on a plus (+) scale. The further up into the bushing the stem moves, the greater the + value shown on the dial. When the stem moves down from the housing, the pointer moves counter-clockwise, or to the left, on a minus (–) scale.

To use the balance dial, there must be stem movement both up and down. This will allow the pointer to move with equal freedom to both the right and left of zero.

When the indicator is at rest and not making contact with an object, the stem is under the force of a small spring inside the unit. With the stem in this extended position, the pointer of the indicator has travelled its furthest distance counter-clockwise and usually comes to rest at about 90° to the left of the zero on the dial. From this position the pointer is free to travel only in a clockwise direction.

To prepare the indicator for use with the correct stem movement, it must be placed in a test set, which is an adjustable clamping device or a holder. The stem must then be brought in contact with the piece to be measured. The indicator is then lowered to rest against the object being measured so that the stem is depressed about half way into the bushing. This allows the pointer to move to the right or left of the zero.

The test set holds the indicator rigidly so that the stem is the only part that moves as a surface is checked. During measurement, any movement of the indicator body in relation to the stem will cause an error in the readings.

Place the stem in contact with the surface to be measured and make sure that it's slightly depressed. If the pointer does not line up with the zero on the dial, loosen the bezel clamp screw. This will allow you to rotate the bezel and to align the dial zero with the pointer. Be sure to tighten the clamp screw again when you have zeroed the dial.

A dial indicator is used to measure things such as:

- gear back lash
- shaft end play
- counter bore depth
- shaft run out
- lobe lift

NOTES

Thickness Gauge

Thickness gauges are commonly called feeler gauges (Figure 32). A thickness gauge is a flat piece of hardened steel of a specified thickness. The thickness of various gauges usually ranges from 0.0015–0.032 in. Metric gauges have a somewhat wider range, from 0.025–1.0 mm. Often both metric and the imperial equivalent are scribed on the gauge.

Gauges are usually grouped in sets of six or more and are protected by a steel case with a locking device. The locking device allows any individual gauge to be locked in any position for use. Some gauges are sold in individual strips.

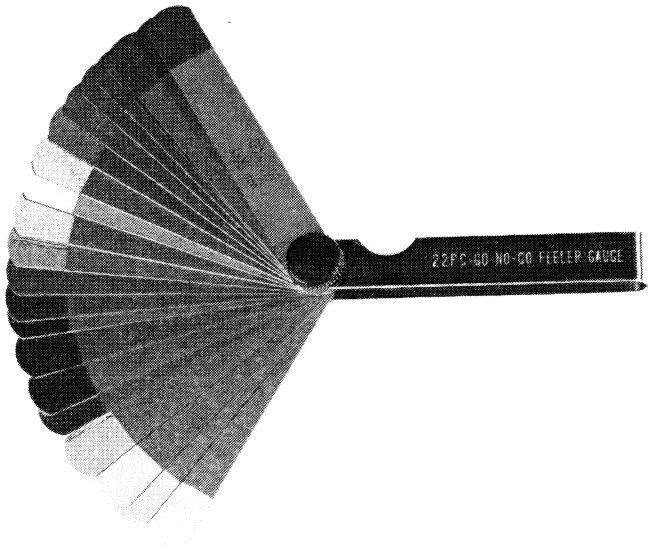

Figure 32. Thickness Gauge Set

A variation is the step feeler gauge or "go-no-go" gauge. These feeler gauge strips have a short section at the end that has been ground 0.05 mm (0.002 in.) thinner than the remainder of the gauge. For example, a step feeler gauge might be 0.1–0.15 mm (0.004–0.006 in.).

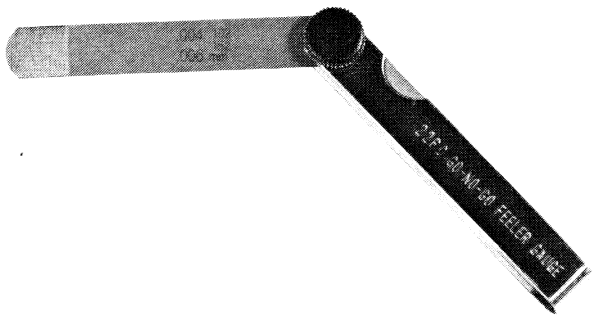

Figure 33. Step Feeler Gauge Set

NOTES

A feeler gauge is used to measure things such as:

- clearance between oil pump gears and the oil pump inner housing
- the side clearance between a connecting rod and the crankshaft of the engine
- ring gap (ring gap is the distance between the two ends of the ring when it is squarely placed in the cylinder bore)
- valve clearances

Bore Gauge

When you want to measure a hole, slot, groove, or recess ranging from 3–12 mm (⅛–½ in.) in diameter or width, a small hole gauge is the proper tool to use (Figure 34).

Two types of small hole gauges are available. One gauge type has a gauging surface made up of half a ball with a flat bottom. The flat bottom permits measurements in the most shallow holes, slots, and recesses. A second type of small hole gauge is the split-ball. It is similar to the half-ball type, but is not capable of measuring holes and recesses quite as well because its measuring surfaces are curved rather than flat. The contacts (split halves) are made of hardened steel to give the tool long life.

Both kinds of gauges are adjusted by a knurled (ridged) knob at the top of the gauge, which provides a smooth adjustment and sensitive feel for accurate measurements. As the knob is turned, a tapered centre piece extends down between the two ball halves, expanding them.

To take measurements, place the hole gauge in the hole, slot, or recess and turn the knurled knob until the split halves of the gauge contact the surfaces to be measured. Carefully remove the gauge from the hole and measure the gauge with an outside micrometer.

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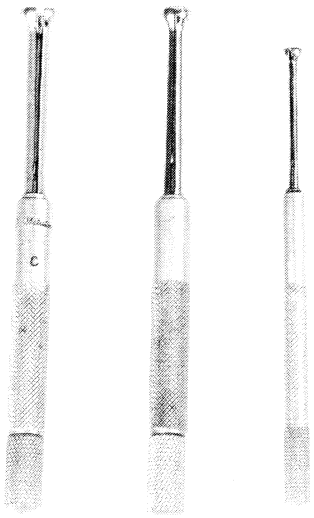

Figure 34. Bore Gauges

A telescoping gauge is used like inside calipers or a small hole gauge. The telescoping gauge is used to measure openings 12 mm (½ in.) and larger, but it has no scale graduations to obtain direct readings. A micrometer or vernier calipers must be used to measure the telescoping gauge itself.

Each telescoping gauge consists of two rods or pins. One rod slips inside the head and is spring loaded. The other rod or pin is fixed to the head and has a locking screw that can lock the rods in place at a desired measurement.

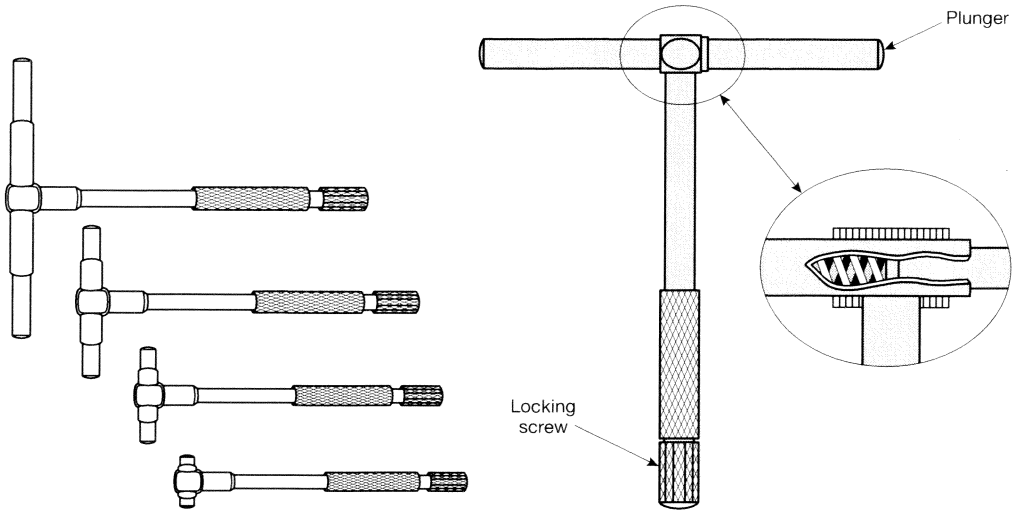

Figure 35. Telescoping Gauges

NOTES

To measure an inside diameter, loosen the lock screw and compress the telescope pin. Lock the pin with the lock screw and place the gauge in the hole. Be sure that the surfaces to be checked are clean as dirt may cause an inaccurate reading. Unlock the locking device on the handle. This allows the telescoping rod to expand to the inside walls of the part. The gauge should not be so tight that it sticks in or scratches the part being measured, but it should not be so loose that it falls out. Lock the rod in place once the proper feel has been obtained. There should be a slight drag on the gauge when you move it in the bore. When the gauge is locked at the correct measurement, transfer it to a micrometer.

Maintaining Measuring Tools

To protect measuring instruments from dirt and contamination, store them in boxes or in cases. Store them away from other tools that could damage them. Never allow measuring tools to become rusty or dirty. Clean them as necessary and oil them lightly with machine oil. Clean the contact faces before measuring to make sure that the measurement is accurate. Never use anything abrasive to wipe the faces clean.

Avoid placing measuring tools where they will become overheated as this will affect their accuracy and may cause damage due to warp. Do not drop measuring instruments. If the instrument has been dropped, check the accuracy of measurement using a master gauge or a standard. Never use a measuring tool for anything other than measuring. They are not designed to be used as pry bars or hammers.

Never over tighten a vernier caliper or micrometer on the work being measured. Do not slide micrometers back and forth across the work being measured as this will wear the faces and affect accuracy.

Feeler gauges should be used carefully to avoid damage to the edges or to the flat surfaces. Any damage will result in inaccurate measurements. Never force a feeler gauge into a space that is too small for the gauge. Never bend or twist a gauge. If the end of the gauge is damaged, worn, or bent, cut off the damaged portion or replace the gauge. Keep gauges clean and lightly oiled to prevent rust and corrosion. If you are not sure about the accuracy of a feeler gauge, measure it with a micrometer.

Never attempt to use a small hole gauge to measure a diameter greater than its maximum or smaller than its minimum size. Expanding a small hole gauge beyond the normal range can cause damage and affect readings. Trying to insert a gauge in a hole that is too small will also damage the gauge.

When using dial indicators and telescoping gauges, never let the plungers snap out uncontrolled as this can affect the future accuracy of the tool. Never cause the gauge on a dial indicator to exceed the maximum or minimum movement as this will damage the meter movement.

NOTES

Learning Task 5

Select, Use, and Maintain Power Tools

To make efficient use of power tools, you must know which tool to use for a given task and whether the tool is performing as it should. Using an incorrect tool is dangerous, both to you and the tool. Maintenance and storage of tools are also very important.

There are three power sources that power tools use:

- pneumatic
- electric
- hydraulic

Pneumatic Power Tools

Air-impact Wrenches

An impact wrench can be used to set, run, or remove nuts and bolts. It's designed to provide sharp hammer blows to start the loosening process or to set a tightened fastener. There are a wide variety of sockets and attachments for this tool. Since impact wrenches are used for both assembly and disassembly, they're usually built for reversible operation.

Pneumatic impact wrenches are made in larger sizes than electrically-operated impact tools and are used more often in heavy-duty applications. These tools operate at speeds up to 10 000 RPM at no load and are capable of delivering as many as 3000 blows per minute.

Impact wrench sizes are designated by the size of the drive on the nose of the tool. The drive is usually square, with the most common sizes being 3/8 in., 1/2 in., 3/4 in., and 1 in.

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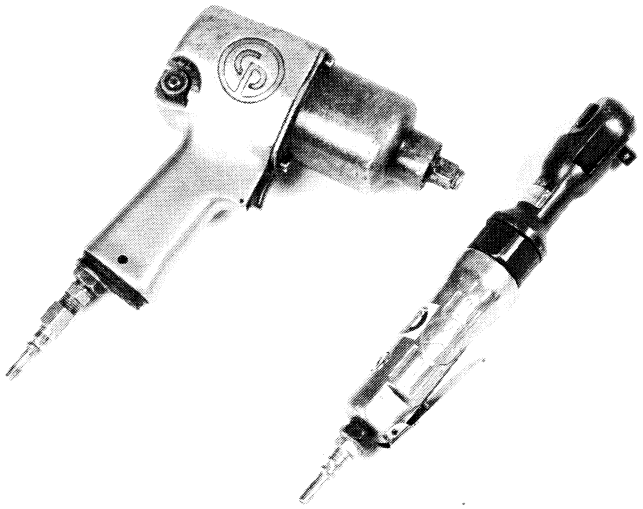

Figure 1. Pneumatic Impact Wrench

Although the sockets used with impact wrenches are similar to the ones used with hand tools, they're of a much stronger design in order to absorb the tremendous forces generated. Do not substitute a conventional socket for an impact socket. Conventional sockets can explode and cause injury.

A pneumatic impact wrench has several advantages. It is small in size and weight for a given capacity. A wrench capable of tightening an 8 mm (3/8 in.) bolt can be easily held in one hand. Another advantage is that because there is almost no torque reaction, the tool is unlikely to twist in your hand.

Torque is controlled by regulating the airflow to the motor of the wrench. Even though there is little torque reaction, air-impact wrenches can produce very high torque values and you need to exercise caution. In-line air pressure regulators are sometimes required to control torque.

Air-operated Grinders

Portable grinders are valuable tools for sharpening other tools, removing burrs, bevelling corners, and grinding welding beads. Accessories for brushing, buffing, filing, and sanding can be attached to certain models, increasing their versatility.

The grinder spindle speed varies proportionally to grinder size and ranges from 4000 RPM on larger models to over 40 000 RPM on smaller ones. Each grinder has a throttle lever to regulate speed. Certain models have a throttle lever stop-screw that limits throttle depression and may be adjusted to maintain a desired maximum RPM.

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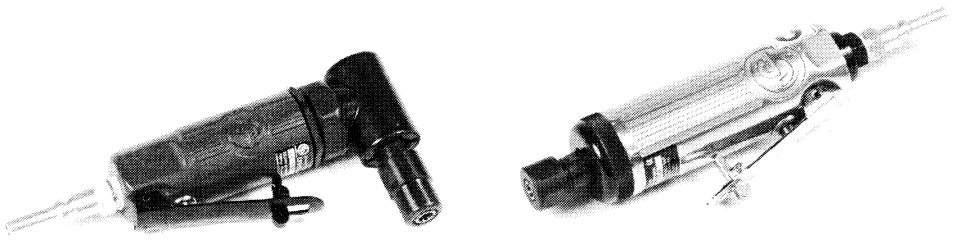


Figure 2. Air-operated Grinders

A portable pneumatic grinder is more convenient to use if a short 2- or 3-foot whip (leader) hose is attached directly to the tool and the air-line coupling is away from the tool. Although larger hoses are preferred for many pneumatic grinders, all hoses must have inside diameters of at least ¼ in. Before use, adjust the throttle lever stop-screw. The grinder speed is regulated by the distance the throttle lever is pulled or turned.

Air-operated Drills and Drivers

Pneumatic drills are operated by the force of air moving over the blades of a rotor. This turning force is transmitted to the chuck through a series of gears. The speed of the drill is controlled by the amount the air-throttle lever or trigger is depressed. Many pneumatic drills are designed with mufflers to reduce the noise caused by the motor.

Chucks for electric and pneumatic drills are made in different sizes corresponding to the drill capacity. Both keyless and key-type chucks are available. Both have three hardened steel jaws that are tightened and released by turning a threaded sleeve.

A keyless chuck has a knurled sleeve to permit hand tightening. The key-type chucks are adjusted by inserting a key into a hole on the chuck so that the teeth on the key engage matching teeth on the chuck sleeve (Figure 3).

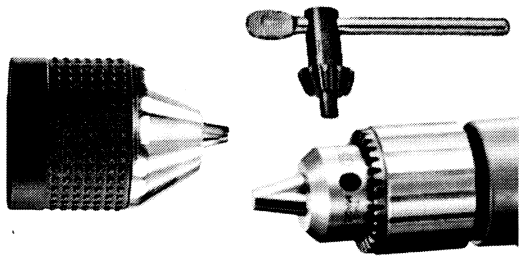


Figure 3. Chucks and Key

NOTES

The portable pneumatic drill is often preferred to an electric drill because it's light and has a high power output. In addition, it cannot overheat or be damaged by overloading. Use a pneumatic drill where air outlets are numerous and speed is of prime importance. Since the speed of the drill can be varied by controlling the depression of the trigger, holes can sometimes be drilled without first using a centre punch. This is achieved by starting the drill at a low speed.

Another feature of the pneumatic drill is that it will stop instantly when the trigger is released.

Select an air-powered drill not only for drilling holes but, with the appropriate accessory attached, for removing carbon and for honing, grinding, sanding, buffing, and brushing tires before vulcanizing. A heavy-duty model having a low RPM rating may be used to power a hole saw when installing air conditioners and radio antennas, or to hone cylinder walls after re-boring.

Air screwdrivers and nut drivers look very much like air drills. The main difference is in the chuck or bit holder. The tool bit is held in place by a ball-and-spring detent, which facilitates quick changes of bits.

To further enhance the versatility of power screwdrivers, a clutch device or a friction drive can be incorporated, which runs the screw or nut to the required depth or tension.

Air drills can be operated safely in wet areas, a condition that makes the operation of an electric drill hazardous.

Air Hammers

Air hammers are used for riveting, metal cutting, and chiselling. They use a reciprocating piston that strikes a tool bit accessory that, in turn, strikes the work piece.

Air hammers can deliver between 1500 and 4000 blows per minute. To achieve this rate, about 0.113 cubic meters of clean dry air per minute must be supplied at a dynamic pressure of 621–690 kPa (90–100 psi). The recommended dynamic pressure for extra heavy-duty models may be higher. Most air hammers weigh from 1–2 kg (2.2–4.4 lbs.).

A typical tool bit (chisel) accessory is manufactured from high-quality alloy steel and heat-treated to withstand and deliver repeated blows from the striker piston. Many different bits are available to perform various tasks.

NOTES

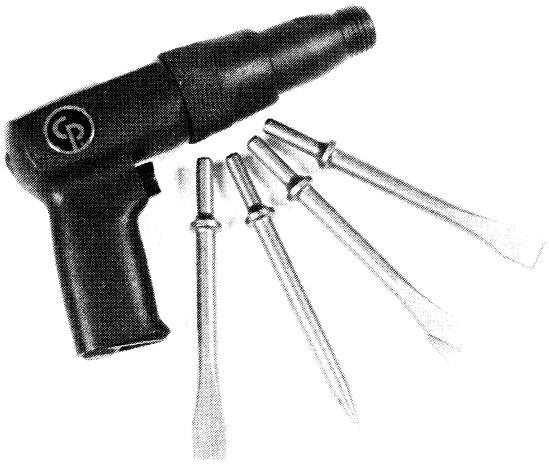


Figure 4. Air Hammer with Chisel Accessories

Important points to remember when operating an air hammer:

- always remove the air hose before making a tool change
- never allow anyone to stand in front of the hammer
- always wear eye and ear protection

Tool bits are retained in the air hammer by various methods. One style is the beehive spring, which threads on the air hammer barrel. The quick-change spring, a slight design variation of the beehive spring, has a retaining hook that can be pushed sideways for fast and easy tool bit installation or removal. To provide a more secure hold in the air hammer, a U-shaped safety collar can be used with either spring. Another retainer that reduces the possibility of a tool bit becoming loose is the safety sleeve. The safety sleeve is not used in conjunction with a spring but simply threads on the air hammer barrel.

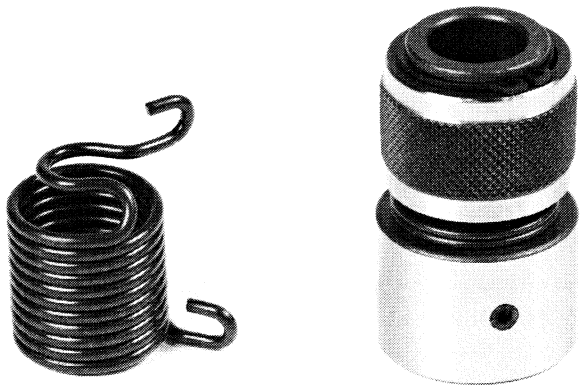


Figure 5. Beehive and Quick Change Retainers

Safety with Air Tools

NOTES

Using high-pressure air powered tools is very hazardous.

Air tools are very noisy. Hearing damage can result unless proper ear protection is worn at all times. Note that this applies not only to the operator of the tool, but all nearby workers. Continuous vibration can cause damage to nerves. Use heavy gloves if you do a lot of impact work.

Fittings often come loose from their retainers and can fly a considerable distance at high speed. When using air hammers, be careful where you point the tool.

High-pressure air is a severe hazard. Make sure that you do not expose yourself or your fellow workers to any direct blasts of air. Such blasts can drive particles under your skin or inject air bubbles into your bloodstream.

Never use air tools in an area where the exhaust could stir up clouds of toxic chemicals or hazardous materials such as asbestos dust.

Air Supply

A clean, dry air supply is of prime importance. Moisture in the air lines can damage tools or interfere with their performance. Water in the line tends to dilute and wash away lubricant and can corrode internal parts. It can also hamper the operation of the speed governor and cause dangerous over-speeding. When air is excessively wet, water shoots out of the exhaust port, which is unpleasant for the operator and can damage the work. In cold weather, moisture in the tool's air passages may freeze, rendering the tool inoperable.

Most of the moisture is removed at the compressor before it can enter the system. To remove any moisture still remaining, a filter and moisture separator is located at the beginning of the airline hose. The trap on the water separator should be drained on a daily basis when the system is in regular use.

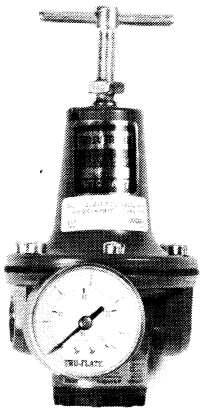


Figure 6. A Filter and Moisture Separator

NOTES

Lubrication

Follow the manufacturer's instructions for each type of tool since lubrication requirements may differ. Air tools require a light oil of SAE 5W or SAE 10W. Heavier oils, unless specifically recommended, should not be used because they can cause sticking and sluggish performance.

Some air tools have built-in oil reservoirs for continuous lubrication. The best way to ensure proper air tool lubrication is to connect air line lubricators at the end of each pipeline leading to an air tool hose. The airline lubricator mixes a small amount of oil with the air and all parts of the tool, except those requiring a grease lubricant, are then kept adequately lubricated. The lubricator reservoirs are usually made from clear plastic, allowing the oil level to be checked easily.

Air tools are rated for capacity and performance at an operating air pressure of 620–690 kPa (90–100 psi). The pressure regulator is pre-set to maintain this level of pressure at the tool.

Avoid adjusting or tampering with the regulator. Air tool speed and power will be reduced in direct proportion to any reduction in air pressure. The air compressed must have enough capacity and the hoses and fittings must be of the correct size to ensure no less than 620 kPa of air at the tool at all times for maximum operating efficiency.

Most air tools require an air hose at least one size larger than the size of the pipe at the tool air inlet. To make the tool easier to handle, it is connected to the main hose with a whip hose or leader hose, which is a short length of smaller-sized hose.

Electric Power Tools

Hand Drills

The portable electric drill is used for a variety of tasks from drilling holes or driving screws to stirring paint.

Most electric drills are manufactured with a pistol grip. A trigger switch is located on the handle to allow for single-handed use during light-duty operations. During heavier drilling operations, two hands should be used, one applying force to the back end of the drill and the other holding the handle to counteract the torque generated by the drill.

NOTES

Figure 7. Electric Drill

The drill bit is secured to the portable power drill by means of a three-jawed chuck. The chuck can be opened and closed by rotating the knurled outer sleeve, but final tightening should be done with a special wrench known as a chuck key (Figure 8).

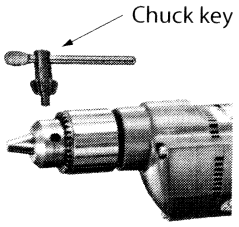


Figure 8. Keyed Chuck

Some portable electric drills only have an on-off switch. This type of switch limits the use of the electric drill to those operations that require a clockwise rotation of the chuck at the fixed speed at which that particular drill turns.

Other drills are manufactured with a variable speed switch. These switches provide control over the chuck speed. This control allows the electric drill to be used for a variety of tasks. Driving screws and drilling hard steel require a slow-turning drill, while other operations require higher speeds. An additional switch found on some drills allows the motor to turn counter-clockwise as well as clockwise. When both a variable speed switch and a reversible switch are present on an electric drill, the drill can be used to remove screws as well as to drive them.

Always allow the motor on a reversible drill to come to a complete stop before switching the motor direction. Failure to do so will lead to an early breakdown of the motor.

NOTES

¼ in. Drills

Most ¼ in. drills are used for light-duty drilling operations. They are used for drilling holes up to 6 mm (¼ in.) in diameter. The chuck on a ¼ in. drill turns at about 1500–1800 RPM. Such high speeds are good for drilling small holes in soft metals but tend to burn drill bits if used for hard metals. The ¼ in. drill does not produce enough torque (turning power) at low speeds for driving screws.

⅜ in. Drills

These drills turn at a much slower speed than a ¼ in. drill. Average chuck speed is 750–900 RPM for ⅜ in. drills. Considerably more torque is generated making the ⅜ in. drill more suitable for drilling larger holes in metal. A ⅜ in. drill is often equipped with a forward/reverse switch as well as a variable speed switch.

½ in. Drills

These drills generate substantial torque and are usually equipped with an additional handle to provide you with added leverage. Heavy-duty models have a pistol grip on one side, a removable T-handle opposite the pistol grip and a D-handle at the back (Figure 9).

Average chuck speed is from 350–500 RPM. With low speeds such as these, most ½ in. drills are equipped with a simple on/off trigger switch and a forward/reverse toggle switch. ½ in. drills may be used to drill holes up to 20 mm (¾ in.) in metal.

Figure 9. ½-inch Drill

NOTES

Cordless Drills

A cordless drill is ideal for elevated work and tasks that must be performed where corded electrical power is unsafe or inaccessible. All cordless drills have a reverse, and most will have a speed controller and torque setting controls. Good speed controllers can deliver slow rotation while providing plenty of torque. Torque settings are used primarily for driving screws. The best tools have a rotor brake that stops the rotation when you release the trigger.

Figure 10. Cordless Drill

The voltage rating for cordless drills gives an approximation of their usefulness:

- 6 V or less: These are basically electric screwdrivers, not drills. They're good for light screw-driving and flat-pack assembly. They will only drill a few holes in wood before going flat. They are not meant for heavier work.
- 7.2 V: These typically have a two-speed gearbox and no speed controller. They are suitable for frequent light screwing and drilling tasks.
- 9 V: This drill will do most wood drilling tasks, but it will struggle with larger spade bits. Hammer action (if available at all) will be feeble. Driving screws into softwood will become difficult with 100 mm (4 in.) and larger screws.
- 12 V: This will drive a 100 mm (4 in.) screw home and perform better on metal.
- 14.4 V: This will deal with pretty much any screw, handle smaller hole saws, and have a reasonable hammer action.
- 18 V: A cordless drill at this level matches the power of a small electric drill, but with far more finesse and controllability. However, the weight and size mean good balance is essential.
- 24 V and more: These are specialized and powerful tools, heavy in weight and price.

NOTES

Hammer Drill

A hammer drill is two tools in one: a conventional rotary drill and a hammer drill for drilling masonry, cinder blocks, and concrete. The hammer drill impacts the material or work piece while rotating the drill bit. A tungsten carbide tip is used in masonry and concrete applications.

Hammer drills are one option for drilling in hard materials but they have their limits. For jobs requiring multiple deep holes in hard concrete and steel, a rotary hammer is a better choice. As with any tool or piece of equipment, pushing a hammer drill beyond its capabilities reduces production, causes excessive wear, and can result in accident or injury.

Safety

If the bit jams, the forces that were being used to turn the drill bit are suddenly directed to turning the electric drill. This sudden spinning of the tool in your hands can bruise, sprain muscles, or break bones. The risk of jamming increases with the diameter of the drill bit.

Large drill bits jam more easily than small diameter bits. The more powerful the motor of the drill, the more force you will need to exert to stop the rotation of the drill. The faster the rotation of the drill bit, the more violent the reaction to jamming. If a risk of jamming exists, you should never lock the switch in the ON position. If the ON/OFF switch is not locked on, the power will automatically switch off when you loosen your grip on the trigger.

Wear eye protection when using an electric drill.

Portable Grinders

When the work piece is too large to bring to a stationary grinder, you can grind it with a portable grinder. Portable grinders are classed as either straight grinders or angle grinders.

Straight Grinders

Straight grinders turn the grinding wheel with a drive shaft aligned with the motor (Figure 11).

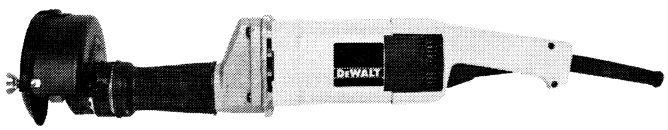


Figure 11. Straight Grinder

NOTES

Straight grinders are available in a variety of sizes and shapes. Large grinders are used for the quick removal of metals, while smaller models are used in hard-to-reach areas. The larger models of straight grinders have a grinding wheel approximately 150 mm (6 in.) in diameter. A guard encloses the upper half of the wheel, which rotates at about 6000 RPM. You must hold these larger models with both hands during use.

Small straight grinders use a small grinding stone mounted on its own shaft, which is in turn held in the collet (a chuck that will accept only one size of bit) of the grinder. These grinding stones are available in a wide range of shapes.

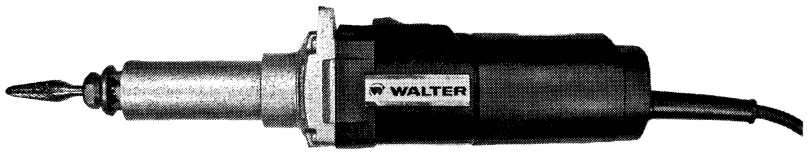


Figure 12. Pencil Grinder

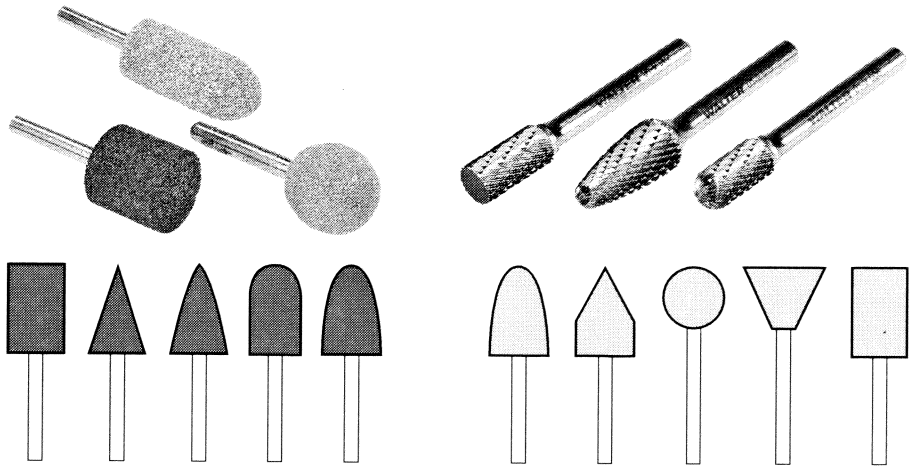


Figure 13. Grindstone and Carbide Burrs

Angle Grinders

Angle grinders have a grinding disk that rotates at 90° to the axis of the motor (Figure 14).

Disks range in diameter from 75–225 mm (3–9 in.) and each disk type and size will have its RPM rating identified. Make sure the RPM rating of the disk either matches or exceeds the RPM of the grinder.

NOTES

The angle grinder has a guard covering half the disk. The grinder is held so that only the exposed portion of the disk makes contact with the work piece.

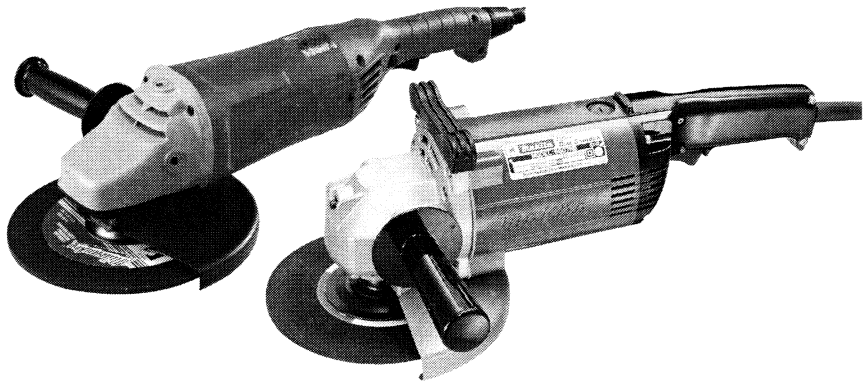
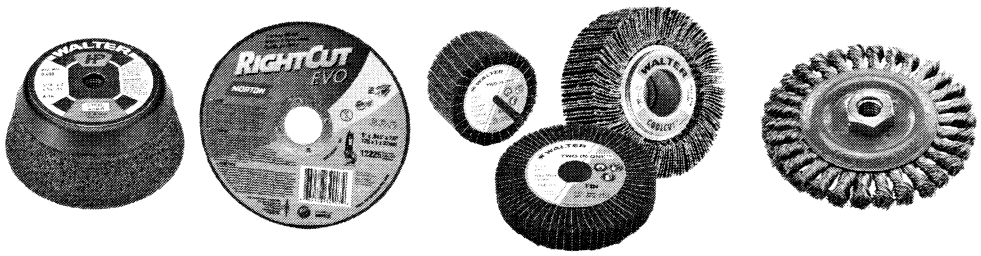


Figure 14. Angle Grinders

There are a wide variety of disks, useful for many purposes besides grinding (Figure 15). With these disks, the angle grinder becomes a very versatile and useful tool.



Cup stone Cutting wheel Flapper wheels Wire brush

Figure 15. Angle Grinder Attachments

Using Portable Grinders

There are some rules that must be observed when using portable grinders:

- always wear a face-shield
- protect other workers from sparks by using a shield
- wear leather gloves and protective clothing
- use both hands to control all but the smallest grinders
- do not exceed the RPM rating of the disk or wheel
- secure the work piece to prevent any movement while grinding
- ensure that the grinding wheel or disk is suitable for the type of material you are grinding
- do not use a damaged disk or wheel

NOTES

Safety

Be sure all grinding wheel safety devices such as wheel guards, spark deflectors, eye shields, and tool rests are installed and properly adjusted before operating a grinder. Always wear eye protection devices when grinding. Wear protective gloves and clothing if appropriate. Remove flammable materials from the work area and ask people not directly involved with the grinding operation to leave the area.

Operating a Grinding Wheel

Check for cracks or defects before using. If a grinding wheel is good with no cracks, striking it will produce a definite ringing sound. If the wheel is cracked, it will give a dull thud when struck.

Do not exert more pressure against the grinding wheel than is necessary to remove material effectively. During grinding, move the work back and forth to promote an even surface on the work and the wheel. Cool the work when necessary to prevent overheating. Periodically check the grinding in progress by visually examining the work or by using an appropriate measuring gauge.

Hydraulic Power Tools

The porta-power press or jack can be very useful for aligning frame members or other assemblies. This jack consists of a power head, a reservoir, and pump assembly connected by high-pressure hydraulic hoses (Figure 16).

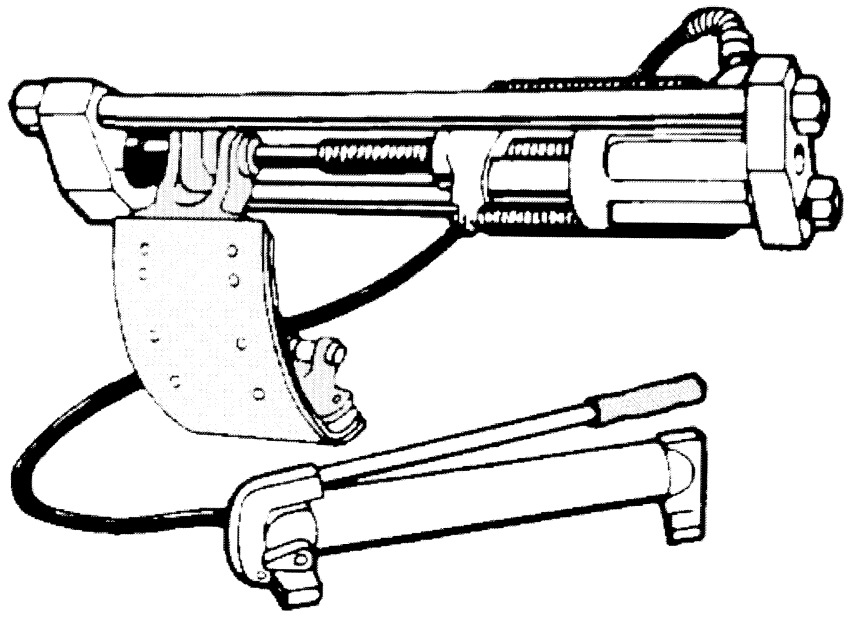


Figure 16. Portable Hydraulic Press

NOTES

The porta-power press is versatile. There are numerous attachments for this unit, all of which increase the number of jobs the press can perform. The porta-power press is available as a push-pull type press capable of two-way action. The double action allows the power piston to be powered or pumped in both directions.

There are also larger portable electro-hydraulic units that can produce extreme pressure. These units have an assortment of adapters to change length, diameter, and whether you are pushing or pulling. These larger units have a 110 volt electric pump which is controlled by a switch. The electric motor drives a hydraulic pump which then moves the cylinder to press on your work piece. Some of these units develop over 344 737 Kpa (50 000 psi).

Learning Task 6

NOTES

Select, Use, and Maintain Drill Bits

Twist Drill Bits

Twist drill bits are the most commonly used bits in the mechanical trade. They are normally made from carbon steel or high-speed steel. Those made of high-speed steel are harder and therefore able to drill harder metals. High-speed steel stays sharp longer than carbon steel and is able to withstand higher temperatures without losing its temper.

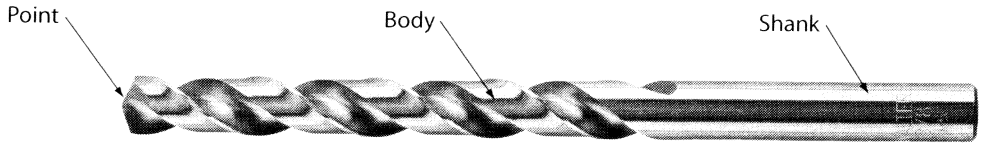


Figure 1. Twist Drill Bit

A twist drill bit consists of three main parts:

- point
- body
- shank

The point is the entire cone-shaped cutting end and consists of the centre and cutting edges.

The body of the drill bit extends from the point to the shank and contains the spiral grooves.

The shank end of the drill bit fits into the holding device (chuck) of the drilling machine. Twist drill bits are available with straight or tapered shanks.

Twist Drill Bit Angles

A correctly sharpened twist drill bit will cut easily into metal. The two cutting lips of the drill bit should each produce the same amount of metal shavings. The point of a twist drill bit can be sharpened to various angles to suit the hardness of the material to be drilled. For normal use, the cutting lips of a twist drill bit are at 59° to the axis of the bit (Figure 2).

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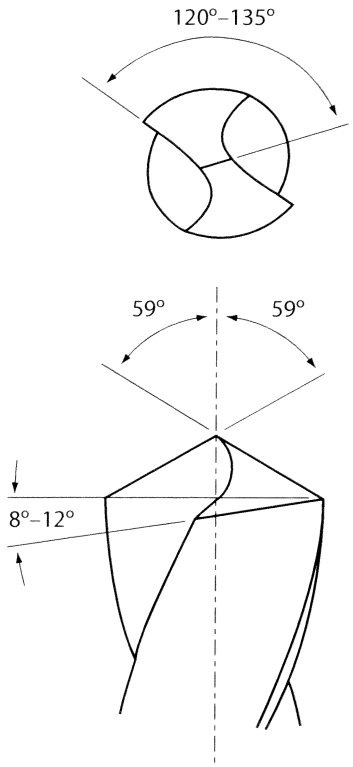

Figure 2. Twist Drill Bit Point Angles

The angle of the cutting edge or lip should be checked with a drill bit point gauge (Figure 3). The gauge is used to check the angle between the lip and the axis of the drill. Both lips should be at the correct angle and equal in length.

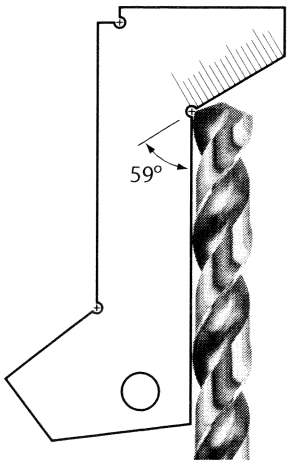

Figure 3. Twist Point Angle Being Checked with a Drill Bit Point Gauge

NOTES

Another important angle is the lip clearance angle (Figure 4). This is the angle between the heel and an imaginary line perpendicular to the lip. A lip clearance of 8–12° is the most common.

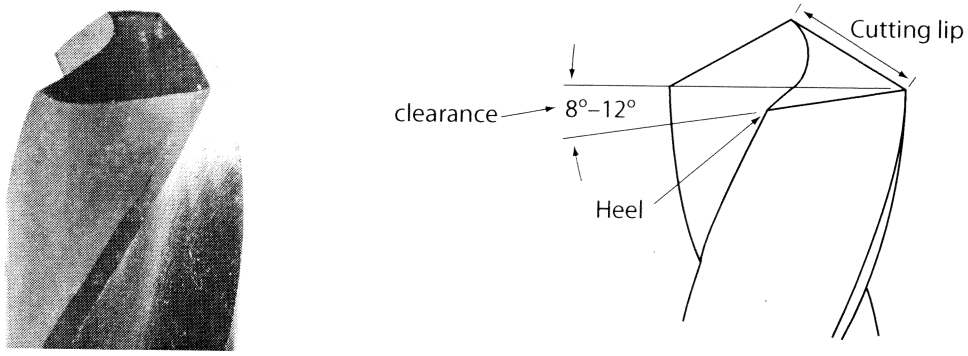

Figure 4. Lip Clearance Angle

Drill Bit Sizes

Twist drill bits are available in diameters designated by one of four different systems:

- metric
- fractional
- number
- letter

The number and letter systems designate very small drill bit sizes. The most commonly used size designations in welding are the metric and the fractional (fraction of an inch). Mechanics generally use twist drill bits ranging in size from 1.5–19 mm (1/16–3/4 in.). Within this range, drill bit diameter size increases in increments of 0.5 mm (1/64 in.).

Other Drill Bits and Attachments

Hole Saw

A hole saw is used to cut circular holes in metal or wood (Figure 5). It looks like a tube, rotates quickly, and has a regular fluted twist drill bit through the centre. When cutting holes, the twist drill bit positions the hole saw, penetrates the material, and acts an axle as the hole saw cuts the hole.

When used on metal, a hole saw always requires lubricant and cooling. Recommended cutting fluids normally provide the required lubrication while cooling. Metal hole saws come in a range of diameters, from 19–83 mm (3/4–3 1/4 in.).

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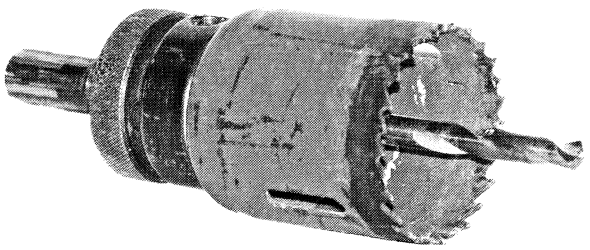

Figure 5. Hole Saw

Stepped Drill Bits

Stepped drill bits are made of high-speed steel coated with titanium nitride. They are commonly used for thinner sheet metal.

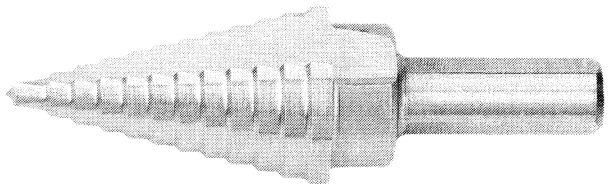

Figure 6. Stepped Drill Bit

Due to its design, a single stepped drill bit can be used to drill a wide range of hole sizes. Some bits come to a point and are thus self-starting. The larger-size bits have blunt tips and are used to enlarge holes. They're available in both metric and fractional inch sizes. Because metals tend to cause premature drill wear and dulling, a metal hole saw is more appropriate for large-hole applications in thicker metals.

Step bits are also used to deburr holes left by other bits, as the sharp increase to the next step size allows the cutting edge to scrape burrs off the entry surface of the work piece. However, the straight flute is poor at chip ejection and it can cause a burr to be formed on the exit side of the hole, more so than a spiral twist drill bit turning at high speed.

NOTES

Carbide-tipped Masonry Drill Bits

Carbide-tipped masonry drill bits are for drilling masonry, cinder blocks, and concrete (Figure 7). The cutting tip is made from tungsten carbide bonded to a spiral fluted shank.

Figure 7. Carbide-tipped Masonry Drill Bit

These bits are generally used with both power drills and hammer drills. Be extremely careful when using these bits with hammer drills. The action on the bit is rigorous, and cheaper bits have been known to shatter under the pounding. Always use a slow rotation speed when drilling into harder materials to avoid overheating the tip. Withdraw the bit frequently to remove dust.

Morse Taper

Larger drill presses have a taper socket, or Morse taper, machined into their spindles (Figure 8). Using a Morse taper on a drill press provides more flexibility in work methods than a simple press alone. The Morse taper shank allows changing of the twist drill bit or tooling in a matter of seconds.

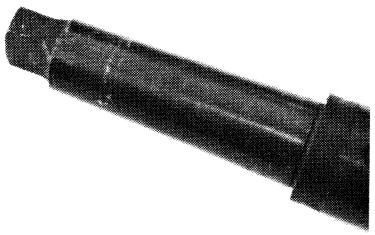

Figure 8. Morse Taper

A Morse taper has a taper of 5/8 inch per foot. Taper shank twist drill bits and accessories come in a series of standard sizes. They have a number designation followed by the letters "MT" (Morse taper). The larger the number, the larger the size of the taper. A #2 MT is larger than a #1 MT, a #3 MT is larger than a #2 MT, and so on.

Sleeves and socket extensions can be used as adapters to fit different sizes of MT together and to add length to the twist drill bit.

NOTES

Effective Procedures for Drilling

Use Cutting Fluids

As a drill bit cuts into metal, the cutting edge (or lip) heats up. This can soften the cutting edge and ruin the drill bit. The main function of a cutting fluid is to cool the cutting edge of the bit and preserve its temper.

Other functions performed by cutting fluids include:

- reducing friction so the drill bit cuts faster, more smoothly and produces a smooth finish in the hole
- washing away the shavings and chips
- cooling the shavings or chips, thereby minimizing the danger of burns

Soluble oil, a mixture of 1 part oil to 40 parts water, is the recommended cutting fluid for copper, low-carbon steel, and tool steel. Specialty lubricants are available for cutting aluminum. Softer metals such as brass, bronze, and cast iron generally require no cutting fluid.

Never use cutting fluid or coolant on a hot drill bit. The sudden cooling can cause surface cracks. The fluid must be introduced while the drill bit is still cool.

Use a Pilot Hole

A pilot hole is used when drilling larger diameter holes. The pilot hole is a smaller hole drilled into the work piece to help locate and control the centre of a larger hole. It also promotes a faster cutting action because the larger bit's chisel edge does not have to promote the cutting action throughout the drilling of the hole.

Larger drill bits require thicker webs to give them strength. As a result, the drill bit's chisel edge is longer. A longer chisel edge has a poorer cutting action and will not follow the centre punch mark accurately. This means that the drill bit will wander and lose centre, resulting in an improperly placed hole. A pilot hole overcomes this problem.

A pilot hole should normally be slightly larger in diameter than the length of the chisel edge of the larger twist drill bit. This provides a centering hole for the larger twist drill bit and clears the way for the cutting edges to do their job. Never drill a pilot hole larger than necessary.

NOTES

Care of Drill Bits

With proper care and maintenance, drill bits will remain in good condition for a long time.

Make sure you keep your twist drill bit sharp and angled correctly. Sharpen it on a grinder, either freehand or by using a jig to hold the drill bit at the correct angle.

Store twist drill bits in a drill bit holder when not in use. If properly stored in their own holder, bits will not be dulled from contact with other tools and are not in danger of being knocked off tables and shelves.

Cutting Speeds for Drill Bits

Select the correct speed for the size of drill bit used and the material to be drilled. The larger the drill bit, the slower the speed. Use a drill speed chart for reference.

Troubleshooting

Figure 9 shows some common problems encountered during drilling and how to avoid them.

Symptom	Problem	Solution
• Cutting edge chips or breaks.	• Feed too fast • Too much lip clearance • Pilot hole too large	• Decrease speed and pressure of feed • Sharpen correctly • Use correct size pilot hole
• Drill bit overheats, might turn blue and lose temper.	• Drill bit dull • Drill speed too fast • Too little lip clearance	• Sharpen • Reduce drill bit speed
• Drill bit jams.	• Might be overheated • Hole clogged with chips	• Sharpen • Reduce drill bit speed • Withdraw drill bit at intervals to remove chips

Figure 9. Common Drilling Problems and Solutions

NOTES

Learning Task 7

Select, Use, and Maintain Shop Equipment

A heavy mechanical shop has equipment useful in your day-to-day work. The shop equipment may be used for cleaning, pressing, drilling, or grinding. You must know how to use the equipment safely, how it operates, and how to maintain it.

Shop Cleaning Equipment

Cold Solution Cleaning

Although small parts can be cleaned in cans or buckets, a faster and more efficient job can be done with a regular cold-solution parts washer.

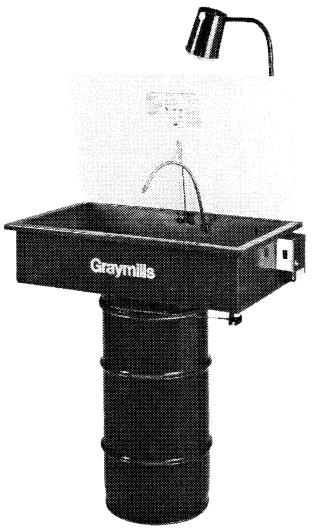

Figure 1. Cold-solution Parts Washer

Many types and sizes of solvent tanks are available, from commercial models to simple drain pans. Some parts washers hold up to 205 L of solvent, have soaking trays, solvent agitation, and a filter to remove impurities from the solvent for rinsing.

Before using the wash tank, you should remove heavy deposits with a scraper. Scrape the parts outside the wash tank to avoid unnecessary fouling of the washing solution.

Place the parts in the basket and submerge them in the solution. Parts with hollow areas should have the hollows facing up to allow air to escape. Some washers have a compartment that is air agitated and a second main tank for soaking, brushing, and rinsing.

After thorough cleaning, parts should be given a final rinse. Following rinsing, parts should be drained and then be blown dry with compressed air. Be sure the air supply or nozzle is equipped with a pressure-limiting device.

Creating a fog of air and solvent vapours can be dangerous if there is the possibility of a spark or flame igniting it. Dust blown up by the compressed air can also be a health hazard for you and anyone working close by.

When drying with compressed air, do not hold parts with your hand—both the air and the part are potential hazards. After drying, parts subject to rusting should be oiled or greased. Keep cleaned parts covered until you're ready to use them.

NOTES

Hot Tank Cleaning

A hot tank usually uses a strong alkaline compound mixed with water to form a solution. Solution temperatures range from 82–99°C (180–210°F). The tank may have an agitator to speed cleaning. Most parts are clean in thirty minutes or less, depending on tank design, solution strength, temperature, and part load.

If aluminum alloys are exposed to a strong alkaline solution, they will be eroded and ruined in a very short time. Alkaline cleaning solutions must be inhibited (weakened) if used for these metals and the cleaning time must be closely monitored to prevent surface erosion.

Another type of hot tank washer is the hot wash cabinet (Figure 2). The parts that are to be cleaned are placed in the cabinet on racks or trays. After the door is closed and the washer turned on, there is a hot, high-pressure spray of a soapy water solution. The rack usually rotates as the solution is sprayed. After the soapy solution wash, there is a hot water rinse. The operation is very similar to a large household dishwasher. This type of wash is safe for both steel and aluminum materials.

NOTES

Figure 2. Hot Wash Cabinet

When parts are removed from the tank, they should be thoroughly rinsed with hot water. Be careful to flush out oil galleries, water jackets, and other internal passages. Parts or surfaces subject to rusting should be oiled.

Modern cleaners use a biodegradable chemical to meet environmental requirements. These tanks are heated to approximately the same temperature as standard hot tanks and will also have an agitator to assist in the cleaning process.

Be extremely careful when using the hot tank. Observe all safety precautions. Have someone who has received training in the operation of the tank give you a demonstration of the proper methods for using the tank.

Carburetor Cleaner

Carburetor cleaner is the most common example of a cold-immersion parts cleaner. This type of cleaner uses a strong liquid chemical that dissolves grease and carbon. The liquid cleaner is not heated. Sometimes an agitating device is used.

The chemical is very strong, so great care must be taken not to get it on your skin or in your eyes. Use rubber gloves and eye protection.

General Rules for Solution Cleaning

Many cleaning solutions are toxic (poisonous), caustic, or corrosive (will burn skin and eyes). Be certain you know what you're using and follow these precautions:

- read and follow manufacturer's instructions and the relevant WHMIS information
- use in a well-ventilated area
- do not use gasoline for cleaning
- wear goggles or a face-shield when working with powerful cleaning solutions
- keep away from sparks and open flame; do not smoke around solutions
- use solutions with relatively high flash-points (temperature at which vapours will ignite when brought into contact with an open flame)
- do not heat solutions unless specifically instructed otherwise
- use protective aprons
- when brushing parts in solvent, use a nylon or brass bristle brush to avoid creating sparks
- solvent wash tanks should have a lid that is held open by a fusible link (a holding device that will melt and drop the lid in the event of fire)
- wash hands and arms thoroughly with soap and water when the cleaning job is complete
- use rubber or neoprene gloves to avoid skin exposure to all types of solvents
- disposal of caustic solutions (i.e., cleaning out the tank) must be done according to strict environmental regulations—do not dispose of solution down a drain

NOTES

NOTES

Steam Cleaners and Pressure Washers

A steam cleaner is a machine that generates live steam with hot water at a temperature of 93–121°C (200–350°F) and delivers it through a hose and nozzle assembly at a pressure of approximately 1034–1724 kPa (150–250 psi). This live steam and hot water is then directed to the equipment or location that is to be cleaned. A cleaning compound is usually added to the water supply for general cleaning tasks.

A pressure washer is a machine that supplies high-pressure water (hot or cold) through a hose and nozzle assembly for cleaning purposes. This type of machine can develop pressure up to 13 790 kPa (3200 psi). In most machines, a detergent may be added to the water supply.

Figure 3. Pressure Washers

You must be careful when using this type of cleaning equipment, as they produce hot, live steam and water under high-pressure. Personal protective equipment must be worn to protect the operator. This equipment includes a face-shield, neoprene or rubber gloves, rubber apron, and rubber boots.

Make sure other personnel are clear of the work area in order to avoid splashing them or accidentally striking them with the high-pressure stream of water or steam.

Watch your footing around the work area, particularly if the cleaning operation is performed on a cement pad. Cement can become quite slippery, especially if the item being steam cleaned is oily or greasy.

NOTES

When using these types of cleaners, care must be taken not to damage sensitive areas of the component being cleaned:

- Avoid direct contact of live steam with painted finishes as the pressure, heat, and chemical may remove the paint.
- Protect open electrical components such as starters, generators, alternators, gauges, and other components.
- Cover openings such as open air intakes, input or output shafts extending from transmissions, or gear box units to prevent water and dirt from entering.
- Remove air cleaners and filters from engines to be steam cleaned.

Remember to clean up after your cleaning operation. Do not leave a mess for the next person.

Each make and type of steam cleaning or pressure washing equipment has its own specific operating instructions. Read the instructions before operating any cleaning machine that you are not familiar with. Have a qualified operator demonstrate the start-up and shutdown procedures.

Glass Bead Cleaner

In a glass bead cleaner, compressed air is used to propel beads against the part to be cleaned. Both wet and dry blast machines are available. This method is used to clean individual parts rather than complete assemblies. Glass beads clean the part down to the base metal, leaving no film of detergent. The beads leave a uniform indented surface imparting strength to the metal by compressing it as it is being cleaned.

The cleaning operation is completely contained in a metal cabinet with a safety-glass viewing window in front.

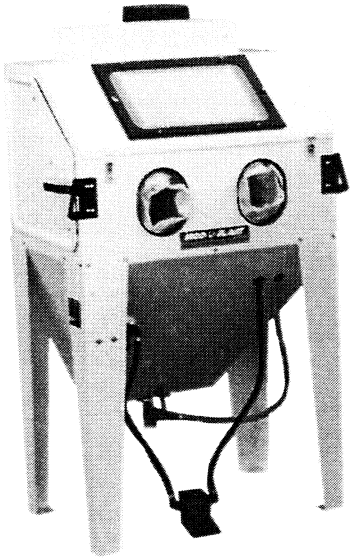

Figure 4. Glass Bead Cleaner

NOTES

Sand Blaster

Some shops may have a sand blaster. The sand blaster uses compressed air to propel sand beads against the material. Usually the sand blaster is used to remove paint and rust from heavy equipment. After the metal is cleaned, it can be repaired and repainted. Sand blasters range in size from small to very large.

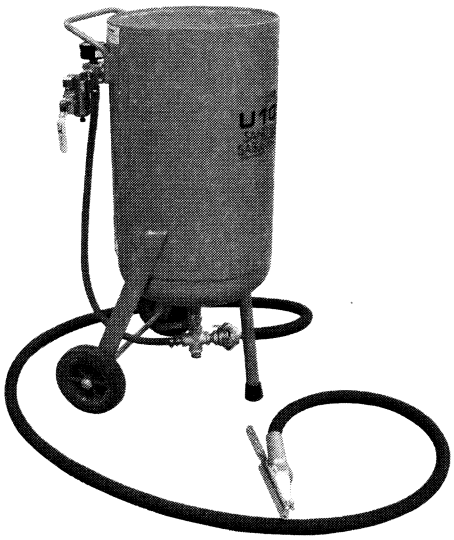

Figure 5. Sand Blaster

Shop Hydraulic Press

Removing bearings, straightening shafts, and pressing bushings often require the use of a hydraulic press (Figure 6). The press is preferred to striking tools because the pressure is smooth and controlled. There is no metal-stressing shock and high pressures can be generated.

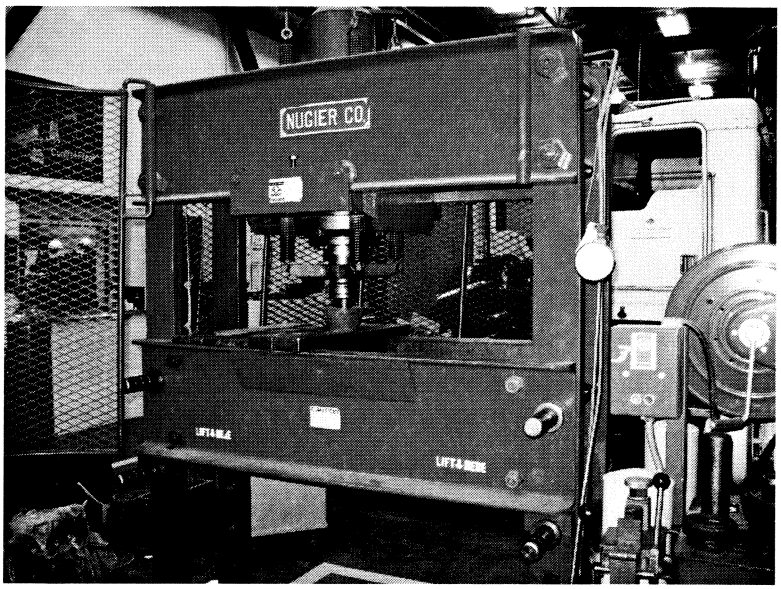

Figure 6. Hydraulic Press

NOTES

Presses are rated according to their pushing capacity in tons. They range from small 9 tonne (10 ton) bench models to large 135 tonne (150 ton) standing models. They are made so either the table or the hydraulic head assembly can be adjusted.

The press has pins supporting the table and holes in the side rack for varying the height. A hydraulic cylinder or hand winch on the side of the press is used to lower the table. Plates across the top of the table are used for pressing. The press's hydraulic pump can be a hand-type, air, or electric, depending on the size of the press. A gauge mounted on the pump indicates the force being applied in tonnes.

All floor hydraulic presses should be equipped with a cage that encloses the ram and the work piece. This cage protects you from injury if the work piece shatters from the loads imposed by the press.

Correct Use and Safety Precautions

Because of the tremendous power that can be developed by hydraulic equipment, a number of safety practices must be followed when you are using either the portable press or the hydraulic press.

A press is used with parts that have an interference fit. Failure to pay attention when applying pressure could result in injury to you or to someone working nearby. Support the part being disassembled. Different assemblies require different methods of support. Know how the pieces come apart before attempting to apply force. Press on the correct spot. If you don't know what it is, find out.

Make sure weight is off the cables that raise and lower the table and that the support pins are fully installed. Stand to one side while operating the press and close the cage door. Wear a face-shield in case something should break. Engage the ram securely and in line with the work and observe the amount of force being applied.

Air Compressor

Pneumatic tools are operated with compressed air supplied by an air compressor. This compressor is pre-set to maintain a constant supply of compressed air at pressures ranging between 350 kPa (50 psi) and 1050 kPa (152 psi). A reservoir tank attached to the compressor retains a supply of compressed air to assure sufficient volume should more than one air-operated tool be in use at one time.

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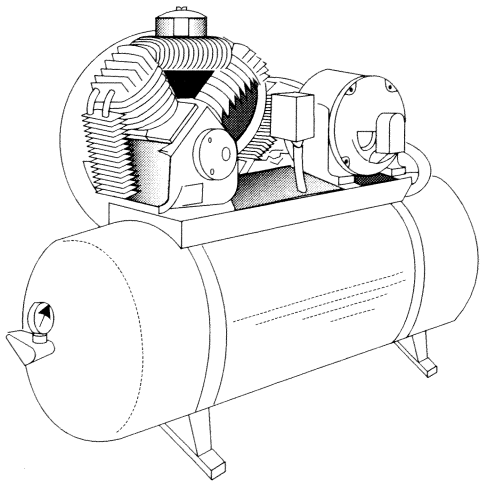

Figure 7. Air Compressor

All air tools require a sufficient volume of compressed air at a specified dynamic pressure in order to operate efficiently. Dynamic air pressure is the pressure that's maintained while the air tool is in use. Static air pressure is the pressure when the tool is not in use and is always higher than the dynamic pressure. An air line and hose of the correct size are prime factors in maintaining adequate dynamic air pressure.

Compressed air is usually piped to quick-connectors placed around the shop. High-pressure flexible rubber air hoses are used to connect the air-operated tool to the wall outlet. These hoses must be kept in good condition and their end connections must be tight. A broken or severed hose can flail uncontrollably causing serious injury.

Air hoses should be coiled neatly and stored when not in use. They can become damaged or weakened if run over by vehicles or equipment.

Power Cut-off Saw

A power cut-off saw is used to cut sections of stock to length. The power cut-off saw uses a thin, abrasive, circular disc as a saw blade. The disc is made from mineral or synthetic grains that are fibre-reinforced and resin-bonded. They come in thicknesses from 2–3 mm (1/16– 1/8 in.) and in diameters from 150–500 mm (6–20 in.).

The saw in Figure 8 is called a chopper-type cut-off machine. The chopper-type machine has the saw mandrel and motor mounted on a pivoting frame. It is operated by grasping the handle and pulling the rotating cut-off wheel into the work piece. The work piece is secured on the bed by a vise or clamp.

NOTES

This machine cuts relatively quickly, but produces a considerable amount of heat at the site of the cut, which may damage the work piece. It's used to cut steel that will not suffer too greatly from heat build up.

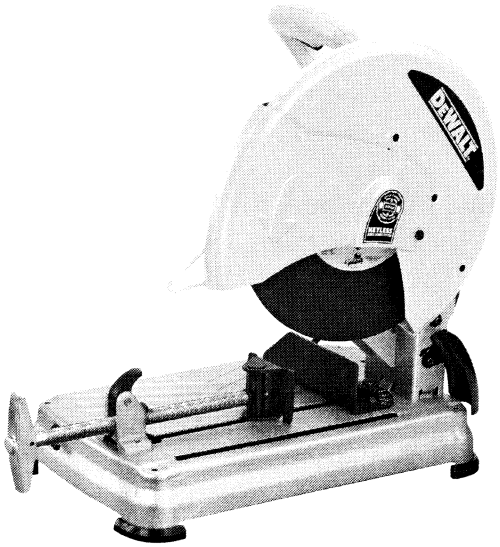

Figure 8. Chopper-type Cut-off Machine

You need to be particularly safety-conscious when operating this machine. Consider the following before using a power cut-off saw:

- Make sure the blade guard is in place.
- Secure the work piece with a vise or clamp,
- When cutting long pieces, have the end supported by an assistant.
- Use a face-shield rather than just eye protection.
- Use leather gloves to handle the cut pieces—they will be hot.
- Do not use excessive force when cutting and be careful not to bump the blade onto the work.
- Stand to one side while cutting (rather than in line with the blade) so that you will not be hit with flying debris.

Abrasive Cut-off Wheels

Abrasive cut-off wheels are designed for cutting masonry products or for cutting metal. Metal cutting wheels are available in two grades: fast-cut or long-life. Fast-cut wheels cut faster but wear out sooner than long-life wheels. Most metal-cutting abrasive wheels will cut steel, stainless steel, cast iron, and aluminum.

Each abrasive cut-off wheel has a maximum speed listed in RPM. You must make sure that the rated speed of the cut-off wheel is greater than the speed of the motor, or the wheel will break apart.

NOTES

Metal-cutting Band Saw

Metal-cutting band saws are available in a variety of models and sizes. The size of the metal-cutting band saw is designated by the thickness of stock you're able to cut with it. Standard sizes are 115 mm, 180 mm, and 255 mm (4½ in., 7 in., and 10 in.). Some larger models are capable of cutting through a pipe that is 50 cm (20 in.) in diameter. The material being cut is held by a built-in vise. The vise can be rotated to allow a cutting angle of up to 90°.

When equipped with a sharp blade, these saws produce an accurate cut without an excessive build up of heat. Some saws are equipped with a mist spray cooling system that cools and lubricates the saw blade.

Smaller models regulate the amount of cutting pressure by use of an adjustable counterweight. Larger models use a hydraulic system to regulate the feed pressure. All models are designed to shut off once the work piece is cut. These features allow the saws to be left unattended during long cutting operations. If several smaller pieces need to be cut, they can be cut simultaneously, providing they can all be secured in the vise.

The speed of the saw blade can be reduced to prevent heat build-up during a heavy cut. Speeds may range between 21–90 m/min (65–300 ft/min).

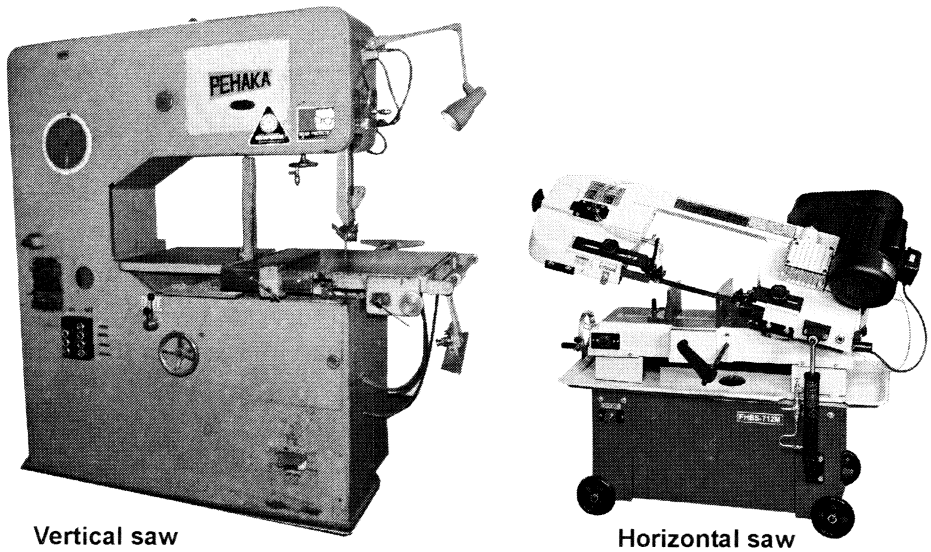

Figure 9. Metal-cutting Band Saws

NOTES

Metal Cutting Blades

Metal-cutting band saw blades are defined by their grades of steel, tooth formation, tooth set, and blade width. Grades of steel include:

- carbon
- semi high-speed
- high-speed

Carbon Steel

Carbon steel blades are used for general purpose cutting on a standard band saw. Blades made of carbon steel are inexpensive to buy but are less durable than other grades.

Semi High-speed Steel

Semi high-speed steel blades cut 50% faster than carbon steel blades. They are harder than carbon steel, but are able to withstand mechanical shocks and vibrations that would break harder, more brittle blades.

High-speed Steel

High-speed steel blades cut better and last longer than other blades, but are more expensive and more delicate than the other two grades.

Tooth formations include:

- regular
- hook
- skip

Regular Tooth

Band saw blades with regular teeth are used for straight and curved cuts in most ferrous and non-ferrous metals. Blades with regular teeth can be considered general-purpose blades.

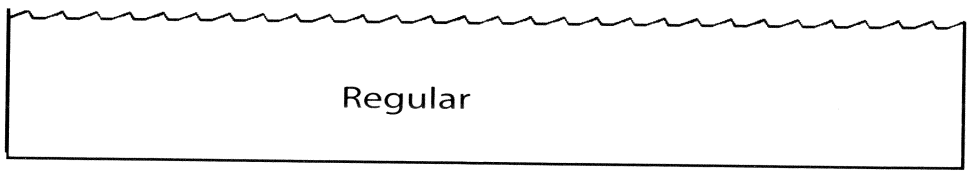

Figure 10. Regular Tooth Blade

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Hook Tooth

The hook tooth blade is best for fast cutting of non-ferrous metals. The large rounded gullets are capable of fast chip removal and the forward slope of the tooth requires less downward pressure to cut. Thin sections of metal should not be cut with this tooth style due to the wide spacing of the teeth.

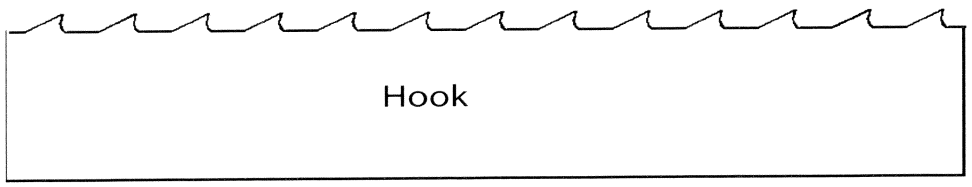

Figure 11. Hook Tooth Blade

Skip Tooth

The skip tooth is very similar to the hook tooth. Unlike the hook tooth, which can only cut softer metals, the skip tooth is capable of cutting ferrous metals. The wide spacing of the skip tooth makes the blade suitable for fast cutting of large sections of steel. Hook and skip tooth types are available in 3 to 6 teeth per inch. Regular tooth styles range from 6 to 32 teeth per inch. The number of teeth per inch affects the cutting speed of a band saw and the size of stock it's best suited to cut. Blades with large numbers of teeth per inch are able to cut small, thin pieces of metal but are slow when cutting large sections. Blades with few teeth per inch cut faster but are too coarse for cutting small sections of metal.

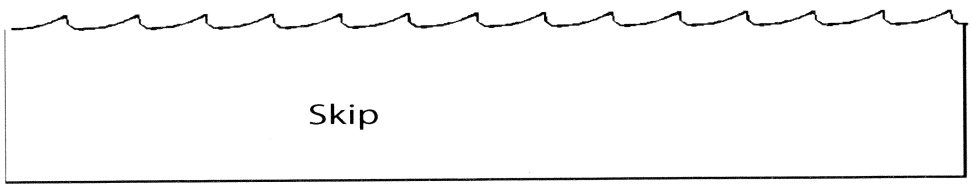

Figure 12. Skip Tooth Blade

Tooth Set

Set is defined as the left-and-right positioning of teeth to provide a wider cut than the thickness of the blade. The wide cut provides clearance for the blade within the cut, preventing binding and overheating.

There are two types of tooth sets available on metal-cutting band saws, the raker set and the wavy set (Figures 13 & 14).

Hook and skip tooth blades have raker set teeth. Regular tooth blades with up to 24 teeth per inch come with either raker set or wavy set teeth. All regular tooth blades with more than 24 teeth per inch have wavy set teeth.

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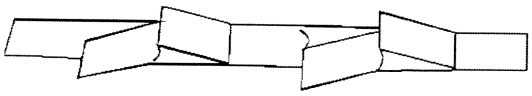

Figure 13. Raker Set

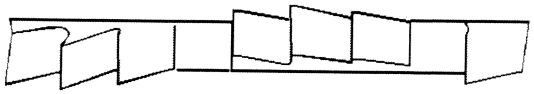

Figure 14. Wavy Set

Blade Width

Band saw blades are available in widths ranging from ¼–1¼ in. The narrower blades are able to cut curves of a smaller radius than wider blades. Wide blades are used for straight cuts.

Drill Press

The drill press is one of the most practical power tools due to its versatility and ease of operation. A drill press can be floor or bench mounted.

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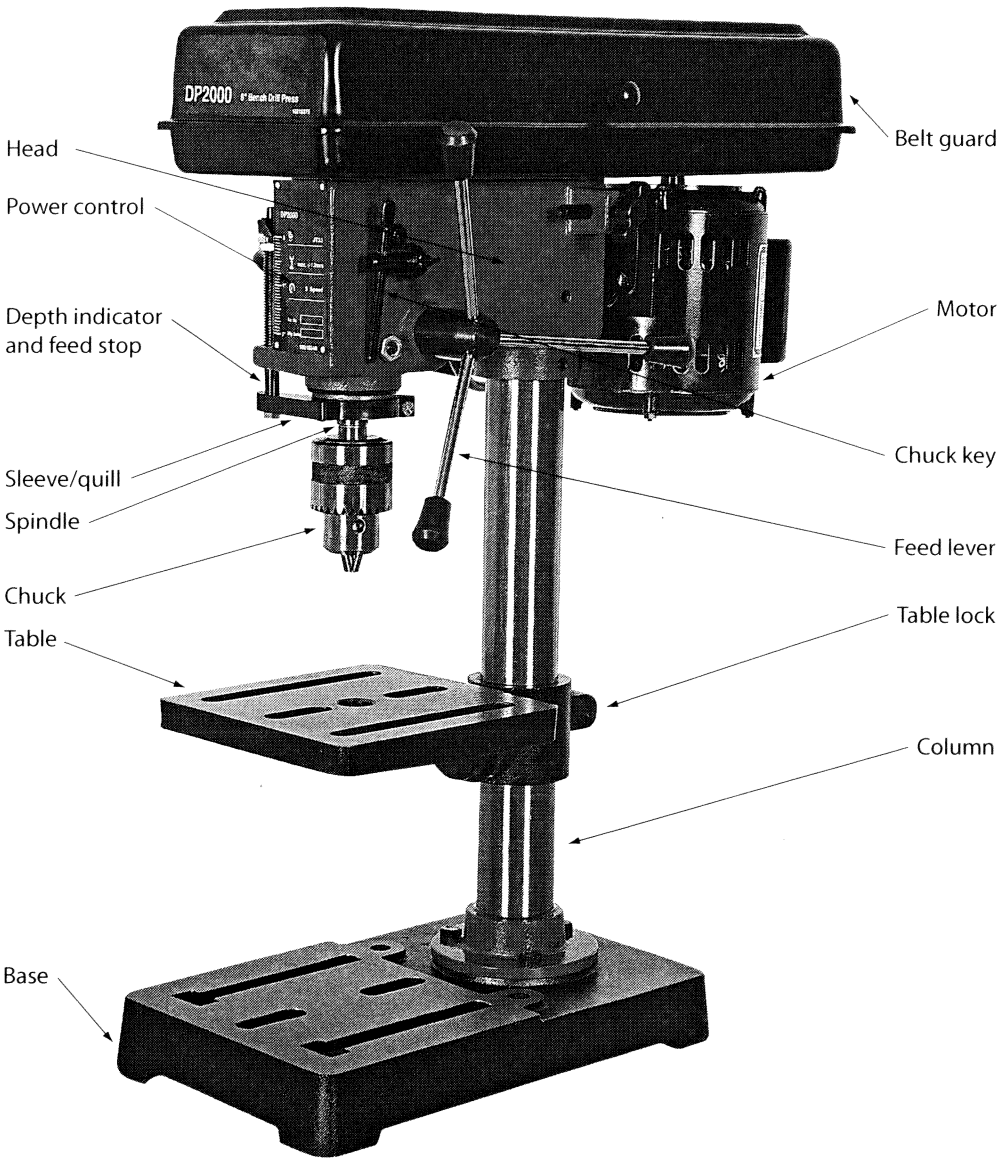


Figure 15. Drill Press

Construction

The four basic parts of the drill press are the base, column, table, and head. The head is the entire working mechanism attached to the upper end of the column. The table can be moved up and down on the column, swung to either side, or tilted.

The chuck is moved downward by means of simple rack-and-pinion gearing worked by the feed lever. The feed lever is returned to its normal position by means of a coil spring. You can lock the feed and pre-set the depth to which it can travel.

NOTES

Power and Speed

The drill press is fitted with pulleys or gears so that different speeds can be obtained. The average drill press can obtain speeds of 680, 1250, 2400, and 4600 RPM. When the machine is used exclusively for metal work, a larger cone pulley is used on the spindle to give lower speeds of about 470, 780, 1300, and 1950 RPM.

Drilling Metal

A drill turning in a piece of metal exerts significant torque, which tends to cause the work to rotate. The twisting action increases when the drill breaks through the underside of the piece being drilled. A piece of work spinning on the end of a drill can cut your hand, break the drill, or spoil the work. This hazard is avoided by clamping the work. A machine vise can be used for holding smaller items (Figure 16). Large pieces should be secured with C-clamps.

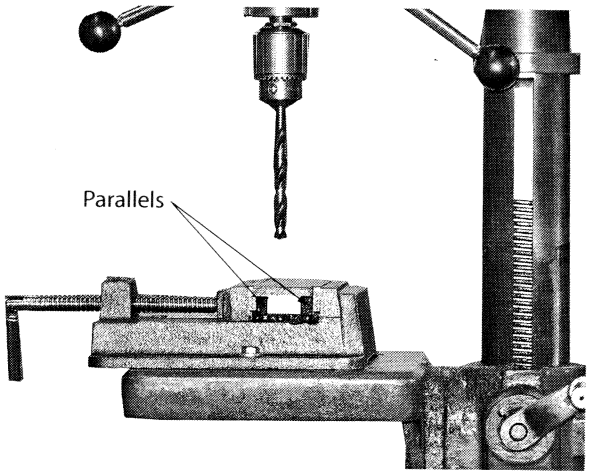


Figure 16. Drill Press Machine Vise

Speed and Feed

The speed in any drilling operation is determined by the type of material being drilled, the size of hole, the type of drill, and the quality of cut desired. The smaller the drill bit, the greater the speed. The speed should also be greater for soft materials than for hard materials.

On most drill presses, it's difficult to obtain the exact recommended speed, but you can come close by adjusting the drive belt on the step-cone pulleys. You will find instructions on adjusting the pulleys in the manufacturer's manual. There's usually a chart in the manual giving the various speed ratios for your particular drill press. You can use the chart in Table 1 as a general guide.

NOTES

Drill bit size		Aluminum bronze brass	Cast iron annealed	Cast iron hard	Low-carbon Steel	Cast steel
mm	in.	RPM	RPM	RPM	RPM	RPM
1.5	1/16	9200	9200	4300	6100	2400
3.5	1/8	9200	4600	2100	3100	1200
4.5	5/16	6100	3100	1400	2000	800
6.5	1/4	4600	2300	1100	1500	600
8.0	5/16	3700	1800	850	1200	500
9.5	3/8	3100	1500	700	1000	400
11.5	7/16	2600	1300	600	875	350
13.0	1/2	2300	1100	525	775	300
16.0	5/8	1800	900	425	600	250
19.0	3/4	1500	775	350	500	200
22.5	7/8	1300	650	300	425	175
25.0	1	1100	575	275	375	150

Table 1. Sample Drill Speed Chart

For intermediate sizes, use the speed suggested for next larger hole. Use slower speeds for deep holes or if the drill bit burns or melts material.

Feed is the amount of pressure you apply to control penetration. Too much pressure will force the tool beyond its cutting capacity and can result in rough cuts and jammed or broken tools. Too light a feed, particularly with metals or other hard materials, will cause overheating of the tool and burning of the cutting edge. The best results will be obtained by matching the correct speed with a steady feed pressure that lets the tool cut easily at an even rate.

As with all power tools, you must ensure the safe operation of a drill press. Before proceeding with any drill press operation, you should understand the following safety precautions:

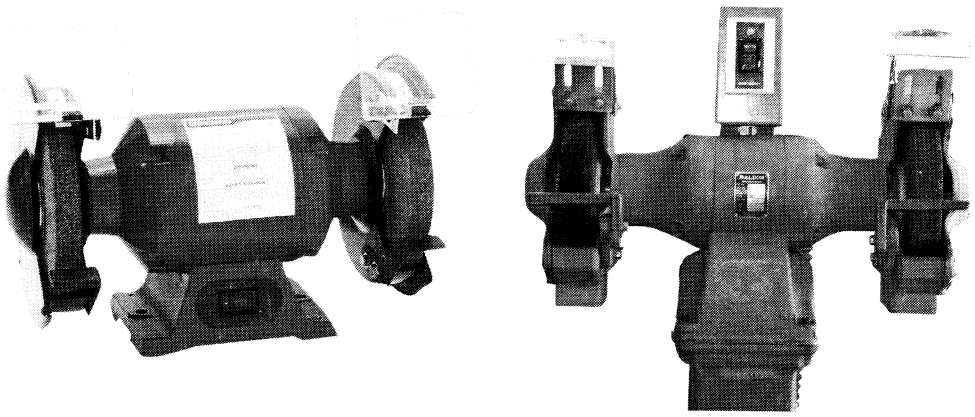
- Do not attempt to hold the work by hand—use a vise or clamp to prevent the work from spinning.
- Use a face-shield to protect yourself from flying chips.
- Do not set speeds or adjust the work while the machine is running.
- Stay as far back from the revolving parts as possible to prevent your clothing from being caught.
- As the drill begins to break through the work, ease up on the drilling pressure and allow the drill to break through gradually.
- Use a file or scraper to remove burrs from a drilled hole, not your hands.
- Do not leave a chuck key in the drill chuck.

NOTES

- Do not attempt to grab work that may have caught in the drill while the drill is still in motion. Stop the machine first.
- Position the table or vise so that the drill bit will not damage either as it penetrates the work.
- Check the drill press speed settings before starting.

Stationary Grinders

Stationary grinders may be bench grinders or pedestal grinders (Figure 17). Bench grinders are mounted on a bench and are usually smaller than pedestal models.



Bench grinder, 1 HP

Pedestal grinder, 5 HP

Figure 17. Bench and Pedestal Grinders

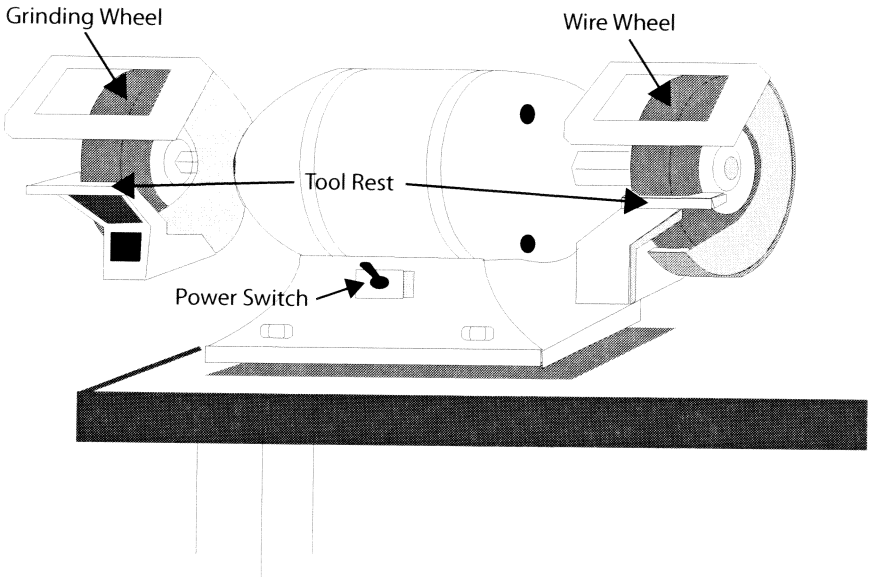


Figure 18. Grinder Parts

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Stationary grinders consist of an electric motor with grinding wheels attached to both ends of the motor shaft. The grinding wheels are enclosed in guards that support a tool rest at the front and a combined eye shield and light near its top. The grinding wheels rotate so that they travel toward the operator from the top of the wheel.

The tool rest is adjustable and must be positioned no lower than the centre of the grinding wheel. The distance between the front edge of the grinding wheel and the tool rest must be 3 mm (⅛ in.) or less (Figure 19).

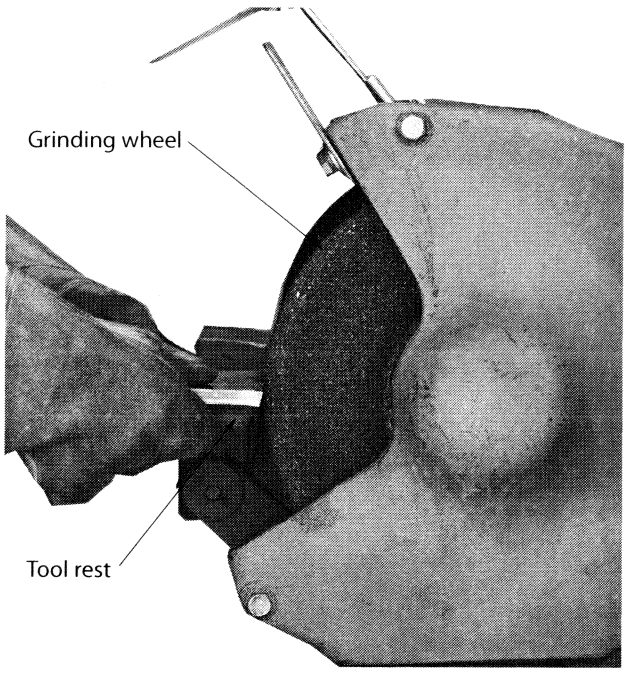

Figure 19. Correct Position of Tool Rest

Sparks are created during the grinding of ferrous metals. A spark guard is mounted at the upper end of the exposed portion of the grinding wheel in order to reduce the number of sparks hitting you. The spark guard should be mounted as close as possible to the grinding surface of the wheel.

Bench grinders have motors with ⅓, ½, or 1 horsepower while pedestal grinders range between 2–7½ horsepower. As the horsepower increases, the grinding wheels become wider and larger in diameter. Motor speeds are reduced as the diameter of the grinding wheel becomes larger.

The grinding wheels on stationary grinders are secured between two large clamping washers or flanges held tight by a nut on the end of the spindles (Figure 20). The nut on the left (as seen from the front) has a left-hand thread. Removing this nut requires clockwise rotation. The nut on the other end of the grinder has a standard right-hand thread.

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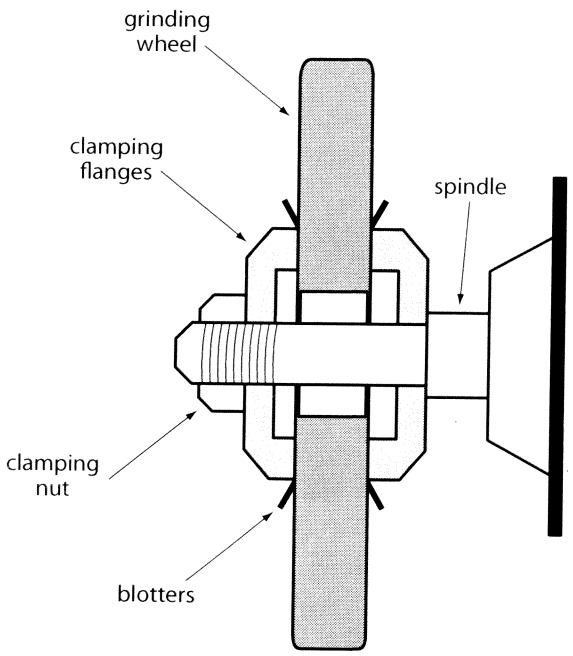

Figure 20. Grinding Wheel Cross-section and Spindle Assembly

When replacing the grinding wheels, make sure the new grinding wheel has an RPM rating that either matches or exceeds the no-load speed of the grinder.

Grinding wheels are supplied with a blotter-type paper disk on each side. The disks serve to cushion the strain caused by the flanges when the clamping nut is tightened.

Grinding wheels with hair-line cracks are unsafe and must be discarded. To test for cracks, simply stand the wheel on edge and tap the sides with a hard object like a screwdriver handle. Cracked grinding wheels will give off a dull sound, while a good wheel will give off a ringing sound.

Using Stationary Grinders

Before starting a grinder, check the condition of the grinding wheel. Place an object on the tool rest so that it just touches the face of the wheel, then turn the wheel by hand. The wheel should just contact the object at all times as it makes a full turn. If not, the wheel is out-of-round and will need to be adjusted. Out-of-round wheels cause the work piece to vibrate during grinding.

Check the condition of the face of the grinding wheel. If it shows excess signs of metal particles, it will need to be cleaned. Grinding wheels with a surface embedded with metal tend to generate heat rather than grind.

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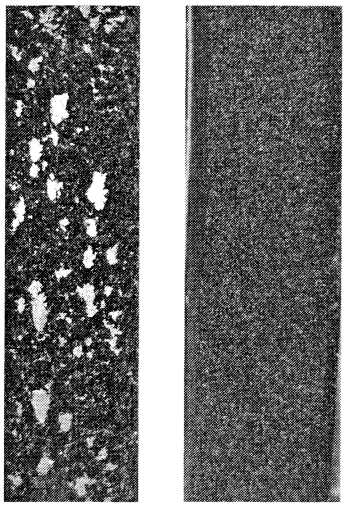

Clogged Clean

Figure 21. Clogged and Clean Grinding Wheel Faces

To remedy out-of-round or dirty wheels, use a wheel dresser on the face of the stone. Where the grinder design permits, the tool rest must be backed away from the grinding wheel enough to allow the dresser to hook over the front edge of the tool rest. While the grinder is running, the handle of the dresser is raised until the sectional washers touch the wheel's face and the dresser is moved across the width of the grinding wheel. Turn off the grinder and when the grinding wheels have stopped turning, check the entire face for metal particles or out-of-round. Repeat dressing as necessary.

Figure 22. Wheel Dresser

Remember to re-position the tool rest no further than 3 mm (⅛ in.) from the wheel after dressing.

When grinding metal with a stationary grinder, you should rest the work piece on the tool rest and apply enough pressure against the grinding wheel so that grinding takes place. Avoid applying so much pressure as to cause a reduction in the grinder's speed. If the work piece can be damaged by heat, you should dip it in water regularly.

NOTES

Tools such as drill bits, screwdriver tips, and cold chisels occasionally require grinding to improve their performance. You should grip such tools close to the area being ground so that you can feel any build-up of heat. If heated to the point of showing colour (yellow, purple, or blue), the hardness of the tool will be affected. To prevent overheating, make sure the grinding wheel is clean and dip the work piece frequently to cool it.

Grinding Wheels

A grinding wheel is a cutting tool made from natural or artificial abrasive particles (Figure 23). The wheels are made in numerous shapes and sizes. A small amount of stock is removed by each abrasive particle as it passes over the work. Grinding wheels are used for rough grinding, smooth finishing, and cutting or removing metal or other materials.

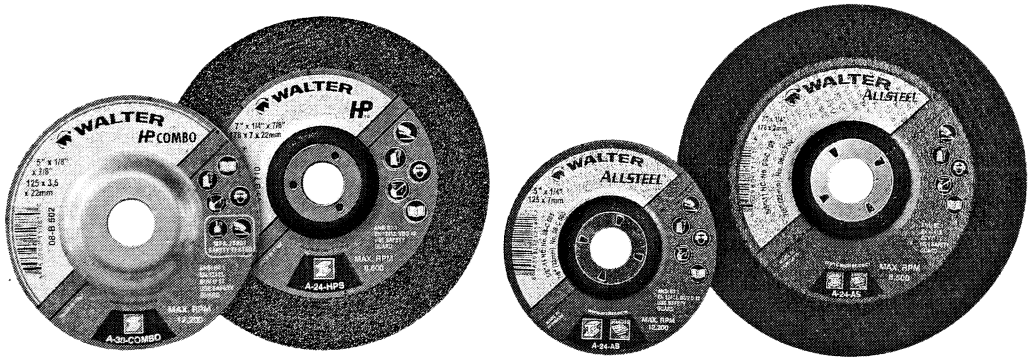

Figure 23. Various Types of Abrasive Grinding Wheels

The most widely used abrasives in grinding wheel construction are silicon carbide, aluminum oxide, and boron carbide. Wheels containing particles of diamonds, either artificial or natural, are also made for limited, special-purpose application.

The abrasive grain size determines the coarseness or fineness of the grinding wheel. The grain size is determined by the smallest screen mesh through which they can pass. For example, if the smallest screen through which the grains pass has 100 openings per inch, the grain size is known as 100 grit and each grain is approximately 1/100 in. Grinding wheel abrasive grits from 6–24 are considered coarse, grits from 30–60 are medium, grits between 70–100 are fine, and those over 100 are known as extra-fine.

The first procedure in the manufacture of grinding wheels is to mix abrasive grains with a bonding agent. This mixture is then placed in a mold and compressed. After compression, the wheel is removed from the mold and dried. The dried wheels are baked (fired) in a kiln. In this process, the grains

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are vitrified (fused together) to convert the wheel into a hard, durable grinding tool. The final manufacturing operations include truing (trimming to finished size), bushing (lining the hole to correct size with lead, babbitt, or plastic), grading (checking for hardness), balancing, and safety testing.

There are five basic bonding methods:

- vitrified
- silicate
- shellac
- rubber
- resinoid (synthetic resin)

The wheel bonding agent and method determine how the wheel holds the abrasives. This affects finish, coolant, and the minimum/maximum speed of the wheel.

- In most cases, a vitrified bond (fused by heat) is suitable for general purpose grinding wheels. These wheels have high strength and are porous for rapid stock removal.
- Silicate-bonded wheels release their particles relatively easily and therefore generate less heat than vitrified wheels. For this reason, they are preferred for sharpening tools and drill bits.
- Shellac-bonded wheels also generate low grinding temperatures and produce a fine finish. They are most often chosen for thin work, such as hardened steel knives.
- Rubber-bonded wheels are somewhat elastic and are able to withstand shock.
- The resinoid bond also provides good shock resistance. These wheels can operate at high speeds.

One function of any bonding material is to hold each abrasive particle intact as long as it is sharp. When the particles become dull, they dislodge and expose other particles with sharp edges.

The hardness (grade) of a grinding wheel refers to the strength with which the bond holds the abrasive particles together in the wheel, not the hardness of the abrasive particles. Grades are rated by letters of the alphabet; the letter A designates the softest wheel and the letter Z the hardest.

The structure of a grinding wheel indicates how far apart the grains are spaced (grain density). If the spacing of the grains is close, the structure is dense. If the spacing is relatively wide, the structure is open. Grinding wheel structures are rated from #1 (dense) to #15 (open). Figure 24 shows the relative spacing of dense and open-grain structures.

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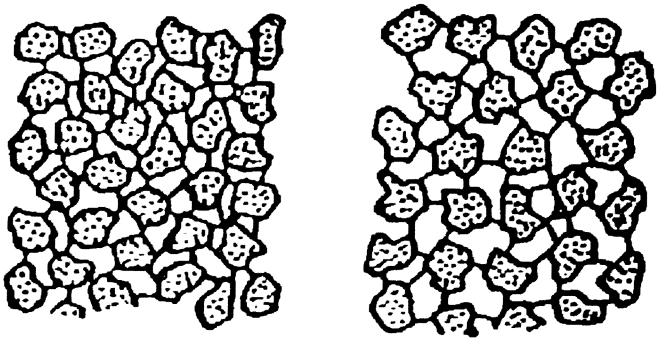

Figure 24. Grinding Wheels: Dense and Open Structures

The primary function of the spaces is to provide chip clearance for the material removed from the work. An open structure coarse grain wheel (which provides better chip clearance) is used on soft materials where finish is of secondary importance.

Dense structure fine grain wheels are used where a smooth surface finish is required. Do not use wheels with a dense structure if the work material tends to clog the grinding wheel face. Choose a wheel structure by compromising between the desired finish and the material removal rate. Always select a grinding wheel having a rated RPM at least as high as the grinder spindle no-load speed.

The standard marking system for most grinding wheels includes a sequence of five parts indicated on the wheel blotter:

- operating speed
- wheel diameter
- wheel thickness
- hole diameter
- grit size

Allowing the wheel to operate at, or slightly below, the maximum safe speed automatically determines the cutting speed preferred for that wheel when used against material for which it was designed.

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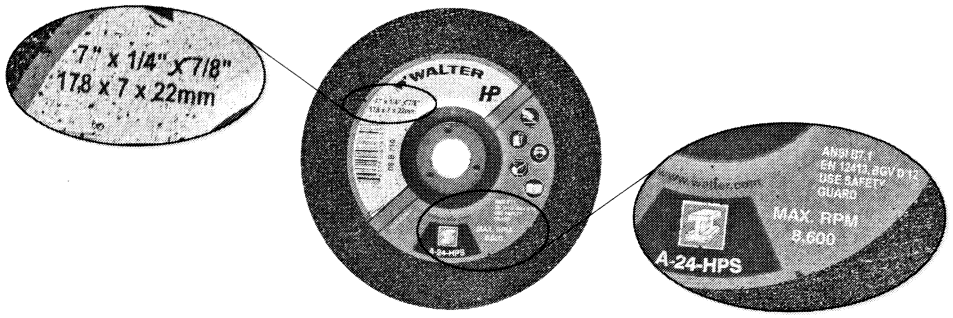


Figure 25. Grinding Wheel Markings

Wheel Selection

Selecting the correct grinding wheel depends not only on the abrasive type, grain size, bonding material, grade, structure, size, and shape but also on the grinding machine, the material to be ground, and the nature of the operation. Medium grain wheels (30–60 grit) are often chosen when only one metal-removing or sharpening operation is desired and the resulting surface finish is acceptable. Wheels having coarse grains (below 30 grit) work best with softer materials where material can be removed rapidly. Many bench grinders will have one wheel with a 30 grit and the other with a 60 grit. Always select a grinding wheel that meets or exceeds the operating RPM of the grinder to be used.

Safety

Be sure all grinding wheel safety devices such as wheel guards, spark deflectors, eye-shields, and tool rests are installed and properly adjusted before operating a grinder. Always wear eye protection devices when grinding. Wear protective gloves and clothing if appropriate. Remove flammable materials from the work area and ask people not directly involved with the grinding operation to leave the area.

Operating a Grinding Wheel

Check for cracks or defects before using. If a grinding wheel is good with no cracks, striking it will produce a definite ringing sound. If the wheel is cracked, it will give a dull thud when struck.

Do not exert more pressure against the grinding wheel than is necessary to remove material effectively. During grinding, move the work back and forth to promote an even surface on the work and the wheel. Cool the work when necessary to prevent overheating. Periodically check the grinding in progress by visually examining the work or by using an appropriate measuring gauge.

Quiz A-4

1. What is worn to protect your hands from repeated hammering when using an air impact wrench?

   a. nitrile gloves
   b. padded palm gloves
   c. leather palm gloves
   d. long gauntlet gloves

2. How should a screw driver be given to a co-worker?

   a. slowly tossed
   b. flipped end over end
   c. passed with the handle in your hand
   d. passed with the handle towards the co-worker

3. What must be done with a shop tool after you have used it?

   a. return it to where you got it from
   b. clean tool and then place it back in storage
   c. give it to your lead hand to store
   d. leave it under the bench so it will not be damaged

4. When referring to a wrench, what does "13 mm" refer to?

   a. distance across the flat of the nut
   b. distance across the points of the nut
   c. depth of the nut
   d. inside diameter of the nut

5. What are some common square drive sizes for ratchets?

   a. ¼", ⅜", ½", ¾"
   b. ⅛", ⅜" ⅝"
   c. 1", 2", 5"
   d. 5⁄16", 7⁄16", 11⁄16"

6. What is the number of points in a socket wrench other than 4, 6, and 12 point?

   a. 2
   b. 5
   c. 8
   d. 10

7. Which of the following wrenches is adjustable?

   a. pipe
   b. tubing
   c. offset
   d. box

8. What colour of Robertson screw drivers is the largest?

   a. green
   b. black
   c. red
   d. yellow

9. What does the number "18" on a hacksaw blade refer to?

   a. thickness of the blade in millimetres
   b. recommended number of strokes per minute
   c. length of the blade in inches
   d. number of teeth per inch

10. What type of file is used to remove metal quickly?

    a. single cut
    b. curved cut
    c. straight cut
    d. double cut

11. What is the angle of the point when regrinding the tip of a centre punch?

    a. 45–60°
    b. 60–90°
    c. 90–120°
    d. 120–145°

12. How is the mushroomed head of a chisel repaired?

    a. heated up and pounded flat
    b. cut off mushroomed material with a hacksaw
    c. grind off mushroomed material
    d. cut the chisel 2.5 cm (1 in.) shorter

13. What can be used to protect the work piece from damage while being clamped in a vise?

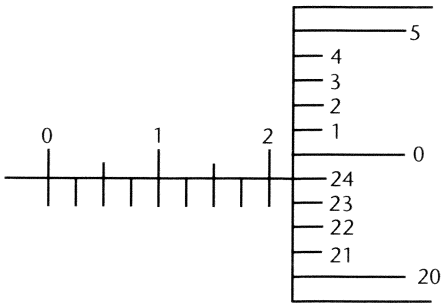
    a. soft jaws
    b. silicone plates
    c. nitrile jaws
    d. cellulose plates

14. What are two common types of jaw pullers?

    a. left hand and right hand
    b. clockwise and counter clockwise
    c. two jaw and three jaw
    d. four jaw and five jaw

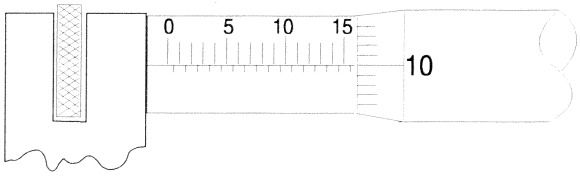
15. What is the measurement reading on this 3–4" outside micrometer?

    a. 3.200"
    b. 3.242"
    c. 3.224"
    d. 3.249"



16. What is the measurement reading on this 0–25 mm outside micrometer?

a. 15.10 mm
b. 15.60 mm
c. 16.00 mm
d. 16.10 mm



17. What must be done before using an outside micrometer?

a. adjust thimble to match anvil
b. check and adjust calibration
c. re-torque ratchet setting
d. adjust frame length

18. What kind of lubricant is used on an air impact wrench?

a. lithium grease
b. gear tool oil
c. light tool oil
d. 15W-40 oil

19. What is the maximum distance between the tool rest and the grinding wheel on a bench grinder?

a. 1.5 mm (1/16")
b. 3 mm (1/8")
c. 6 mm (1/4")
d. 7.5 mm (5/16")

Learning Task 6

NOTES

Select, Use, and Maintain Drill Bits

Twist Drill Bits

Twist drill bits are the most commonly used bits in the mechanical trade. They are normally made from carbon steel or high-speed steel. Those made of high-speed steel are harder and therefore able to drill harder metals. High-speed steel stays sharp longer than carbon steel and is able to withstand higher temperatures without losing its temper.

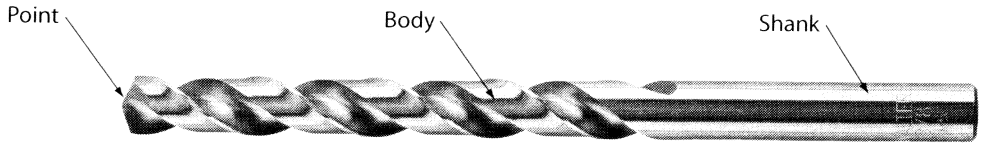


Figure 1. Twist Drill Bit

A twist drill bit consists of three main parts:

- point
- body
- shank

The point is the entire cone-shaped cutting end and consists of the centre and cutting edges.

The body of the drill bit extends from the point to the shank and contains the spiral grooves.

The shank end of the drill bit fits into the holding device (chuck) of the drilling machine. Twist drill bits are available with straight or tapered shanks.

Twist Drill Bit Angles

A correctly sharpened twist drill bit will cut easily into metal. The two cutting lips of the drill bit should each produce the same amount of metal shavings. The point of a twist drill bit can be sharpened to various angles to suit the hardness of the material to be drilled. For normal use, the cutting lips of a twist drill bit are at 59° to the axis of the bit (Figure 2).

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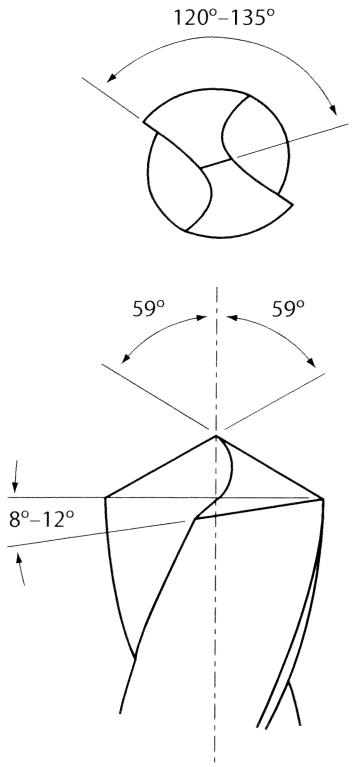

Figure 2. Twist Drill Bit Point Angles

The angle of the cutting edge or lip should be checked with a drill bit point gauge (Figure 3). The gauge is used to check the angle between the lip and the axis of the drill. Both lips should be at the correct angle and equal in length.

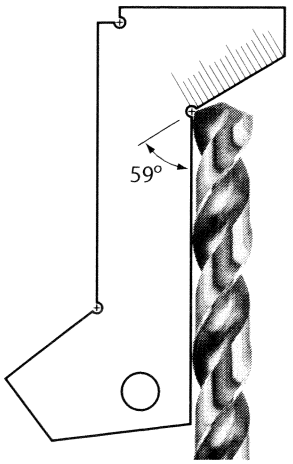

Figure 3. Twist Point Angle Being Checked with a Drill Bit Point Gauge

NOTES

Another important angle is the lip clearance angle (Figure 4). This is the angle between the heel and an imaginary line perpendicular to the lip. A lip clearance of 8–12° is the most common.

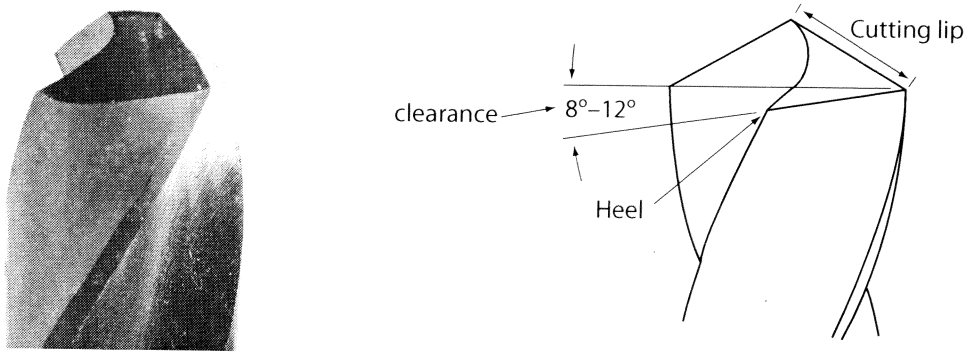

Figure 4. Lip Clearance Angle

Drill Bit Sizes

Twist drill bits are available in diameters designated by one of four different systems:

- metric
- fractional
- number
- letter

The number and letter systems designate very small drill bit sizes. The most commonly used size designations in welding are the metric and the fractional (fraction of an inch). Mechanics generally use twist drill bits ranging in size from 1.5–19 mm (1/16–3/4 in.). Within this range, drill bit diameter size increases in increments of 0.5 mm (1/64 in.).

Other Drill Bits and Attachments

Hole Saw

A hole saw is used to cut circular holes in metal or wood (Figure 5). It looks like a tube, rotates quickly, and has a regular fluted twist drill bit through the centre. When cutting holes, the twist drill bit positions the hole saw, penetrates the material, and acts an axle as the hole saw cuts the hole.

When used on metal, a hole saw always requires lubricant and cooling. Recommended cutting fluids normally provide the required lubrication while cooling. Metal hole saws come in a range of diameters, from 19–83 mm (3/4–3 1/4 in.).

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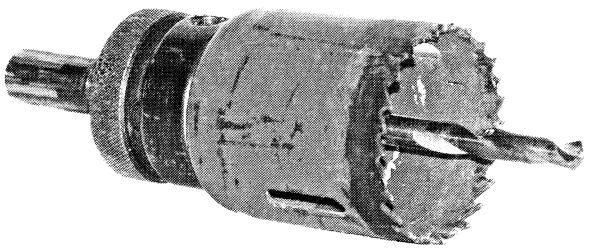

Figure 5. Hole Saw

Stepped Drill Bits

Stepped drill bits are made of high-speed steel coated with titanium nitride. They are commonly used for thinner sheet metal.

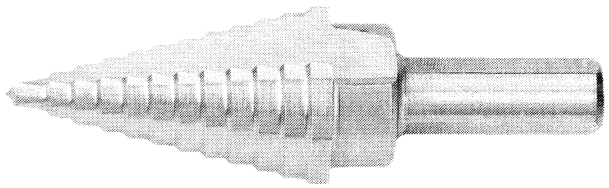

Figure 6. Stepped Drill Bit

Due to its design, a single stepped drill bit can be used to drill a wide range of hole sizes. Some bits come to a point and are thus self-starting. The larger-size bits have blunt tips and are used to enlarge holes. They're available in both metric and fractional inch sizes. Because metals tend to cause premature drill wear and dulling, a metal hole saw is more appropriate for large-hole applications in thicker metals.

Step bits are also used to deburr holes left by other bits, as the sharp increase to the next step size allows the cutting edge to scrape burrs off the entry surface of the work piece. However, the straight flute is poor at chip ejection and it can cause a burr to be formed on the exit side of the hole, more so than a spiral twist drill bit turning at high speed.

NOTES

Carbide-tipped Masonry Drill Bits

Carbide-tipped masonry drill bits are for drilling masonry, cinder blocks, and concrete (Figure 7). The cutting tip is made from tungsten carbide bonded to a spiral fluted shank.

Figure 7. Carbide-tipped Masonry Drill Bit

These bits are generally used with both power drills and hammer drills. Be extremely careful when using these bits with hammer drills. The action on the bit is rigorous, and cheaper bits have been known to shatter under the pounding. Always use a slow rotation speed when drilling into harder materials to avoid overheating the tip. Withdraw the bit frequently to remove dust.

Morse Taper

Larger drill presses have a taper socket, or Morse taper, machined into their spindles (Figure 8). Using a Morse taper on a drill press provides more flexibility in work methods than a simple press alone. The Morse taper shank allows changing of the twist drill bit or tooling in a matter of seconds.

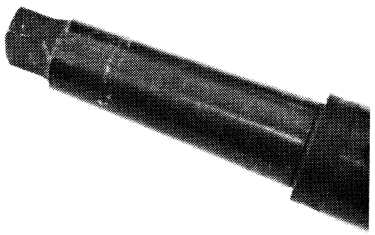

Figure 8. Morse Taper

A Morse taper has a taper of 5/8 inch per foot. Taper shank twist drill bits and accessories come in a series of standard sizes. They have a number designation followed by the letters "MT" (Morse taper). The larger the number, the larger the size of the taper. A #2 MT is larger than a #1 MT, a #3 MT is larger than a #2 MT, and so on.

Sleeves and socket extensions can be used as adapters to fit different sizes of MT together and to add length to the twist drill bit.

NOTES

Effective Procedures for Drilling

Use Cutting Fluids

As a drill bit cuts into metal, the cutting edge (or lip) heats up. This can soften the cutting edge and ruin the drill bit. The main function of a cutting fluid is to cool the cutting edge of the bit and preserve its temper.

Other functions performed by cutting fluids include:

- reducing friction so the drill bit cuts faster, more smoothly and produces a smooth finish in the hole
- washing away the shavings and chips
- cooling the shavings or chips, thereby minimizing the danger of burns

Soluble oil, a mixture of 1 part oil to 40 parts water, is the recommended cutting fluid for copper, low-carbon steel, and tool steel. Specialty lubricants are available for cutting aluminum. Softer metals such as brass, bronze, and cast iron generally require no cutting fluid.

Never use cutting fluid or coolant on a hot drill bit. The sudden cooling can cause surface cracks. The fluid must be introduced while the drill bit is still cool.

Use a Pilot Hole

A pilot hole is used when drilling larger diameter holes. The pilot hole is a smaller hole drilled into the work piece to help locate and control the centre of a larger hole. It also promotes a faster cutting action because the larger bit's chisel edge does not have to promote the cutting action throughout the drilling of the hole.

Larger drill bits require thicker webs to give them strength. As a result, the drill bit's chisel edge is longer. A longer chisel edge has a poorer cutting action and will not follow the centre punch mark accurately. This means that the drill bit will wander and lose centre, resulting in an improperly placed hole. A pilot hole overcomes this problem.

A pilot hole should normally be slightly larger in diameter than the length of the chisel edge of the larger twist drill bit. This provides a centering hole for the larger twist drill bit and clears the way for the cutting edges to do their job. Never drill a pilot hole larger than necessary.

NOTES

Care of Drill Bits

With proper care and maintenance, drill bits will remain in good condition for a long time.

Make sure you keep your twist drill bit sharp and angled correctly. Sharpen it on a grinder, either freehand or by using a jig to hold the drill bit at the correct angle.

Store twist drill bits in a drill bit holder when not in use. If properly stored in their own holder, bits will not be dulled from contact with other tools and are not in danger of being knocked off tables and shelves.

Cutting Speeds for Drill Bits

Select the correct speed for the size of drill bit used and the material to be drilled. The larger the drill bit, the slower the speed. Use a drill speed chart for reference.

Troubleshooting

Figure 9 shows some common problems encountered during drilling and how to avoid them.

Symptom	Problem	Solution
• Cutting edge chips or breaks.	• Feed too fast • Too much lip clearance • Pilot hole too large	• Decrease speed and pressure of feed • Sharpen correctly • Use correct size pilot hole
• Drill bit overheats, might turn blue and lose temper.	• Drill bit dull • Drill speed too fast • Too little lip clearance	• Sharpen • Reduce drill bit speed
• Drill bit jams.	• Might be overheated • Hole clogged with chips	• Sharpen • Reduce drill bit speed • Withdraw drill bit at intervals to remove chips

Figure 9. Common Drilling Problems and Solutions

NOTES

Learning Task 7

Select, Use, and Maintain Shop Equipment

A heavy mechanical shop has equipment useful in your day-to-day work. The shop equipment may be used for cleaning, pressing, drilling, or grinding. You must know how to use the equipment safely, how it operates, and how to maintain it.

Shop Cleaning Equipment

Cold Solution Cleaning

Although small parts can be cleaned in cans or buckets, a faster and more efficient job can be done with a regular cold-solution parts washer.

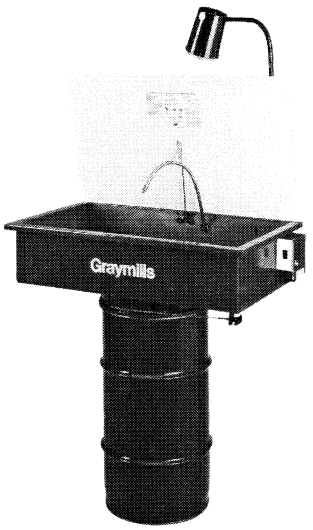

Figure 1. Cold-solution Parts Washer

Many types and sizes of solvent tanks are available, from commercial models to simple drain pans. Some parts washers hold up to 205 L of solvent, have soaking trays, solvent agitation, and a filter to remove impurities from the solvent for rinsing.

Before using the wash tank, you should remove heavy deposits with a scraper. Scrape the parts outside the wash tank to avoid unnecessary fouling of the washing solution.

Place the parts in the basket and submerge them in the solution. Parts with hollow areas should have the hollows facing up to allow air to escape. Some washers have a compartment that is air agitated and a second main tank for soaking, brushing, and rinsing.

After thorough cleaning, parts should be given a final rinse. Following rinsing, parts should be drained and then be blown dry with compressed air. Be sure the air supply or nozzle is equipped with a pressure-limiting device.

Creating a fog of air and solvent vapours can be dangerous if there is the possibility of a spark or flame igniting it. Dust blown up by the compressed air can also be a health hazard for you and anyone working close by.

When drying with compressed air, do not hold parts with your hand—both the air and the part are potential hazards. After drying, parts subject to rusting should be oiled or greased. Keep cleaned parts covered until you're ready to use them.

NOTES

Hot Tank Cleaning

A hot tank usually uses a strong alkaline compound mixed with water to form a solution. Solution temperatures range from 82–99°C (180–210°F). The tank may have an agitator to speed cleaning. Most parts are clean in thirty minutes or less, depending on tank design, solution strength, temperature, and part load.

If aluminum alloys are exposed to a strong alkaline solution, they will be eroded and ruined in a very short time. Alkaline cleaning solutions must be inhibited (weakened) if used for these metals and the cleaning time must be closely monitored to prevent surface erosion.

Another type of hot tank washer is the hot wash cabinet (Figure 2). The parts that are to be cleaned are placed in the cabinet on racks or trays. After the door is closed and the washer turned on, there is a hot, high-pressure spray of a soapy water solution. The rack usually rotates as the solution is sprayed. After the soapy solution wash, there is a hot water rinse. The operation is very similar to a large household dishwasher. This type of wash is safe for both steel and aluminum materials.

NOTES

Figure 2. Hot Wash Cabinet

When parts are removed from the tank, they should be thoroughly rinsed with hot water. Be careful to flush out oil galleries, water jackets, and other internal passages. Parts or surfaces subject to rusting should be oiled.

Modern cleaners use a biodegradable chemical to meet environmental requirements. These tanks are heated to approximately the same temperature as standard hot tanks and will also have an agitator to assist in the cleaning process.

Be extremely careful when using the hot tank. Observe all safety precautions. Have someone who has received training in the operation of the tank give you a demonstration of the proper methods for using the tank.

Carburetor Cleaner

Carburetor cleaner is the most common example of a cold-immersion parts cleaner. This type of cleaner uses a strong liquid chemical that dissolves grease and carbon. The liquid cleaner is not heated. Sometimes an agitating device is used.

The chemical is very strong, so great care must be taken not to get it on your skin or in your eyes. Use rubber gloves and eye protection.

General Rules for Solution Cleaning

Many cleaning solutions are toxic (poisonous), caustic, or corrosive (will burn skin and eyes). Be certain you know what you're using and follow these precautions:

- read and follow manufacturer's instructions and the relevant WHMIS information
- use in a well-ventilated area
- do not use gasoline for cleaning
- wear goggles or a face-shield when working with powerful cleaning solutions
- keep away from sparks and open flame; do not smoke around solutions
- use solutions with relatively high flash-points (temperature at which vapours will ignite when brought into contact with an open flame)
- do not heat solutions unless specifically instructed otherwise
- use protective aprons
- when brushing parts in solvent, use a nylon or brass bristle brush to avoid creating sparks
- solvent wash tanks should have a lid that is held open by a fusible link (a holding device that will melt and drop the lid in the event of fire)
- wash hands and arms thoroughly with soap and water when the cleaning job is complete
- use rubber or neoprene gloves to avoid skin exposure to all types of solvents
- disposal of caustic solutions (i.e., cleaning out the tank) must be done according to strict environmental regulations—do not dispose of solution down a drain

NOTES

NOTES

Steam Cleaners and Pressure Washers

A steam cleaner is a machine that generates live steam with hot water at a temperature of 93–121°C (200–350°F) and delivers it through a hose and nozzle assembly at a pressure of approximately 1034–1724 kPa (150–250 psi). This live steam and hot water is then directed to the equipment or location that is to be cleaned. A cleaning compound is usually added to the water supply for general cleaning tasks.

A pressure washer is a machine that supplies high-pressure water (hot or cold) through a hose and nozzle assembly for cleaning purposes. This type of machine can develop pressure up to 13 790 kPa (3200 psi). In most machines, a detergent may be added to the water supply.

Figure 3. Pressure Washers

You must be careful when using this type of cleaning equipment, as they produce hot, live steam and water under high-pressure. Personal protective equipment must be worn to protect the operator. This equipment includes a face-shield, neoprene or rubber gloves, rubber apron, and rubber boots.

Make sure other personnel are clear of the work area in order to avoid splashing them or accidentally striking them with the high-pressure stream of water or steam.

Watch your footing around the work area, particularly if the cleaning operation is performed on a cement pad. Cement can become quite slippery, especially if the item being steam cleaned is oily or greasy.

NOTES

When using these types of cleaners, care must be taken not to damage sensitive areas of the component being cleaned:

- Avoid direct contact of live steam with painted finishes as the pressure, heat, and chemical may remove the paint.
- Protect open electrical components such as starters, generators, alternators, gauges, and other components.
- Cover openings such as open air intakes, input or output shafts extending from transmissions, or gear box units to prevent water and dirt from entering.
- Remove air cleaners and filters from engines to be steam cleaned.

Remember to clean up after your cleaning operation. Do not leave a mess for the next person.

Each make and type of steam cleaning or pressure washing equipment has its own specific operating instructions. Read the instructions before operating any cleaning machine that you are not familiar with. Have a qualified operator demonstrate the start-up and shutdown procedures.

Glass Bead Cleaner

In a glass bead cleaner, compressed air is used to propel beads against the part to be cleaned. Both wet and dry blast machines are available. This method is used to clean individual parts rather than complete assemblies. Glass beads clean the part down to the base metal, leaving no film of detergent. The beads leave a uniform indented surface imparting strength to the metal by compressing it as it is being cleaned.

The cleaning operation is completely contained in a metal cabinet with a safety-glass viewing window in front.

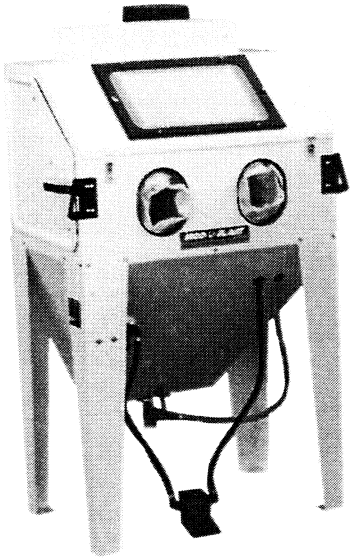

Figure 4. Glass Bead Cleaner

NOTES

Sand Blaster

Some shops may have a sand blaster. The sand blaster uses compressed air to propel sand beads against the material. Usually the sand blaster is used to remove paint and rust from heavy equipment. After the metal is cleaned, it can be repaired and repainted. Sand blasters range in size from small to very large.

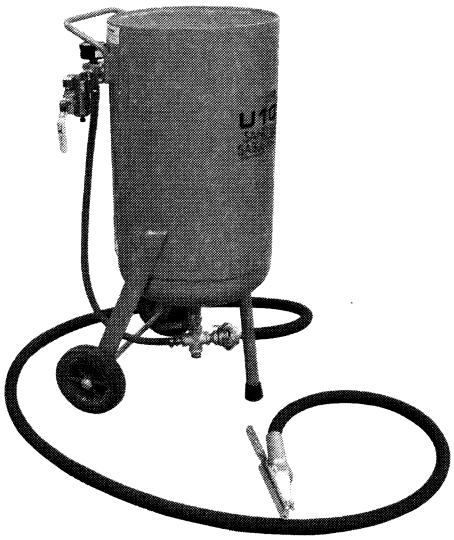

Figure 5. Sand Blaster

Shop Hydraulic Press

Removing bearings, straightening shafts, and pressing bushings often require the use of a hydraulic press (Figure 6). The press is preferred to striking tools because the pressure is smooth and controlled. There is no metal-stressing shock and high pressures can be generated.

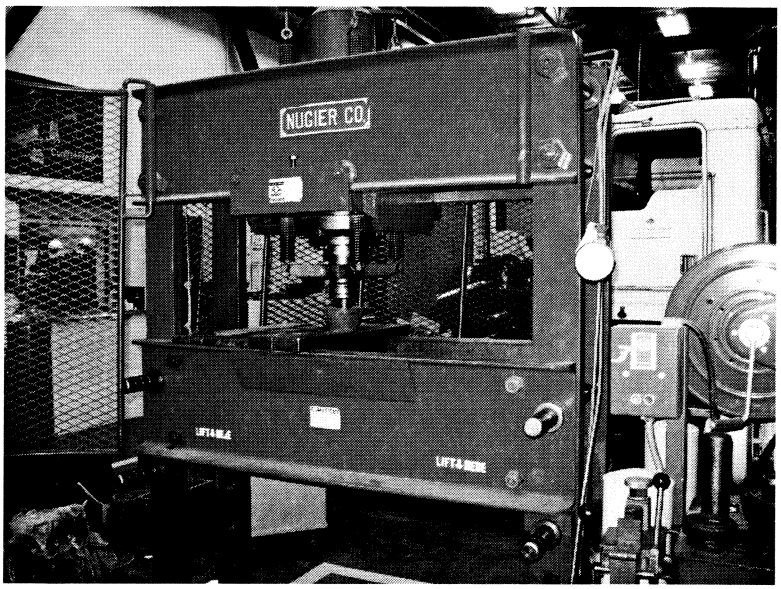

Figure 6. Hydraulic Press

NOTES

Presses are rated according to their pushing capacity in tons. They range from small 9 tonne (10 ton) bench models to large 135 tonne (150 ton) standing models. They are made so either the table or the hydraulic head assembly can be adjusted.

The press has pins supporting the table and holes in the side rack for varying the height. A hydraulic cylinder or hand winch on the side of the press is used to lower the table. Plates across the top of the table are used for pressing. The press's hydraulic pump can be a hand-type, air, or electric, depending on the size of the press. A gauge mounted on the pump indicates the force being applied in tonnes.

All floor hydraulic presses should be equipped with a cage that encloses the ram and the work piece. This cage protects you from injury if the work piece shatters from the loads imposed by the press.

Correct Use and Safety Precautions

Because of the tremendous power that can be developed by hydraulic equipment, a number of safety practices must be followed when you are using either the portable press or the hydraulic press.

A press is used with parts that have an interference fit. Failure to pay attention when applying pressure could result in injury to you or to someone working nearby. Support the part being disassembled. Different assemblies require different methods of support. Know how the pieces come apart before attempting to apply force. Press on the correct spot. If you don't know what it is, find out.

Make sure weight is off the cables that raise and lower the table and that the support pins are fully installed. Stand to one side while operating the press and close the cage door. Wear a face-shield in case something should break. Engage the ram securely and in line with the work and observe the amount of force being applied.

Air Compressor

Pneumatic tools are operated with compressed air supplied by an air compressor. This compressor is pre-set to maintain a constant supply of compressed air at pressures ranging between 350 kPa (50 psi) and 1050 kPa (152 psi). A reservoir tank attached to the compressor retains a supply of compressed air to assure sufficient volume should more than one air-operated tool be in use at one time.

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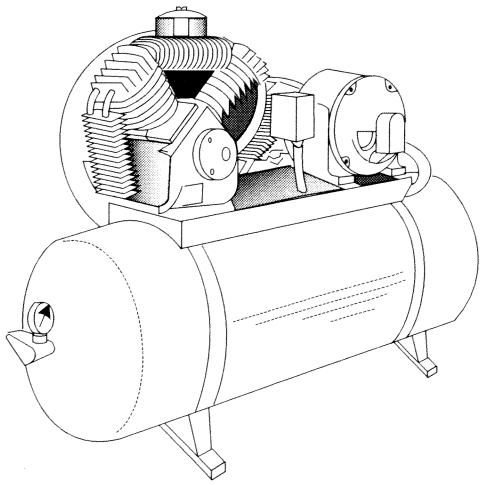

Figure 7. Air Compressor

All air tools require a sufficient volume of compressed air at a specified dynamic pressure in order to operate efficiently. Dynamic air pressure is the pressure that's maintained while the air tool is in use. Static air pressure is the pressure when the tool is not in use and is always higher than the dynamic pressure. An air line and hose of the correct size are prime factors in maintaining adequate dynamic air pressure.

Compressed air is usually piped to quick-connectors placed around the shop. High-pressure flexible rubber air hoses are used to connect the air-operated tool to the wall outlet. These hoses must be kept in good condition and their end connections must be tight. A broken or severed hose can flail uncontrollably causing serious injury.

Air hoses should be coiled neatly and stored when not in use. They can become damaged or weakened if run over by vehicles or equipment.

Power Cut-off Saw

A power cut-off saw is used to cut sections of stock to length. The power cut-off saw uses a thin, abrasive, circular disc as a saw blade. The disc is made from mineral or synthetic grains that are fibre-reinforced and resin-bonded. They come in thicknesses from 2–3 mm (1/16– 1/8 in.) and in diameters from 150–500 mm (6–20 in.).

The saw in Figure 8 is called a chopper-type cut-off machine. The chopper-type machine has the saw mandrel and motor mounted on a pivoting frame. It is operated by grasping the handle and pulling the rotating cut-off wheel into the work piece. The work piece is secured on the bed by a vise or clamp.

NOTES

This machine cuts relatively quickly, but produces a considerable amount of heat at the site of the cut, which may damage the work piece. It's used to cut steel that will not suffer too greatly from heat build up.

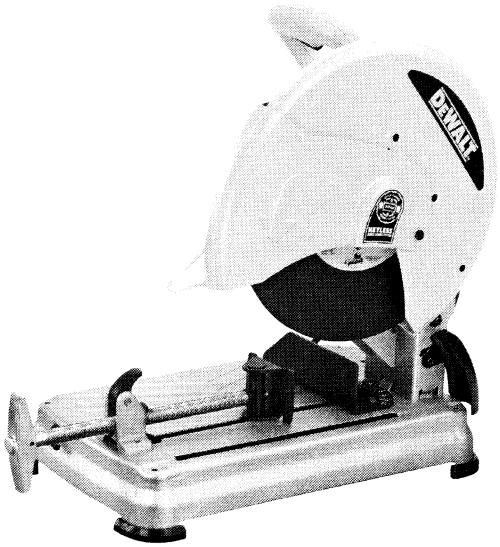

Figure 8. Chopper-type Cut-off Machine

You need to be particularly safety-conscious when operating this machine. Consider the following before using a power cut-off saw:

- Make sure the blade guard is in place.
- Secure the work piece with a vise or clamp,
- When cutting long pieces, have the end supported by an assistant.
- Use a face-shield rather than just eye protection.
- Use leather gloves to handle the cut pieces—they will be hot.
- Do not use excessive force when cutting and be careful not to bump the blade onto the work.
- Stand to one side while cutting (rather than in line with the blade) so that you will not be hit with flying debris.

Abrasive Cut-off Wheels

Abrasive cut-off wheels are designed for cutting masonry products or for cutting metal. Metal cutting wheels are available in two grades: fast-cut or long-life. Fast-cut wheels cut faster but wear out sooner than long-life wheels. Most metal-cutting abrasive wheels will cut steel, stainless steel, cast iron, and aluminum.

Each abrasive cut-off wheel has a maximum speed listed in RPM. You must make sure that the rated speed of the cut-off wheel is greater than the speed of the motor, or the wheel will break apart.

NOTES

Metal-cutting Band Saw

Metal-cutting band saws are available in a variety of models and sizes. The size of the metal-cutting band saw is designated by the thickness of stock you're able to cut with it. Standard sizes are 115 mm, 180 mm, and 255 mm (4½ in., 7 in., and 10 in.). Some larger models are capable of cutting through a pipe that is 50 cm (20 in.) in diameter. The material being cut is held by a built-in vise. The vise can be rotated to allow a cutting angle of up to 90°.

When equipped with a sharp blade, these saws produce an accurate cut without an excessive build up of heat. Some saws are equipped with a mist spray cooling system that cools and lubricates the saw blade.

Smaller models regulate the amount of cutting pressure by use of an adjustable counterweight. Larger models use a hydraulic system to regulate the feed pressure. All models are designed to shut off once the work piece is cut. These features allow the saws to be left unattended during long cutting operations. If several smaller pieces need to be cut, they can be cut simultaneously, providing they can all be secured in the vise.

The speed of the saw blade can be reduced to prevent heat build-up during a heavy cut. Speeds may range between 21–90 m/min (65–300 ft/min).

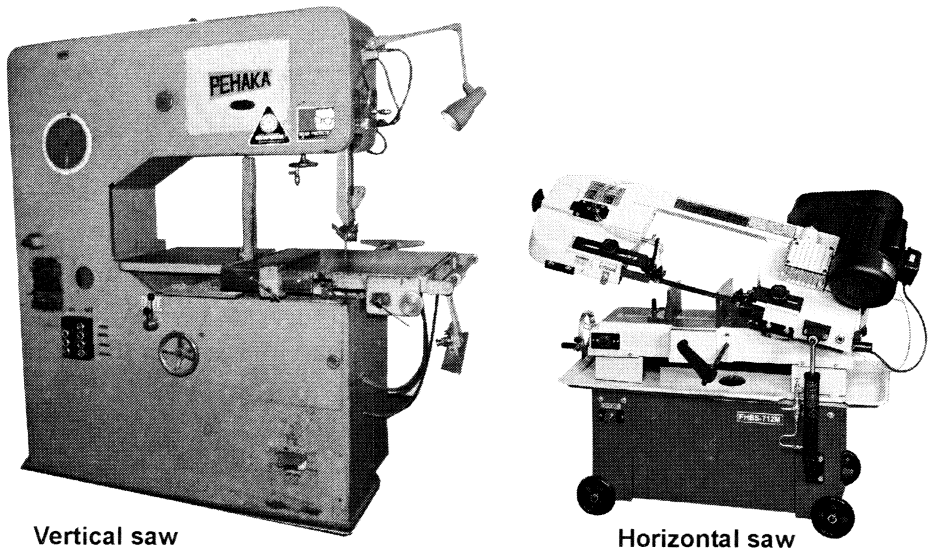

Figure 9. Metal-cutting Band Saws

NOTES

Metal Cutting Blades

Metal-cutting band saw blades are defined by their grades of steel, tooth formation, tooth set, and blade width. Grades of steel include:

- carbon
- semi high-speed
- high-speed

Carbon Steel

Carbon steel blades are used for general purpose cutting on a standard band saw. Blades made of carbon steel are inexpensive to buy but are less durable than other grades.

Semi High-speed Steel

Semi high-speed steel blades cut 50% faster than carbon steel blades. They are harder than carbon steel, but are able to withstand mechanical shocks and vibrations that would break harder, more brittle blades.

High-speed Steel

High-speed steel blades cut better and last longer than other blades, but are more expensive and more delicate than the other two grades.

Tooth formations include:

- regular
- hook
- skip

Regular Tooth

Band saw blades with regular teeth are used for straight and curved cuts in most ferrous and non-ferrous metals. Blades with regular teeth can be considered general-purpose blades.

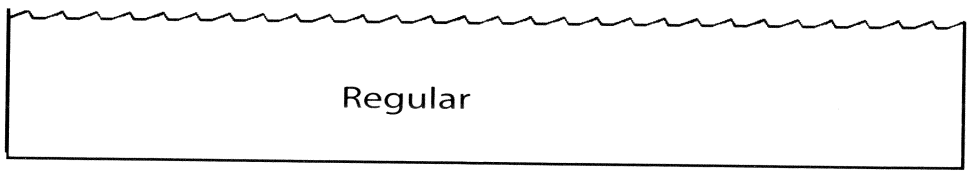

Figure 10. Regular Tooth Blade

NOTES

Hook Tooth

The hook tooth blade is best for fast cutting of non-ferrous metals. The large rounded gullets are capable of fast chip removal and the forward slope of the tooth requires less downward pressure to cut. Thin sections of metal should not be cut with this tooth style due to the wide spacing of the teeth.

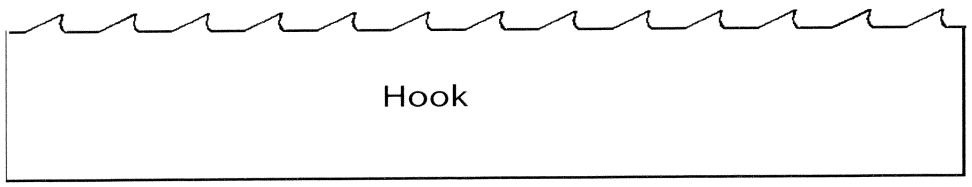

Figure 11. Hook Tooth Blade

Skip Tooth

The skip tooth is very similar to the hook tooth. Unlike the hook tooth, which can only cut softer metals, the skip tooth is capable of cutting ferrous metals. The wide spacing of the skip tooth makes the blade suitable for fast cutting of large sections of steel. Hook and skip tooth types are available in 3 to 6 teeth per inch. Regular tooth styles range from 6 to 32 teeth per inch. The number of teeth per inch affects the cutting speed of a band saw and the size of stock it's best suited to cut. Blades with large numbers of teeth per inch are able to cut small, thin pieces of metal but are slow when cutting large sections. Blades with few teeth per inch cut faster but are too coarse for cutting small sections of metal.

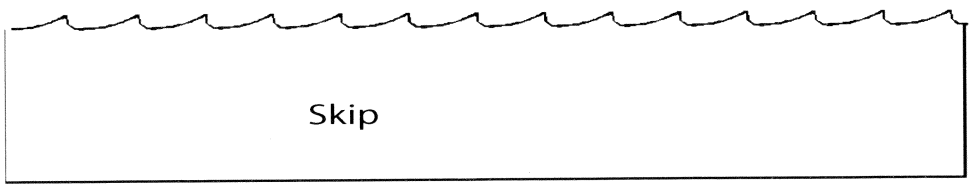

Figure 12. Skip Tooth Blade

Tooth Set

Set is defined as the left-and-right positioning of teeth to provide a wider cut than the thickness of the blade. The wide cut provides clearance for the blade within the cut, preventing binding and overheating.

There are two types of tooth sets available on metal-cutting band saws, the raker set and the wavy set (Figures 13 & 14).

Hook and skip tooth blades have raker set teeth. Regular tooth blades with up to 24 teeth per inch come with either raker set or wavy set teeth. All regular tooth blades with more than 24 teeth per inch have wavy set teeth.

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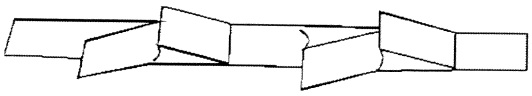

Figure 13. Raker Set

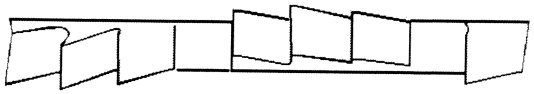

Figure 14. Wavy Set

Blade Width

Band saw blades are available in widths ranging from ¼–1¼ in. The narrower blades are able to cut curves of a smaller radius than wider blades. Wide blades are used for straight cuts.

Drill Press

The drill press is one of the most practical power tools due to its versatility and ease of operation. A drill press can be floor or bench mounted.

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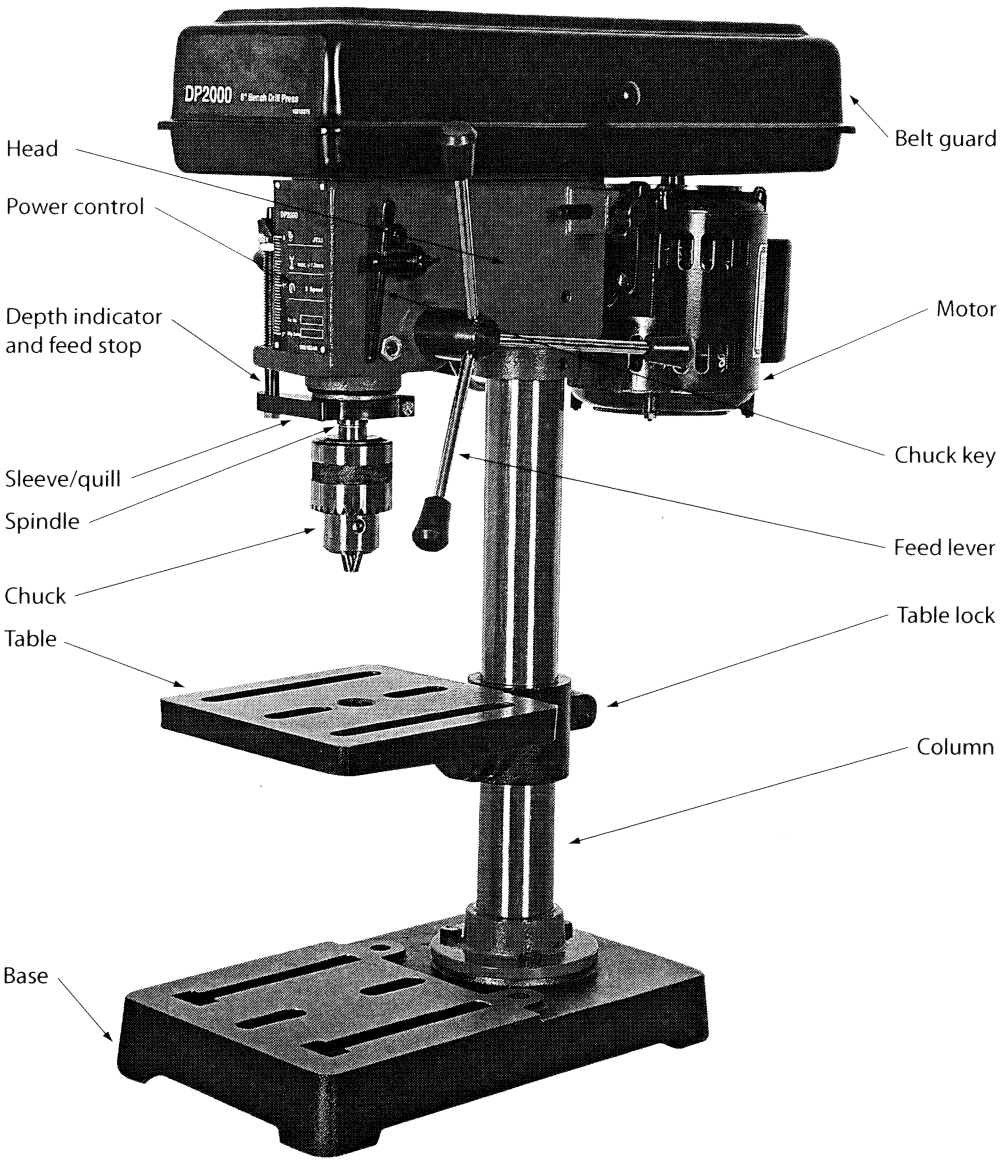


Figure 15. Drill Press

Construction

The four basic parts of the drill press are the base, column, table, and head. The head is the entire working mechanism attached to the upper end of the column. The table can be moved up and down on the column, swung to either side, or tilted.

The chuck is moved downward by means of simple rack-and-pinion gearing worked by the feed lever. The feed lever is returned to its normal position by means of a coil spring. You can lock the feed and pre-set the depth to which it can travel.

NOTES

Power and Speed

The drill press is fitted with pulleys or gears so that different speeds can be obtained. The average drill press can obtain speeds of 680, 1250, 2400, and 4600 RPM. When the machine is used exclusively for metal work, a larger cone pulley is used on the spindle to give lower speeds of about 470, 780, 1300, and 1950 RPM.

Drilling Metal

A drill turning in a piece of metal exerts significant torque, which tends to cause the work to rotate. The twisting action increases when the drill breaks through the underside of the piece being drilled. A piece of work spinning on the end of a drill can cut your hand, break the drill, or spoil the work. This hazard is avoided by clamping the work. A machine vise can be used for holding smaller items (Figure 16). Large pieces should be secured with C-clamps.

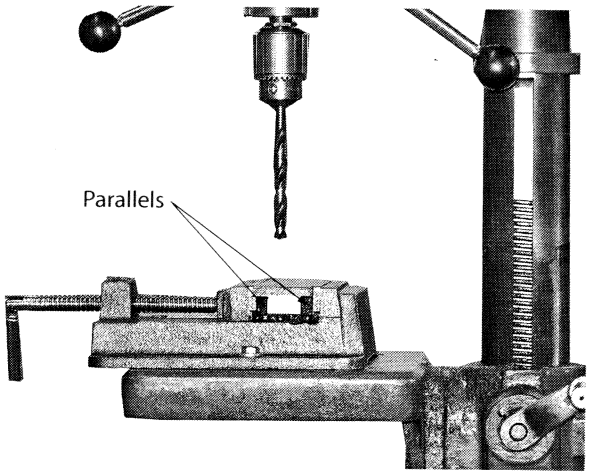


Figure 16. Drill Press Machine Vise

Speed and Feed

The speed in any drilling operation is determined by the type of material being drilled, the size of hole, the type of drill, and the quality of cut desired. The smaller the drill bit, the greater the speed. The speed should also be greater for soft materials than for hard materials.

On most drill presses, it's difficult to obtain the exact recommended speed, but you can come close by adjusting the drive belt on the step-cone pulleys. You will find instructions on adjusting the pulleys in the manufacturer's manual. There's usually a chart in the manual giving the various speed ratios for your particular drill press. You can use the chart in Table 1 as a general guide.

NOTES

Drill bit size		Aluminum bronze brass	Cast iron annealed	Cast iron hard	Low-carbon Steel	Cast steel
mm	in.	RPM	RPM	RPM	RPM	RPM
1.5	1/16	9200	9200	4300	6100	2400
3.5	1/8	9200	4600	2100	3100	1200
4.5	5/16	6100	3100	1400	2000	800
6.5	1/4	4600	2300	1100	1500	600
8.0	5/16	3700	1800	850	1200	500
9.5	3/8	3100	1500	700	1000	400
11.5	7/16	2600	1300	600	875	350
13.0	1/2	2300	1100	525	775	300
16.0	5/8	1800	900	425	600	250
19.0	3/4	1500	775	350	500	200
22.5	7/8	1300	650	300	425	175
25.0	1	1100	575	275	375	150

Table 1. Sample Drill Speed Chart

For intermediate sizes, use the speed suggested for next larger hole. Use slower speeds for deep holes or if the drill bit burns or melts material.

Feed is the amount of pressure you apply to control penetration. Too much pressure will force the tool beyond its cutting capacity and can result in rough cuts and jammed or broken tools. Too light a feed, particularly with metals or other hard materials, will cause overheating of the tool and burning of the cutting edge. The best results will be obtained by matching the correct speed with a steady feed pressure that lets the tool cut easily at an even rate.

As with all power tools, you must ensure the safe operation of a drill press. Before proceeding with any drill press operation, you should understand the following safety precautions:

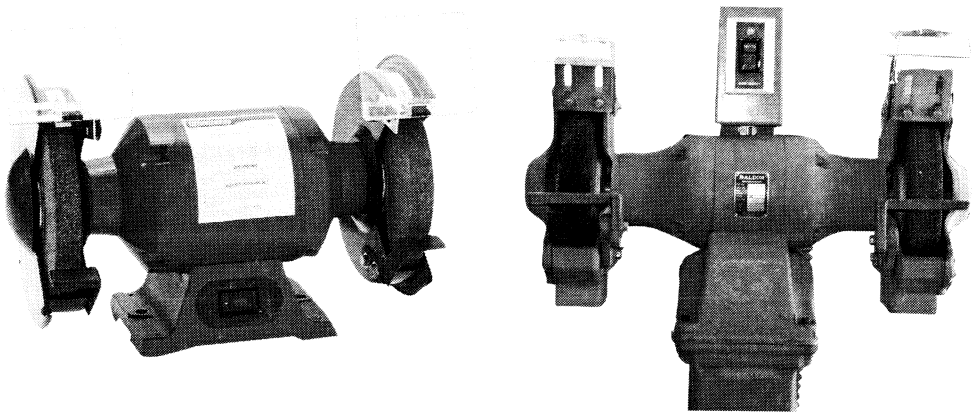
- Do not attempt to hold the work by hand—use a vise or clamp to prevent the work from spinning.
- Use a face-shield to protect yourself from flying chips.
- Do not set speeds or adjust the work while the machine is running.
- Stay as far back from the revolving parts as possible to prevent your clothing from being caught.
- As the drill begins to break through the work, ease up on the drilling pressure and allow the drill to break through gradually.
- Use a file or scraper to remove burrs from a drilled hole, not your hands.
- Do not leave a chuck key in the drill chuck.

NOTES

- Do not attempt to grab work that may have caught in the drill while the drill is still in motion. Stop the machine first.
- Position the table or vise so that the drill bit will not damage either as it penetrates the work.
- Check the drill press speed settings before starting.

Stationary Grinders

Stationary grinders may be bench grinders or pedestal grinders (Figure 17). Bench grinders are mounted on a bench and are usually smaller than pedestal models.



Bench grinder, 1 HP

Pedestal grinder, 5 HP

Figure 17. Bench and Pedestal Grinders

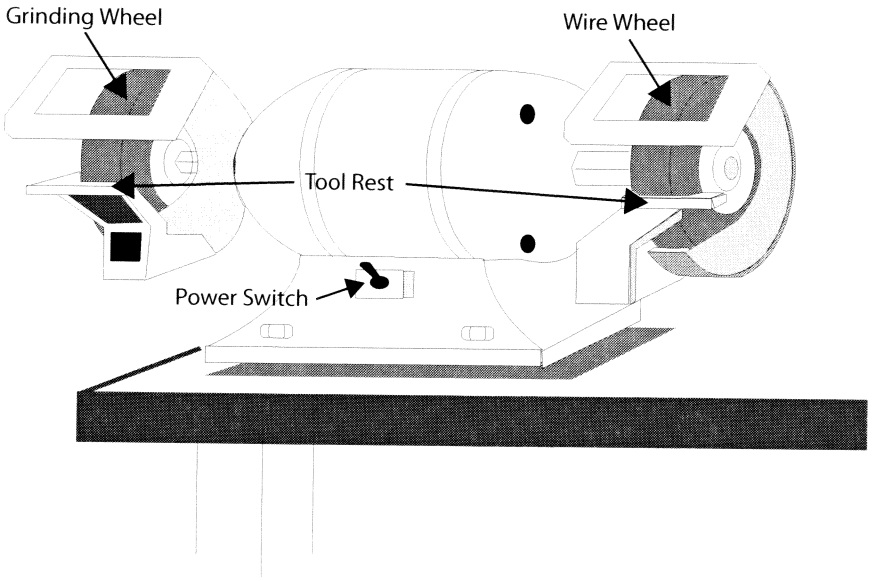


Figure 18. Grinder Parts

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Stationary grinders consist of an electric motor with grinding wheels attached to both ends of the motor shaft. The grinding wheels are enclosed in guards that support a tool rest at the front and a combined eye shield and light near its top. The grinding wheels rotate so that they travel toward the operator from the top of the wheel.

The tool rest is adjustable and must be positioned no lower than the centre of the grinding wheel. The distance between the front edge of the grinding wheel and the tool rest must be 3 mm (⅛ in.) or less (Figure 19).

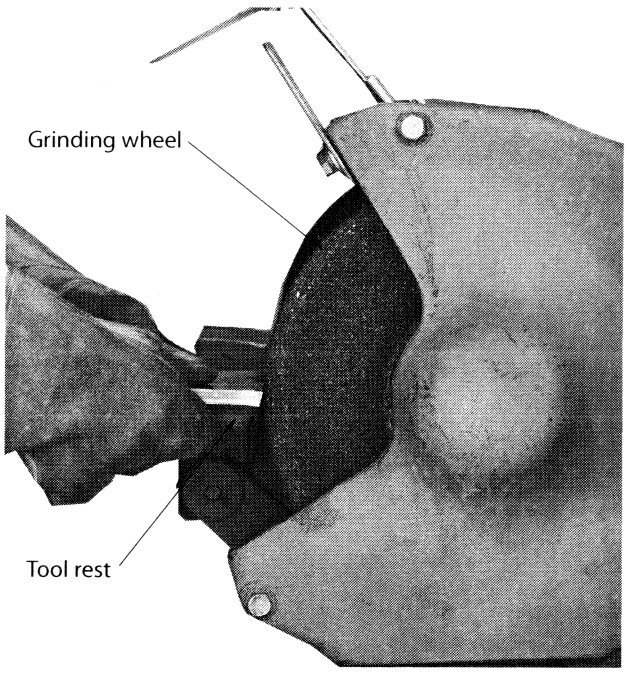

Figure 19. Correct Position of Tool Rest

Sparks are created during the grinding of ferrous metals. A spark guard is mounted at the upper end of the exposed portion of the grinding wheel in order to reduce the number of sparks hitting you. The spark guard should be mounted as close as possible to the grinding surface of the wheel.

Bench grinders have motors with ⅓, ½, or 1 horsepower while pedestal grinders range between 2–7½ horsepower. As the horsepower increases, the grinding wheels become wider and larger in diameter. Motor speeds are reduced as the diameter of the grinding wheel becomes larger.

The grinding wheels on stationary grinders are secured between two large clamping washers or flanges held tight by a nut on the end of the spindles (Figure 20). The nut on the left (as seen from the front) has a left-hand thread. Removing this nut requires clockwise rotation. The nut on the other end of the grinder has a standard right-hand thread.

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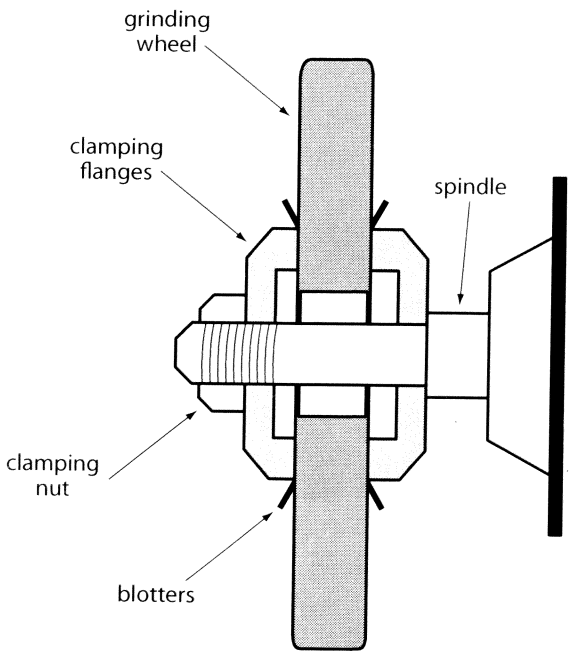

Figure 20. Grinding Wheel Cross-section and Spindle Assembly

When replacing the grinding wheels, make sure the new grinding wheel has an RPM rating that either matches or exceeds the no-load speed of the grinder.

Grinding wheels are supplied with a blotter-type paper disk on each side. The disks serve to cushion the strain caused by the flanges when the clamping nut is tightened.

Grinding wheels with hair-line cracks are unsafe and must be discarded. To test for cracks, simply stand the wheel on edge and tap the sides with a hard object like a screwdriver handle. Cracked grinding wheels will give off a dull sound, while a good wheel will give off a ringing sound.

Using Stationary Grinders

Before starting a grinder, check the condition of the grinding wheel. Place an object on the tool rest so that it just touches the face of the wheel, then turn the wheel by hand. The wheel should just contact the object at all times as it makes a full turn. If not, the wheel is out-of-round and will need to be adjusted. Out-of-round wheels cause the work piece to vibrate during grinding.

Check the condition of the face of the grinding wheel. If it shows excess signs of metal particles, it will need to be cleaned. Grinding wheels with a surface embedded with metal tend to generate heat rather than grind.

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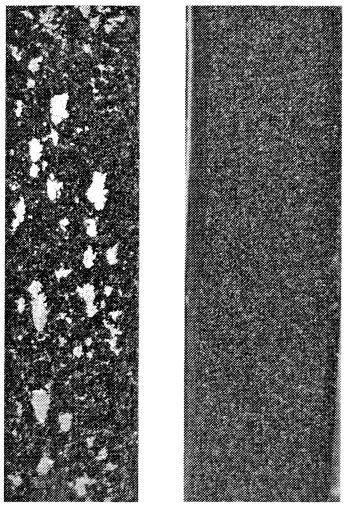

Clogged Clean

Figure 21. Clogged and Clean Grinding Wheel Faces

To remedy out-of-round or dirty wheels, use a wheel dresser on the face of the stone. Where the grinder design permits, the tool rest must be backed away from the grinding wheel enough to allow the dresser to hook over the front edge of the tool rest. While the grinder is running, the handle of the dresser is raised until the sectional washers touch the wheel's face and the dresser is moved across the width of the grinding wheel. Turn off the grinder and when the grinding wheels have stopped turning, check the entire face for metal particles or out-of-round. Repeat dressing as necessary.

Figure 22. Wheel Dresser

Remember to re-position the tool rest no further than 3 mm (⅛ in.) from the wheel after dressing.

When grinding metal with a stationary grinder, you should rest the work piece on the tool rest and apply enough pressure against the grinding wheel so that grinding takes place. Avoid applying so much pressure as to cause a reduction in the grinder's speed. If the work piece can be damaged by heat, you should dip it in water regularly.

NOTES

Tools such as drill bits, screwdriver tips, and cold chisels occasionally require grinding to improve their performance. You should grip such tools close to the area being ground so that you can feel any build-up of heat. If heated to the point of showing colour (yellow, purple, or blue), the hardness of the tool will be affected. To prevent overheating, make sure the grinding wheel is clean and dip the work piece frequently to cool it.

Grinding Wheels

A grinding wheel is a cutting tool made from natural or artificial abrasive particles (Figure 23). The wheels are made in numerous shapes and sizes. A small amount of stock is removed by each abrasive particle as it passes over the work. Grinding wheels are used for rough grinding, smooth finishing, and cutting or removing metal or other materials.

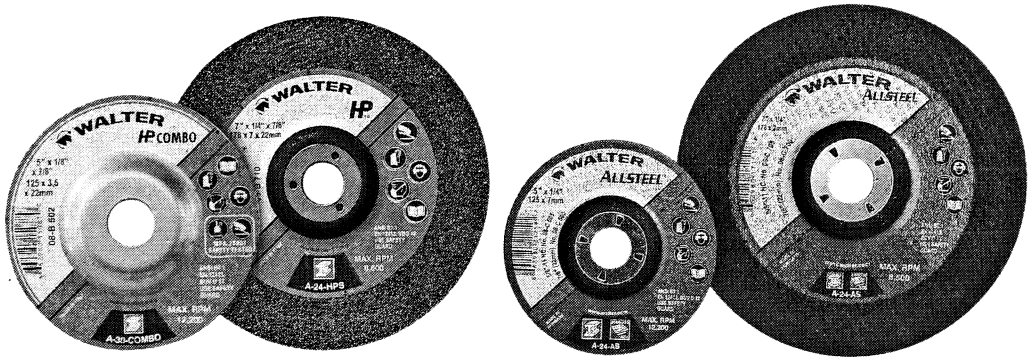

Figure 23. Various Types of Abrasive Grinding Wheels

The most widely used abrasives in grinding wheel construction are silicon carbide, aluminum oxide, and boron carbide. Wheels containing particles of diamonds, either artificial or natural, are also made for limited, special-purpose application.

The abrasive grain size determines the coarseness or fineness of the grinding wheel. The grain size is determined by the smallest screen mesh through which they can pass. For example, if the smallest screen through which the grains pass has 100 openings per inch, the grain size is known as 100 grit and each grain is approximately 1/100 in. Grinding wheel abrasive grits from 6–24 are considered coarse, grits from 30–60 are medium, grits between 70–100 are fine, and those over 100 are known as extra-fine.

The first procedure in the manufacture of grinding wheels is to mix abrasive grains with a bonding agent. This mixture is then placed in a mold and compressed. After compression, the wheel is removed from the mold and dried. The dried wheels are baked (fired) in a kiln. In this process, the grains

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are vitrified (fused together) to convert the wheel into a hard, durable grinding tool. The final manufacturing operations include truing (trimming to finished size), bushing (lining the hole to correct size with lead, babbitt, or plastic), grading (checking for hardness), balancing, and safety testing.

There are five basic bonding methods:

- vitrified
- silicate
- shellac
- rubber
- resinoid (synthetic resin)

The wheel bonding agent and method determine how the wheel holds the abrasives. This affects finish, coolant, and the minimum/maximum speed of the wheel.

- In most cases, a vitrified bond (fused by heat) is suitable for general purpose grinding wheels. These wheels have high strength and are porous for rapid stock removal.
- Silicate-bonded wheels release their particles relatively easily and therefore generate less heat than vitrified wheels. For this reason, they are preferred for sharpening tools and drill bits.
- Shellac-bonded wheels also generate low grinding temperatures and produce a fine finish. They are most often chosen for thin work, such as hardened steel knives.
- Rubber-bonded wheels are somewhat elastic and are able to withstand shock.
- The resinoid bond also provides good shock resistance. These wheels can operate at high speeds.

One function of any bonding material is to hold each abrasive particle intact as long as it is sharp. When the particles become dull, they dislodge and expose other particles with sharp edges.

The hardness (grade) of a grinding wheel refers to the strength with which the bond holds the abrasive particles together in the wheel, not the hardness of the abrasive particles. Grades are rated by letters of the alphabet; the letter A designates the softest wheel and the letter Z the hardest.

The structure of a grinding wheel indicates how far apart the grains are spaced (grain density). If the spacing of the grains is close, the structure is dense. If the spacing is relatively wide, the structure is open. Grinding wheel structures are rated from #1 (dense) to #15 (open). Figure 24 shows the relative spacing of dense and open-grain structures.

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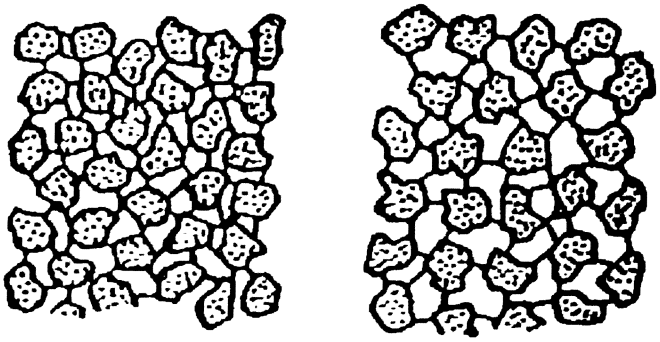

Figure 24. Grinding Wheels: Dense and Open Structures

The primary function of the spaces is to provide chip clearance for the material removed from the work. An open structure coarse grain wheel (which provides better chip clearance) is used on soft materials where finish is of secondary importance.

Dense structure fine grain wheels are used where a smooth surface finish is required. Do not use wheels with a dense structure if the work material tends to clog the grinding wheel face. Choose a wheel structure by compromising between the desired finish and the material removal rate. Always select a grinding wheel having a rated RPM at least as high as the grinder spindle no-load speed.

The standard marking system for most grinding wheels includes a sequence of five parts indicated on the wheel blotter:

- operating speed
- wheel diameter
- wheel thickness
- hole diameter
- grit size

Allowing the wheel to operate at, or slightly below, the maximum safe speed automatically determines the cutting speed preferred for that wheel when used against material for which it was designed.

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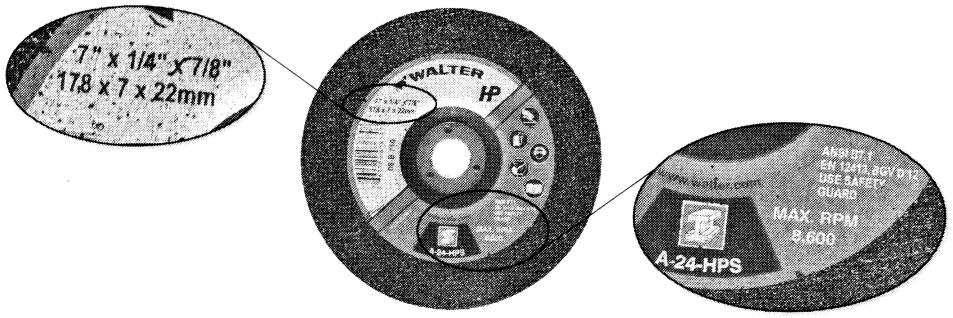


Figure 25. Grinding Wheel Markings

Wheel Selection

Selecting the correct grinding wheel depends not only on the abrasive type, grain size, bonding material, grade, structure, size, and shape but also on the grinding machine, the material to be ground, and the nature of the operation. Medium grain wheels (30–60 grit) are often chosen when only one metal-removing or sharpening operation is desired and the resulting surface finish is acceptable. Wheels having coarse grains (below 30 grit) work best with softer materials where material can be removed rapidly. Many bench grinders will have one wheel with a 30 grit and the other with a 60 grit. Always select a grinding wheel that meets or exceeds the operating RPM of the grinder to be used.

Safety

Be sure all grinding wheel safety devices such as wheel guards, spark deflectors, eye-shields, and tool rests are installed and properly adjusted before operating a grinder. Always wear eye protection devices when grinding. Wear protective gloves and clothing if appropriate. Remove flammable materials from the work area and ask people not directly involved with the grinding operation to leave the area.

Operating a Grinding Wheel

Check for cracks or defects before using. If a grinding wheel is good with no cracks, striking it will produce a definite ringing sound. If the wheel is cracked, it will give a dull thud when struck.

Do not exert more pressure against the grinding wheel than is necessary to remove material effectively. During grinding, move the work back and forth to promote an even surface on the work and the wheel. Cool the work when necessary to prevent overheating. Periodically check the grinding in progress by visually examining the work or by using an appropriate measuring gauge.

Quiz A-4

1. What is worn to protect your hands from repeated hammering when using an air impact wrench?

   a. nitrile gloves
   b. padded palm gloves
   c. leather palm gloves
   d. long gauntlet gloves

2. How should a screw driver be given to a co-worker?

   a. slowly tossed
   b. flipped end over end
   c. passed with the handle in your hand
   d. passed with the handle towards the co-worker

3. What must be done with a shop tool after you have used it?

   a. return it to where you got it from
   b. clean tool and then place it back in storage
   c. give it to your lead hand to store
   d. leave it under the bench so it will not be damaged

4. When referring to a wrench, what does "13 mm" refer to?

   a. distance across the flat of the nut
   b. distance across the points of the nut
   c. depth of the nut
   d. inside diameter of the nut

5. What are some common square drive sizes for ratchets?

   a. ¼", ⅜", ½", ¾"
   b. ⅛", ⅜" ⅝"
   c. 1", 2", 5"
   d. 5⁄16", 7⁄16", 11⁄16"

6. What is the number of points in a socket wrench other than 4, 6, and 12 point?

   a. 2
   b. 5
   c. 8
   d. 10

7. Which of the following wrenches is adjustable?

   a. pipe
   b. tubing
   c. offset
   d. box

8. What colour of Robertson screw drivers is the largest?

   a. green
   b. black
   c. red
   d. yellow

9. What does the number "18" on a hacksaw blade refer to?

   a. thickness of the blade in millimetres
   b. recommended number of strokes per minute
   c. length of the blade in inches
   d. number of teeth per inch

10. What type of file is used to remove metal quickly?

    a. single cut
    b. curved cut
    c. straight cut
    d. double cut

11. What is the angle of the point when regrinding the tip of a centre punch?

    a. 45–60°
    b. 60–90°
    c. 90–120°
    d. 120–145°

12. How is the mushroomed head of a chisel repaired?

    a. heated up and pounded flat
    b. cut off mushroomed material with a hacksaw
    c. grind off mushroomed material
    d. cut the chisel 2.5 cm (1 in.) shorter

13. What can be used to protect the work piece from damage while being clamped in a vise?

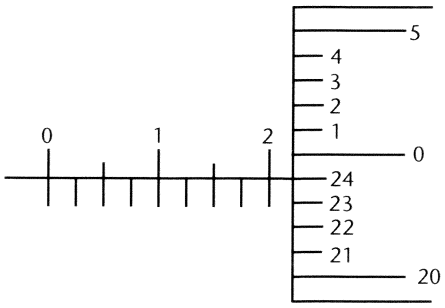
    a. soft jaws
    b. silicone plates
    c. nitrile jaws
    d. cellulose plates

14. What are two common types of jaw pullers?

    a. left hand and right hand
    b. clockwise and counter clockwise
    c. two jaw and three jaw
    d. four jaw and five jaw

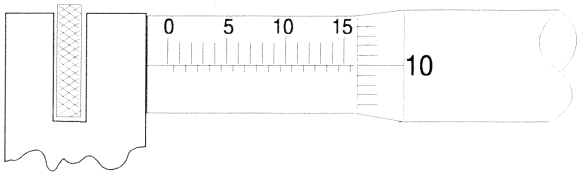
15. What is the measurement reading on this 3–4" outside micrometer?

    a. 3.200"
    b. 3.242"
    c. 3.224"
    d. 3.249"



16. What is the measurement reading on this 0–25 mm outside micrometer?

a. 15.10 mm
b. 15.60 mm
c. 16.00 mm
d. 16.10 mm



17. What must be done before using an outside micrometer?

a. adjust thimble to match anvil
b. check and adjust calibration
c. re-torque ratchet setting
d. adjust frame length

18. What kind of lubricant is used on an air impact wrench?

a. lithium grease
b. gear tool oil
c. light tool oil
d. 15W-40 oil

19. What is the maximum distance between the tool rest and the grinding wheel on a bench grinder?

a. 1.5 mm (1/16")
b. 3 mm (1/8")
c. 6 mm (1/4")
d. 7.5 mm (5/16")

Learning Task 3

Select, Use, and Repair Pipe, Tubing, and Fittings

NOTES

Pipe

Pipe is manufactured from several different materials. The most common materials are steel, plastic, copper, and brass. Pipes of the same material may be made with different wall thickness to withstand different pressures.

Steel pipes may be joined together by welding, flange connections, or threads. Plastic pipe fittings are most commonly joined with solvent cement and copper pipe fittings are joined by soldering. Brass fittings are normally threaded.

Pipe is identified by its nominal or approximate inside diameter. Male pipe will have a consistent outside diameter but its inside diameter will change depending on wall thickness. The opposite is true of female pipe: consistent inside diameter and variable outside diameter depending on wall thickness. This leads to confusion when trying to figure out pipe size by physically measuring it because neither the inside nor the outside diameter is the correct one in all circumstances. A general rule of thumb for sizing pipe is to measure the outside of the pipe sealing surface or thread (Figure 1) and subtract ¼ in.

For example, ½ in. standard pipe will have an approximate outside diameter of 27/32 in. (Table 1). Subtracting ¼ in. from 27/32 in. leaves 19/32 in. which is closer to ½ in. than it is to ¾ in. This is not an exact method, but it works with some practice. It also helps that pipe comes in a limited range of sizes: 1/16 in., ⅛ in., ¼ in., ⅜ in., ½ in., ¾ in., 1 in., 1¼ in., 1½ in., 2½ in., 3 in., 4 in., 5 in., 6 in., and larger.

The equipment repair and manufacturing industry deals mostly with steel pipe and its related fittings.

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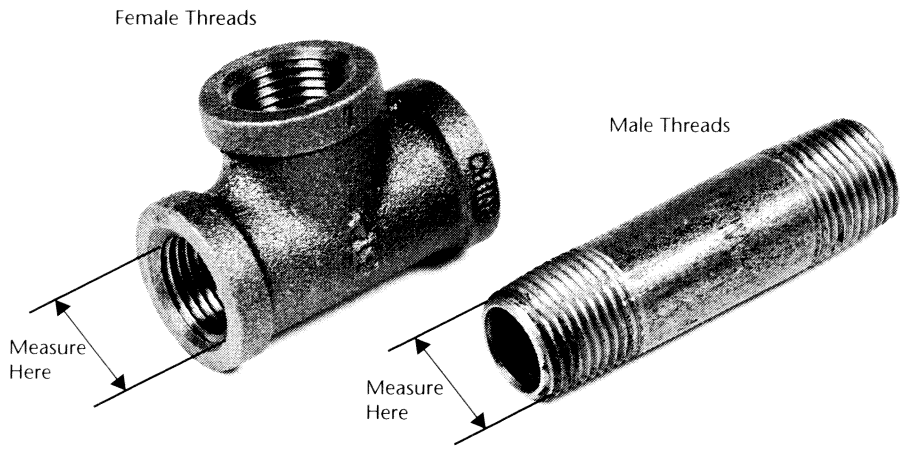


Figure 1. Measuring Pipe

Steel pipe is manufactured either as seamless or with a welded seam along its length. Choice of finishes are either "black" (unfinished) or "galvanized" (zinc coated).

Wall thickness of steel pipe is referred to as "Schedule #" (Figure 2). While there are many schedules available, two are common in this trade: Schedule 40 (standard) and Schedule 80 (extra-strong). Schedule 160 is available in larger sizes but is not commonly used.

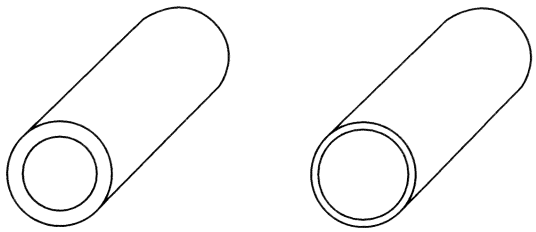


Figure 2. Schedule 80 (LEFT) and Schedule 40 (RIGHT) pipe

NOTES

Nominal Size	Outside Diameter		Threads Per Inch	Wall Thickness		
	Fractional	Decimal		Schedule 40	Schedule 80	Schedule 160
1/16"	5/16"	0.313"	27	-	-	-
1/8"	13/32"	0.405"	27	0.068"	0.095"	-
1/4"	17/32"	0.540"	18	0.088"	0.119"	-
3/8"	11/16"	0.675"	18	0.091"	0.126"	-
1/2"	27/32"	0.840"	14	0.109"	0.147"	0.188"
3/4"	1 1/32"	1.050"	14	0.113"	0.154"	0.219"
1"	1 5/16"	1.315"	11 1/2	0.133"	0.179"	0.250"
1 1/4"	1 21/32"	1.660"	11 1/2	0.140"	0.191"	0.250"
1 1/2"	1 29/32"	1.900"	11 1/2	0.145"	0.200"	0.281"
2"	2 3/8"	2.375"	11 1/2	0.154"	0.218"	0.343"
2 1/2"	2 7/8"	2.875"	8	0.203"	0.276"	0.375"

Table 1. NPT Pipe Dimensions

NPT (National Pipe Thread)

The thread system most frequently used for pipe and pipe fittings is the "American National Standard Taper Pipe Thread" or the "National Pipe Thread" (NPT). NPT connections seal by the flanks of the male and female threads binding together. To create a better seal, the male and female threads are cut on a taper. The taper is slight at 3/4 in. for every foot of thread, but that's enough for the threads to bind tightly after about four rotations by hand. Further tightening with hand tools is required, but you must be careful to not over-tighten and strip the threads. Even a properly tightened NPT connection will leak due to spiral clearance between the crest of one thread and the root of the mating thread. A sealing compound must be used to prevent this leak.

NOTES

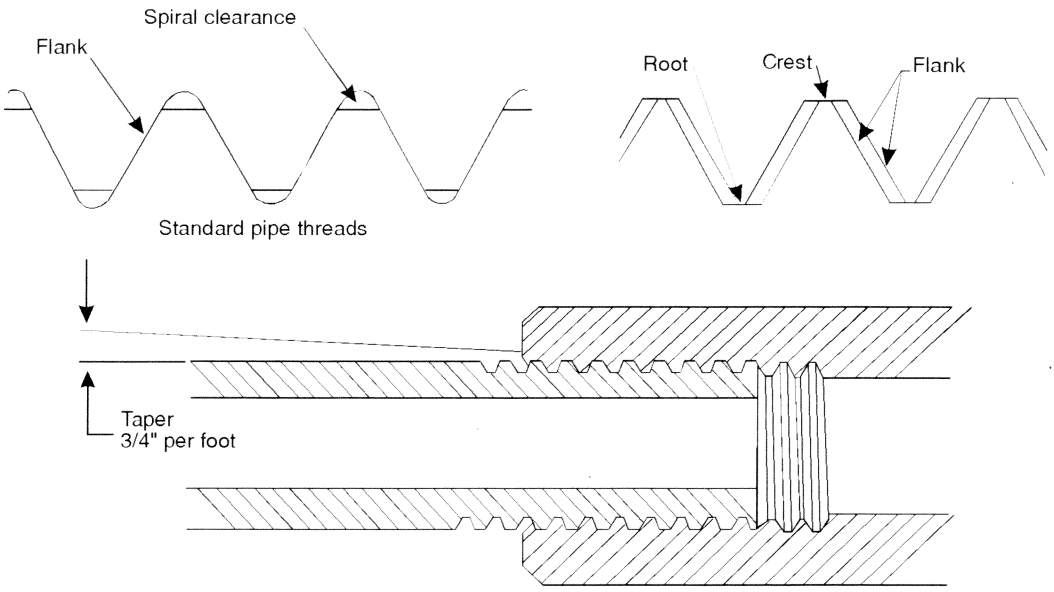


Figure 3. NPT Construction and Sealing

Although NPT is the most common pipe thread in use today, there are other pipe thread systems you may come across:

- **NPTF (National Pipe Thread Fuel)**—thread is cut so root and crest meet before the flanks so spiral leakage is avoided. This still requires the use of a lubricate/sealant during assembly.
- **NPSM (National Pipe Straight Mechanical)**—thread is same as NPT but cut straight, without a taper. The seal is not in the threads but rather in two 30° metal face seats compressed together. No sealant is required.
- **BSPT (British Standard Pipe Taper)**—same sealing as NPT but the threads are different (pitch and angle of thread) and will not mate with NPT thread.
- **BSPP (British Standard Parallel Pipe)**—same sealing as NPSM but thread pitches are different so will not mate to NPSM. Note: BSPP is popular with off-shore equipment but it's used with a special O-ring for sealing.

NPT Steel Fittings

NOTES

NPT pipe fittings permit steel pipe to be joined to other steel pipe or to other types of pipe, tubing, or fixtures. Fittings can be made either of malleable iron (unfinished or galvanized), forged steel, or stainless steel (Figure 4).

Malleable iron fittings are cast then subjected to further treatment so they can deform slightly without cracking (this is important for the threads to seal). Malleable fittings have a rough exterior and should not be used in high-pressure systems.

Forged steel fittings are formed by placing molten steel under pressure to conform to the desired shape then machined to the final product. These fittings are more compact and streamlined than malleable iron fittings and can be used in higher pressure systems.

Stainless steel fittings are forged from molten steel that has low iron content but high nickel and chromium. They are non-magnetic and used in systems where fluid compatibility is a concern.

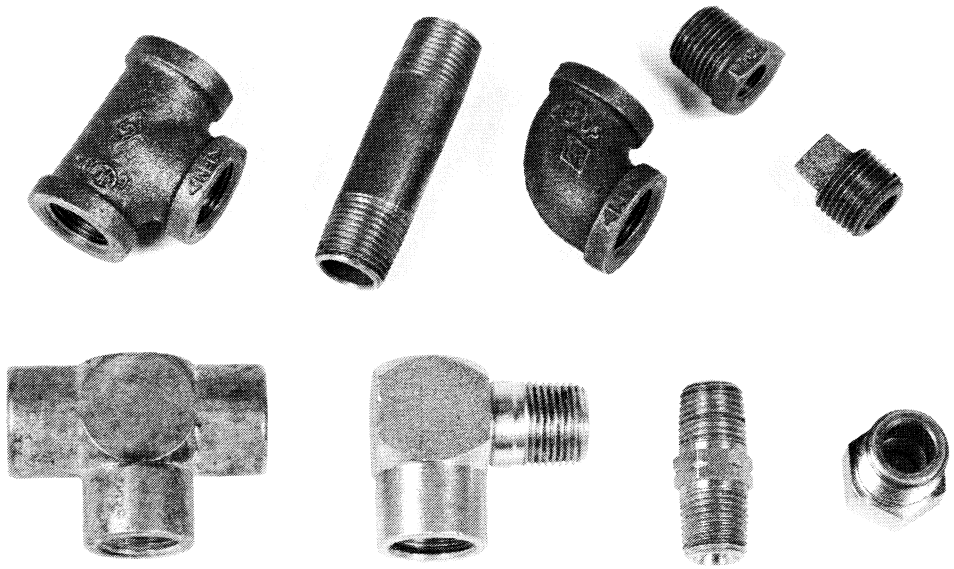


Figure 4. Fittings: Malleable Iron and Forged Steel

NOTES

NPT Fitting Description

NPT fittings are available in a variety of shapes and sizes, each designed for a specific purpose. When ordering fittings, you will have to know size (nominal diameter), schedule (40 or 80), composition (forged steel, brass, etc.), physical description (elbow, cross, etc.) and sometimes length (nipples). Physical description is done by names given to each particular shape of pipe fitting available. It's very important that you know the names of pipe fitting shapes.

Nipples

Nipples are short sections of pipe that have been pre-threaded at each end. They are installed between fittings that are close together and save the effort of cutting threads in short sections of pipe. Nipples are available in a variety of lengths. The shortest has threads touching at the centre and is called a "close nipple." Longer nipples increase in short steps from 13–150 mm (½–6 in.), then in larger steps from 150–300 mm (6–12 in.). Nipples with a large portion of pipe showing between the threaded ends are known as "long nipples" (Figure 5).

Close Nipple Long Nipple

Figure 5. Pipe Nipples

NOTES

Couplings

Couplings are used to join pipe ends or male threaded fittings together to form a straight line (Figure 6). Reducer couplings join fittings of different diameters while maintaining a straight line.

R.H. Coupling Reducer

Figure 6. Pipe Couplings

Bushings

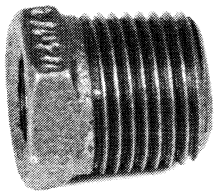


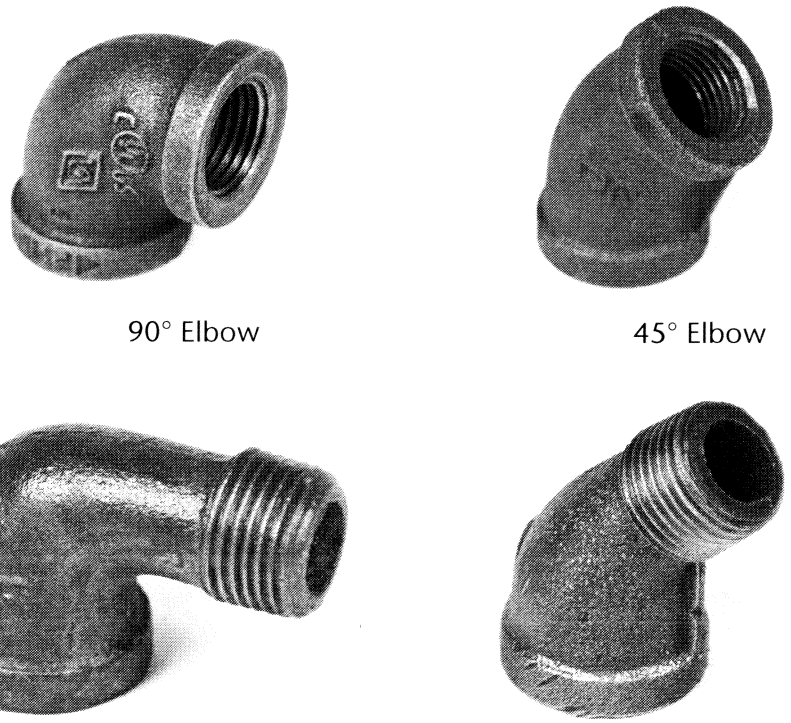
Figure 7. Bushing

Bushings (sometimes referred to as reducer bushings) are made with a male and a female thread that are used to either increase or decrease thread size as needed (Figure 7). For example, if you have a component with a ⅜ in. female thread and a fitting with a ¼ in. male thread, using a ⅜ in. × ¼ in. bushing would allow you to make the connection. Bushings are always listed by the largest size first and smallest size second. (e.g., ¼ in. × ⅛ in.)

NOTES

Elbows

Elbow fittings (Figure 8) are used to join male pipes together and to change the direction of the piping. Elbows are available in 90°, 45°, or 22.5° bends. If the elbow has male threads on one side it's called a "Street Elbow."



90° Elbow

45° Elbow

90° Street Elbow

45° Street Elbow

Figure 8. Pipe Elbows

Tees

Tee fittings have three ports and come in many configurations (Figure 9). A regular tee has three female ports of the same size. A reducer tee will have one smaller port. A service tee will have one male port. A run tee will have two male ports.

Figure 9. Pipe Tee

NOTES

Cross

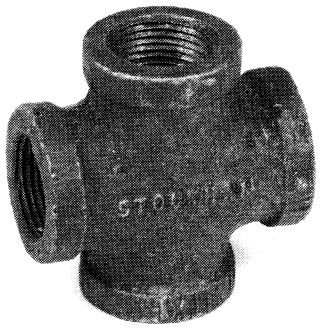


Figure 10. Pipe Cross

A pipe cross has four female threads of the same size (Figure 10). Other fittings will have to be added to change port size or orientation of thread.

Unions

Systems constructed of pipe fittings are rigid in nature. It's difficult to connect two large objects with pipe because the last connection requires spinning one of the objects to wind in the thread for a seal. This is not practical in many applications so a union fitting was designed. It consists of three parts: two halves that have a seal face and female port each, and a nut that joins them together (Figure 11). Each half can be threaded to a section of pipe, then the two halves coupled to form a reliable seal.

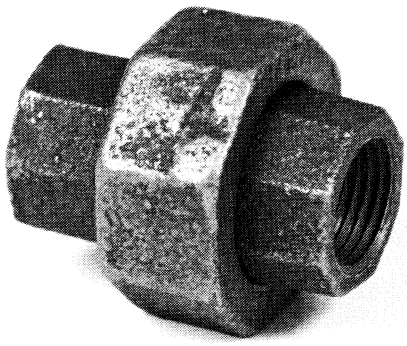
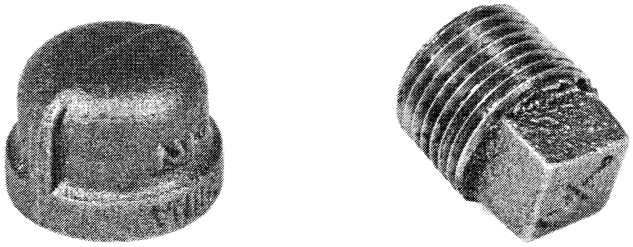


Figure 11. Pipe Union

NOTES

Cap and Plug

To block off the end of a pipe or a fitting, a cap or a plug is used (Figure 12). Caps are designed to fit over male threaded pipe, while plugs fit into female threaded fittings.



Cap Plug

Figure 12. Pipe Cap and Plug

Thread Compounds

Thread compounds are used to seal and lubricate threaded pipe joints. The compound fills the tiny imperfections on the mating thread surfaces so that leaks do not occur. It also acts as a lubricant when assembling pipe fittings and reduces corrosion so assemblies are easier to take apart.

To be effective, a sealant must:

- flow to match the piping thread surfaces
- lubricate to assist assembling
- be non-hardening
- withstand operating temperatures and pressures
- be compatible with the fluid in the pipe
- prevent rust and corrosion

Numerous types of thread compounds are available and a number of them may fit any particular application. Sealing compounds can be paste, liquid, or tape. Pastes are usually brushed on and come in containers or stick form. Liquid sealing compound is squeezed from a tube and tape comes in rolls.

Pipe sealants use either Teflon or graphite in their composition.

NOTES

Teflon Thread Compound

Teflon is the best multi-purpose lubricant and sealer for pipe joints and screwed fittings. Teflon has superior chemical, thermal, electrical, and mechanical properties. It's a tough, flexible, non-toxic, and non-flammable plastic that's chemically inert and weatherproof. The temperature range is -157–260°C (-250–500°F). The pressure tolerance is extremely high as well, reaching as high as 105,000 kPa (15,000 psi). It can be applied to steel, brass, copper, plastic, and aluminum fittings.

Teflon thread compound is made in liquid form or as tape (Figure 13). Teflon tape is widely used because it's simple to use, clean, and extremely effective.

Figure 13. Pipe Sealant—Teflon

Graphite Thread Compound

Graphite is finely flaked carbon that is used in dry form for lubrication and as an additive in oils and greases. As a pipe joint compound, it's used to seal and lubricate threads, flanges, and gasket joints on pipes carrying alkalis, brine, acids, steam, air, gas, hot or cold water, and other substances. Disassembly is easier with this non-hardening thread compound.

Applying Thread Compounds

Whenever thread compounds are to be applied, the male and female threads of the pipe joint must be inspected for damage and cleaned of dirt, excess oil, and burrs.

NOTES

To apply thread compounds, follow these steps:

1. Clean both the external and internal threads with a wire brush.

2. Inspect the threads for damage. Run a tap or a die over the threads to repair them if they are damaged.

3. Apply thread compound to male threads only. Start from the second thread and apply compound to the remaining threads (Figure 14). This will prevent compound from squeezing into the pipe.

4. Start the thread engagement by hand and run it up as far as it will go. Complete the job with a wrench.

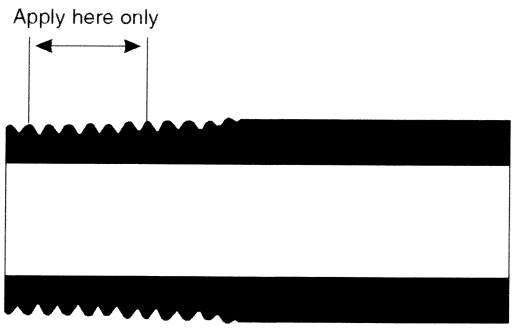


Figure 14. Sealant Location

Teflon tape is applied beginning at the second thread from the pipe end and wrapped in the direction of the threads (clock-wise for right-hand threads) so it will not unravel when the joint is tightened. Spiral wrap the pipe, overlapping half the width of the tape as you go up the pipe. This will give two layers of tape as far as the threads are engaged. Do not over-wrap the fitting thread—too much tape will cause the joint to over-expand.

Tubing

Tubing, like pipe, is commonly manufactured from steel, copper, brass, and plastic. Each type of tubing has qualities making it suitable for specific applications. For example, steel tubing is able to withstand very high pressures, while plastic tubing is more flexible. Tubing size can be designated by its actual outside diameter and is available in metric and imperial sizes. Tubing connections are done through welding, flaring, and compression. They are not threaded.

NOTES

Steel Tubing

Steel tubing is used extensively in locations where high pressures are involved (Figure 15). Most stationary hydraulic lines are made of seamless steel tubing rather than high-pressure hose because it's more compact and lighter. Steel tubing can be damaged by vibrations so it's important to securely mount longer sections.

Hydraulic brake lines are normally made from steel tubing. Brake lines are subjected to high pressures and corrosive conditions so the steel tubing may be double-wrapped, brazed, and tin-plated. The double wall construction gives good strength and makes the tubing easier to bend. The tin plating protects the steel from corrosion.

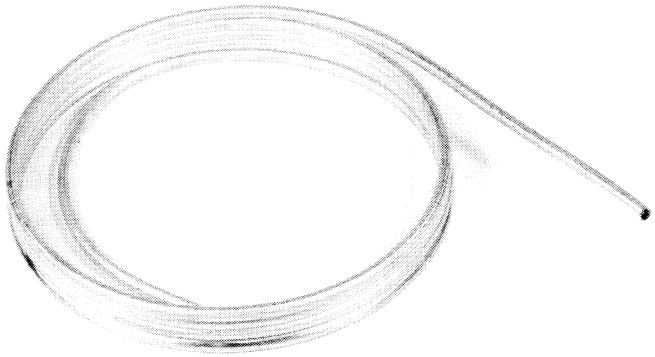


Figure 15. Steel Tubing

Plastic Tubing

Plastic tubing is made from many types of plastics, but the two most common are polyethylene and nylon. Soft plastic tubing has the advantages of flexibility, resistance to corrosion, and resistance to work hardening. Plastic tubing will not withstand excessive heat.

Advancement in plastic tubing construction has allowed smaller sizes to be used in high-pressure hydraulic systems. Plastic tubing has little internal flexing from pressure pulses so it's preferred over traditional rubber reinforced hose for forklifts and man-lifts.

Common uses for plastic tubing include fuel lines, air lines, vacuum lines, and lubrication lines.

NOTES

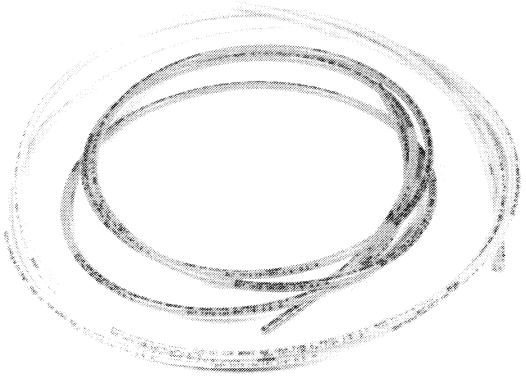


Figure 16. Plastic Tubing

Copper and Brass Tubing

Copper and brass tubing is not widely used in the mechanical repair field.

Copper has been used in the past for air and coolant lines but these have mostly been replaced by lines constructed of other materials. Brake lines are being developed which have high copper content which can withstand high pressures and avoid the problem of corrosion associated with steel brake lines. We may see more copper line in the industry in the coming years.

Tube Fittings

Tube fittings are used to join two or more tubes to each other and to connect tubes to other components. Remember that tubing is made with a consistent outside diameter which plays a large role in achieving a leak-proof seal. Tubing does not use threads to seal so at no time should thread sealing compound be used.

There are a variety of configurations of tube fittings available. Selecting the correct fitting type for the tubing and its application is an important part of your job. Tube fittings can be divided into three groups:

- flare fittings
- compression fittings
- push-in fittings

NOTES

Flare Fittings

Flared fittings are used with steel, copper, and brass tubing. The end of the tube is mechanically forced outwards by a flaring tool to create an angled seat. The fitting that will connect the flared tube has two parts, a body and a nut (Figure 17). The nut of the fitting is slipped over the tubing before flaring and tightened to the body once the flare is complete. As the nut is tightened, it squeezes the angled seat of the tubing to the angled seat of the fitting and makes a leak-proof joint.

The four types of flared fittings are SAE flared tube fittings, inverted flared tube fittings, ISO flare fittings, and JIC flared fittings.

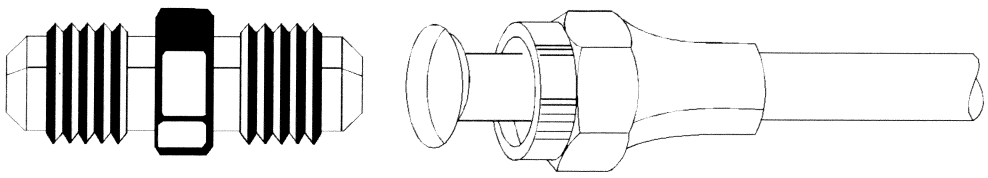


Figure 17. Flared Fitting

SAE Flared Tube Fittings

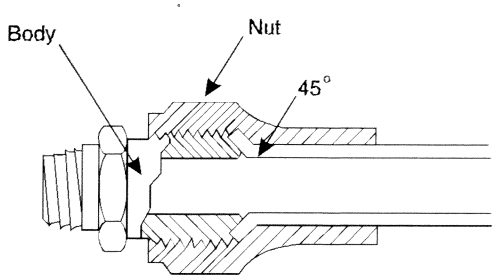
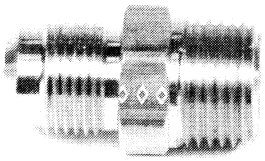


Figure 18. SAE Flare Fitting

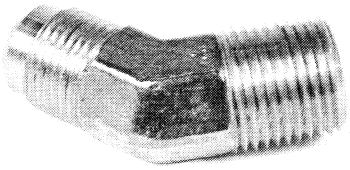
On SAE flared tube fittings, the nut is threaded internally and the body is threaded externally (Figure 18). The body seat is tapered at a 45° angle and the tubing is flared to the same 45° angle. This makes a tight seal and secure joint which will withstand moderate pressures. SAE fittings are normally made of brass.

Figure 19 shows some of the more common available fittings. It's important to know how to properly describe these fittings for ordering purposes. As we are dealing with both tube size and pipe thread size when describing one of these fittings, the order in which they are given must be correct. Industry standard is to use the tube size first, followed by the pipe size. For example, ⅜ in. × ¼ in. straight male connector is a ⅜ in. tube with ¼ in. NPT.

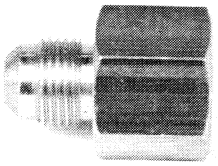
NOTES



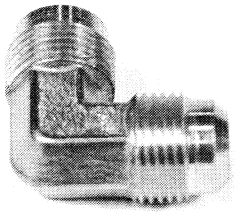
External Thread Connector



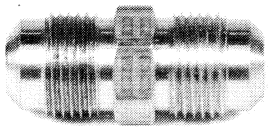
External Thread 45° Elbow



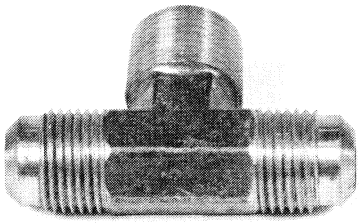
External to Internal Thread Connector



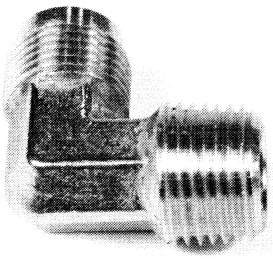
Union Elbow



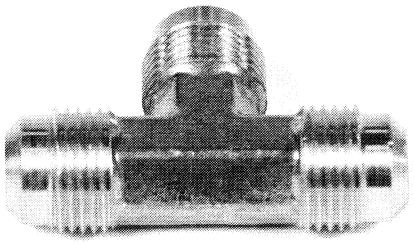
Union



External Thread Tee



External Thread Elbow



External Thread Run Tee

Figure 19. Flared Tube Fittings

NOTES

Inverted Flare Tube Fitting

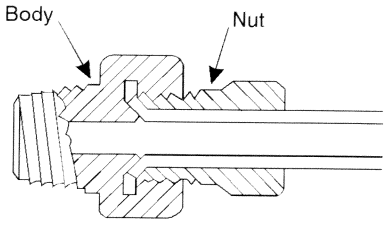


Figure 20. Inverted Flare Fitting

On inverted flared tube fittings, the nut has an external thread and the body component has an internal thread (Figure 20). The nut is placed over the end of the tubing and the tubing is flared to a 45° angle as it was for assembly of the SAE fittings. The method of assembly and sealing is much the same as with SAE flared tube fittings.

Inverted flare fittings are used in hydraulic brakes and power steering systems. In these applications, a double flare must be used. As with the SAE fittings, there are a variety of fitting configurations available.

ISO Flare Tube Fittings

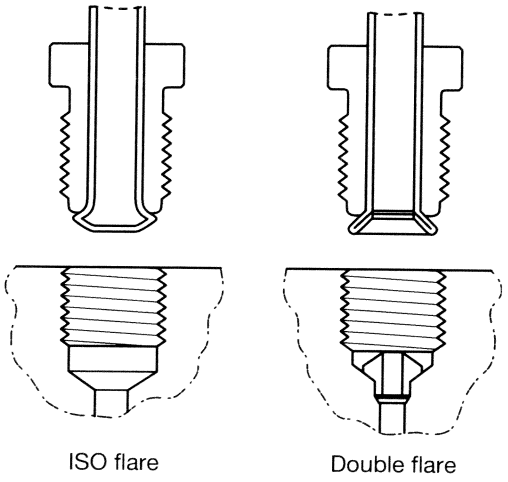


Figure 21. ISO Flare Comparison

A common flare used on metric brake tubing is the ISO or bubble flare. It's similar to the inverted flare but the flare end of the tubing forms a protruding seat which looks like a bubble. The included angle of the seats is 115° ± 2°. Figure 21 shows an ISO flare compared to a SAE double flare. Both use an inverted style nut but the body of the fittings are different.

NOTES

JIC Flared Tube Fittings

The JIC (Joint Industry Conference) flared tube fitting is similar to the SAE type except the angle of the JIC flare is 37°. JIC fittings are used for high-pressure hydraulic fittings and on steel tubing. The reduced angle of the flare reduces the risk of splitting the steel tube at the flare. For very high pressure systems, the steel tubing is not double flared, instead a back up sleeve is used (Figure 22). JIC fittings are the most common fittings used for hydraulic systems. The selection of fittings exceeds that of SAE fittings.

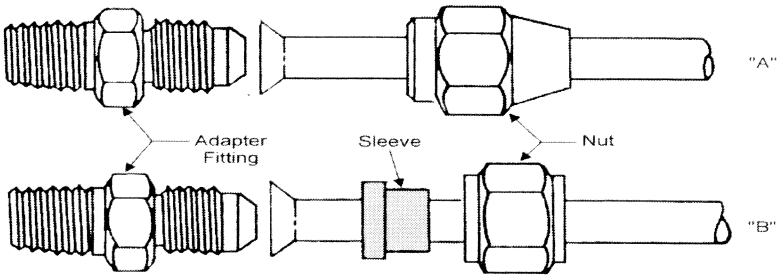


Figure 22. JIC Flared Tube Fitting

Compression Fittings

Compression fittings are used on all types of tubing. Traditionally, compression connections were limited to low-pressure applications but advances in design has seen them being used in high-pressure systems.

Compression fittings for steel, copper, and brass use either a two- or three-piece construction (Figure 23). As the nut is tightened onto the body, the sleeve or ferrule is forced to dig into the outer surface of the tubing. The sleeve is also forced into contact with the body and the seal is created. Reuse is possible but the seal degrades with each loosening and tightening of the fitting.

There are so many different compression systems that it isn't practical to list them. It's important to realize that there is no compatibility between compression fitting types even when they are made by the same manufacturer. The nut, body, and sleeve (if used) are made to work as a unit and must be of the same size and type.

NOTES

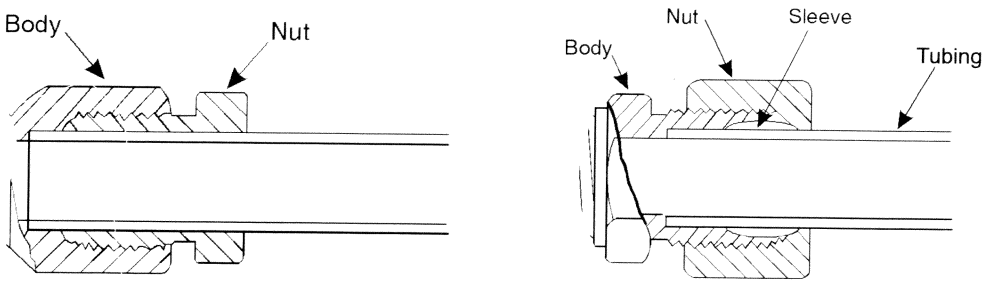


Figure 23. Two- and Three-piece Compression Fittings

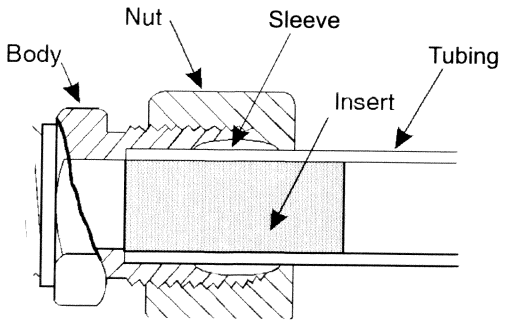


Figure 24. Plastic Tube Compression Fitting

Compression fittings used with plastic tubing normally have an extra part that protrudes into the tubing (Figure 24). This insert prevents the tubing from being crushed when the nut is tightened onto the body of the fitting. All the components must be matched in order for a sealed connection to be made.

Push-in Fittings

Push-in fittings are used with plastic tubing. No special tools are required for assembly or disassembly. The end of the plastic tubing is cut square then pushed into the fitting by hand until it bottoms. The seal is created with either packing or an O-ring on the outside of the tubing. Lock claw or jaws prevent the tubing from coming out. To remove the tubing, push in on the release sleeve which will release the lock claw. The plastic tubing can be pulled out by hand. Both the tubing and fitting can be reused. Corrosion and dirt are reasons for failure of these fittings so make sure they are clean when working on them.

Push-in fittings must have a DOT rating when used in air brake systems.

NOTES

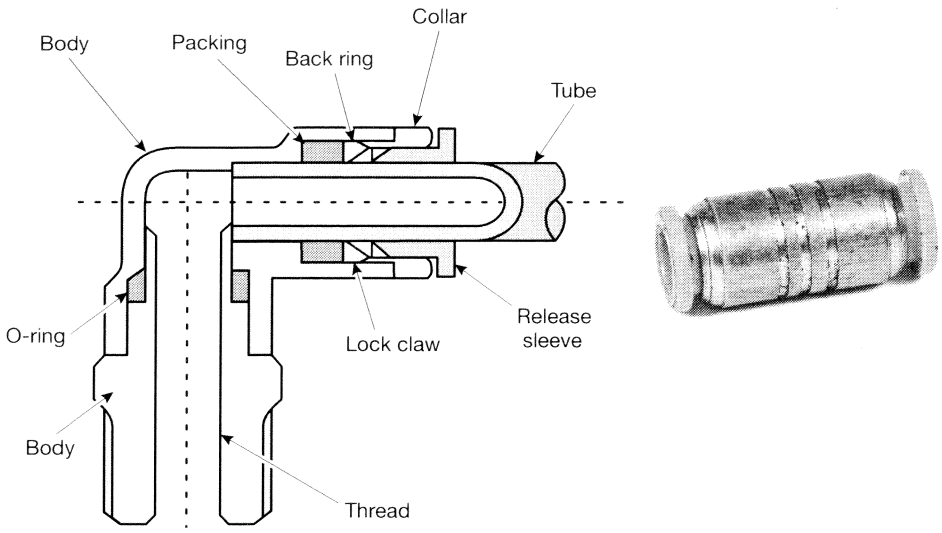


Figure 25. Push-in Fitting

Threading and Assembling Pipe

Most of the pipe-work you'll do as a heavy-duty equipment technician involves fittings and pipe that have already been threaded. For large projects involving considerable amounts of pipe, pipe fitters are usually employed. You may be asked to do some work with pipe so what follows is a general outline of the procedures involved.

Pipe Threading

If you're working with unthreaded pipe, you'll use one of two methods to determine the length of pipe required.

For the first method, you measure from the centre of one fitting to the centre of the next (Figure 26). Then, subtract a fitting allowance for each end of the pipe. The fitting allowance varies depending on the type, the brand, and the size of the fitting.

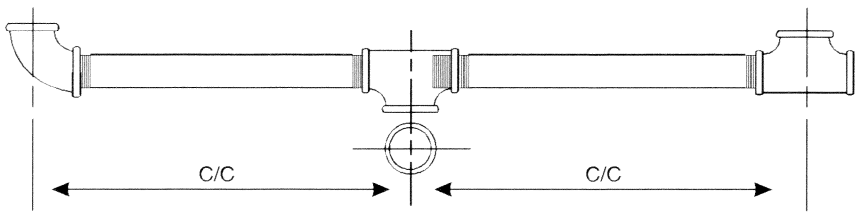


Figure 26. Measuring Pipe for Assembling

NOTES

For the second method, you measure the distance between the two fittings and add the length of the two threaded sections. This method is not as accurate as the centre to centre method.

Once the correct length is determined, pipe can be cut to that length. Metal pipe can be cut with a hacksaw, but is most often cut with a pipe cutter.

Pipe cutters have a thin, hardened steel wheel that scores the pipe as it rotates around the pipe's circumference. Pressure is applied to the cutting wheel by slightly tightening the handle after each rotation. When the cutter wheel has penetrated the pipe's wall, the end of the pipe will be cut perfectly square.

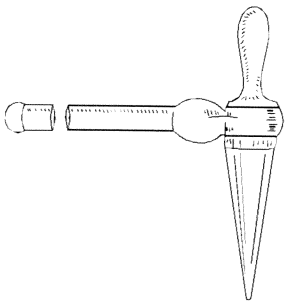


Figure 27. Reamer

Pipes cut with pipe cutters have a slightly burred inside edge. A reamer is used to remove this burr (Figure 27). The reamer is inserted in the end of the pipe and then rotated. The cutting edges cut a slight chamfer on the inside of the pipe, leaving a smooth surface.

The thread cutting process is similar to any external thread cutting except that a special pipe cutting die is required (Figure 28). When cutting pipe threads, run the die onto the pipe until the end of the pipe projects just past the end of the die. Try a fitting on the pipe to see how far it winds on before coming tight. Use cutting oil to prevent the threads from tearing.

NPT internal or female threads can be cut into material using a pipe tap. If the hole is not drilled, you will have to consult a NPT tap drill chart for the correct size drill bit (Table 2). The procedure is similar to tapping bolts threads except you must pay close attention to how far the tap is travelling down the hole. Remove the tap several times to check the thread depth with a fitting. If you tap too shallow, there may not be enough thread engagement to get a proper seal. If you tape too deep, the fitting will bottom out before the threads become tight.

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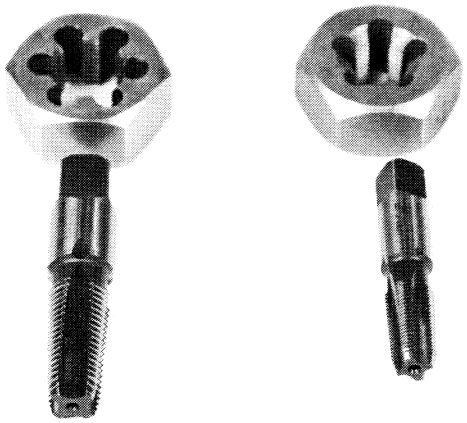

Figure 28. NPT Tap and Die Set

Nominal Size	Tap Drill		Threads Per Inch
	Inches	mm	
1/16	C	6.1	27
1/8	Q	8.8	27
1/4	7/16	11.0	18
3/8	9/16	14.5	18
1/2	45/64	18.0	14
3/4	29/32	23.0	14
1	1 9/64	29.0	11 1/2
1 1/4	1 31/64	38.0	11 1/2
1 1/2	1 47/64	44.0	11 1/2
2	2 13/64	56.0	11 1/2
2 1/2	2 5/8	66.0	8

Table 2. NPT Tap Drill Chart

Tube Cutting, Bending, and Flaring

Cutting Tubing

Plastic tubing should be cut with cutters designed to leave a clean, square end.

Copper, brass, or steel tubing is best cut with a tubing cutter (Figure 29).

NOTES

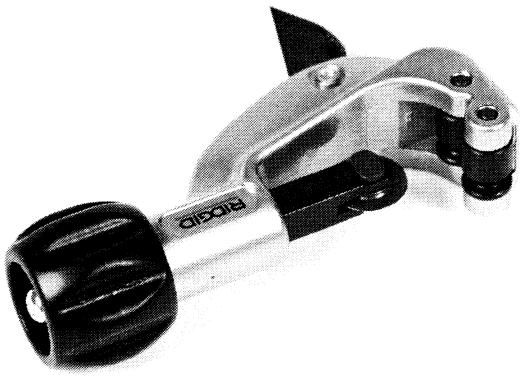

Figure 29. Tubing Cutter

Avoid applying too much pressure on the cutting wheel while it rotates around the tubing. Only a slight amount of tightening is required after each full rotation of the tool. Too much pressure will reduce the outside diameter of the tube near the cut.

As the tubing cutter cuts through the tube, the cutter wheel leaves a burr on the inner surface of the tube. This burr must be removed to provide a smooth inner surface. Smaller tube cutters like the one shown in Figure 30 have a retractable blade reamer that can be used to remove the burr.

Cutting

Reaming

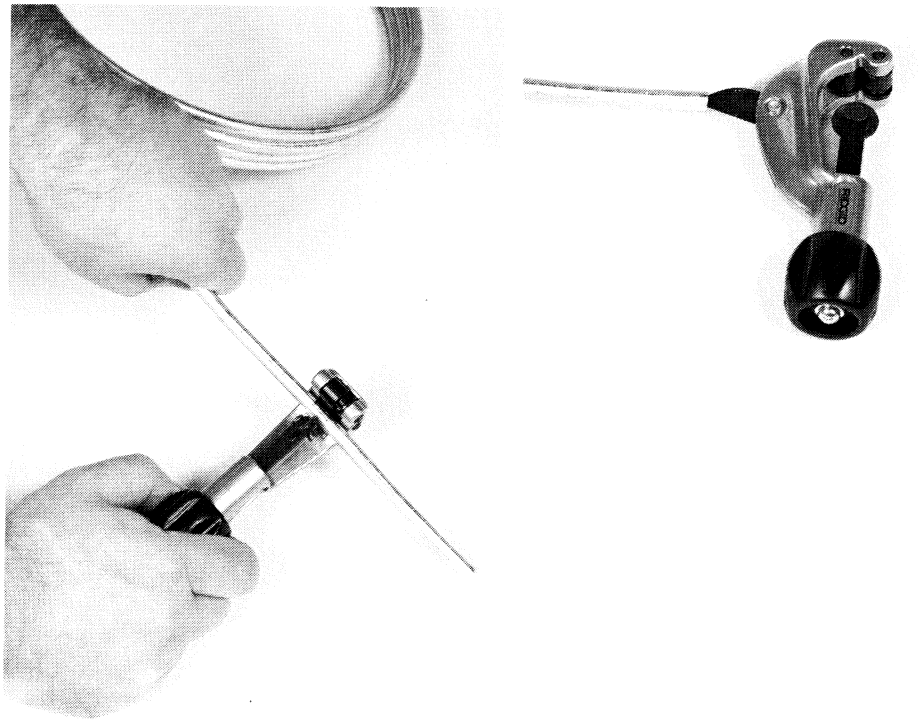

Figure 30. Cutting Tubing
(continued on the next page)

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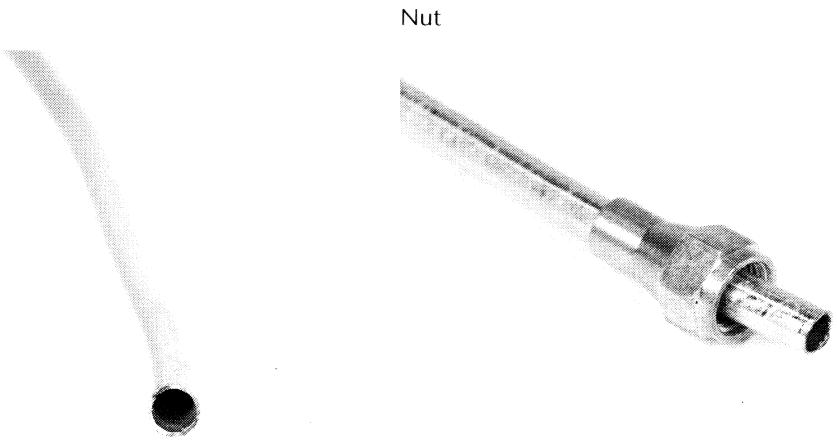


Figure 30. Cutting Tubing

Bending Tubing

Rather than using fittings to change direction, tubing is often bent using a tube bender. There are several types of tube benders available. All are used to bend tubing without kinking. Kinks reduce the inside diameter of the tubing and restrict the ability of the tubing to carry fluids. Two types of tube benders are the bending spring and the lever-type.

Bending springs are used to bend soft copper and thin wall steel tubing (Figure 31). The spring is inserted around the tube as it's bent and helps the tube keep its shape.

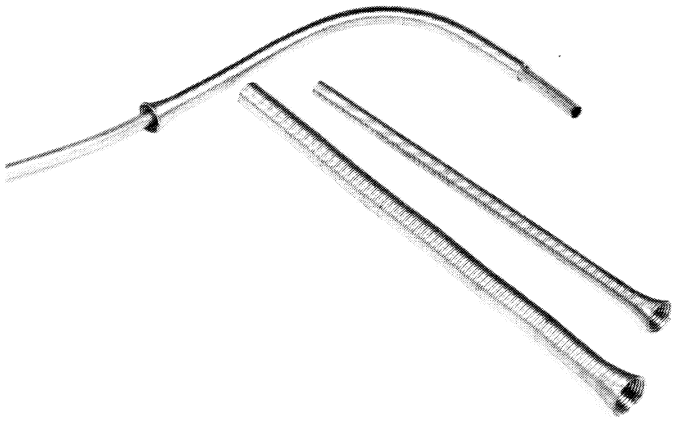


Figure 31. Spring-type Tubing Benders

NOTES

Heavier and stiffer tubing requires the use of a lever-type tube bender (Figure 32). The bender, which looks somewhat like a pair of pliers, is hooked over the tubing and the levers are forced toward each other until the tubing is bent the desired amount. Some lever benders have a scale showing the degree of bend applied to the tubing.

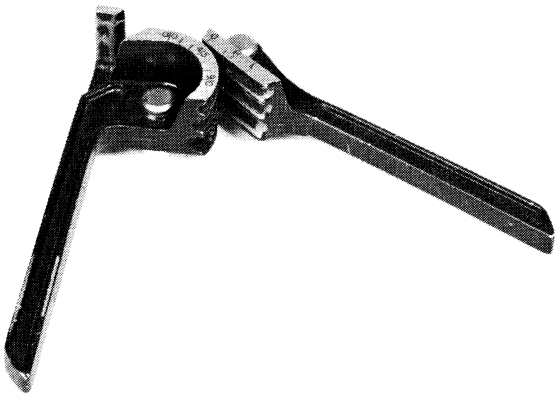


Figure 32. Lever-type Tubing Benders

It's usually advisable to bend tubing before flaring. However, if the bend is going to be close to the flare you should make the flare first so that the bend will not interfere with the flaring tool. The distance between a flare and a bend should never be less than about twice the length of the nut.

Flaring Tubing

A special tool is used to form a flare on tubing. The tool shown in Figure 33 is a common style that forms single flares and, with the addition of special adapters, can form double flares.

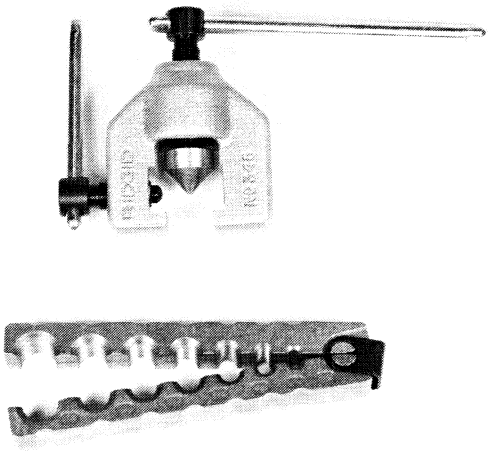


Figure 33. Flaring Tool

NOTES

Single Flare

The single flare is formed on the end of soft copper tubing. Form the flare by following these steps:

1. Make sure the tube end is cut square and smooth. Ream the inside edge and file a slight chamfer to the outside edge.

2. Slide the nuts onto the tubing, making sure they're facing the correct way.

3. Make sure the die plates are right side up with the chamfered sides of the holes facing up. Then place the end of the tubing to be flared in the appropriate opening of the flaring tool so that the end of the tube is just slightly above the surface of the opening in the flaring tool. Tighten the wing nuts to clamp the die bars around the tube.

4. Hook the yoke over the die bars and tighten the flaring cone down on the end of the tubing. Tighten the cone until it's fully seated and the flare is complete.

Double Flare

The double flare is required on steel tubing to prevent splitting of the flare. Double flares are required by regulation on brake lines. Forming double flares requires that a special adapter be added to the flaring tool.

1. Make sure the end of the tubing is cut square and that the inside and outside edges are chamfered.

2. Place all parts of the required fitting onto the tubing.

3. Place the end of the tubing in the correct size opening of the die bars and position the end of the tubing to project above the die bars a distance equal to the thickness of the head of the correct sized adapter (Figure 34). Tighten the wing nuts to make sure the tubing is gripped firmly.

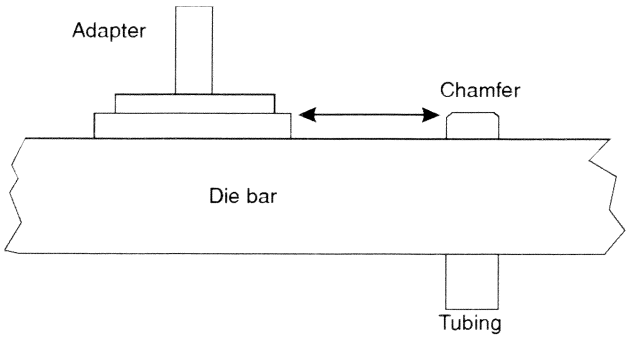


Figure 34. Set Tube Height

NOTES

4. Place the shaft of the adapter inside the tube and mount the yoke on the die bars so that the flaring cone is centred on the adapter.

5. Turn the handle of the yoke until the adapter is flat against the surface of the die bars. This pushes the edges of the tubing inward as shown in Figure 35.

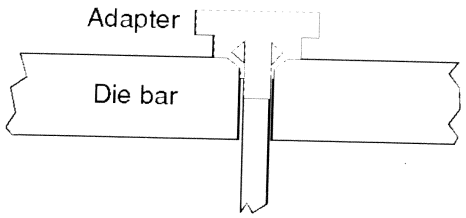


Figure 35. Bottom Adapter on Bar

6. Remove the adapter from the end of the tubing and then place the flaring cone on the end of the tubing. Tighten the cone onto the tubing until it's fully seated and the flare is completed (Figure 36).

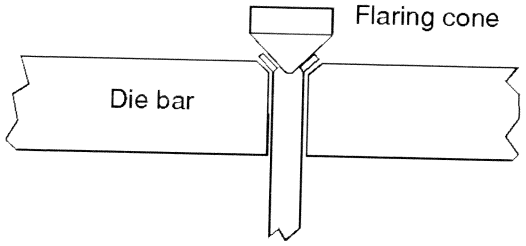


Figure 36. Finish Flare

Avoid the following common faults in flaring:

- crooked flares are caused by a tube that is not cut square
- cracks are caused by forming single flares in brittle tubing
- flares will be too large if the tubing projects too far above the die bars
- flares will be too small if the flaring cone is not fully seated or if the tubing is not projected the correct amount above the die bars
- forgetting to install the nuts, or installing the nuts backwards, requires that you cut off the flare and start again

NOTES

Learning Task 4

Select and Use Hose and Hose Fittings

Industrial Hose

Hose is used extensively throughout the equipment repair industry. From trucks to bulldozers to trains, you will find hoses as part of the mechanical operation of these machines. You need to have a good understanding of the basic construction and application of hoses. There are so many types of hose and related fittings that it's not realistic to expect anyone to know everything about hoses, but you'll find your knowledge will expand as you gain experience repairing equipment.

Hose Construction

Most hoses are formed of several layers of material (Figure 1). The outer layer is the visible part of the hose and can be made from fabric, synthetic rubber, various plastics compositions, or stainless steel braid. The cover is designed to protect the inner layers from mechanical damage, weather, temperature, and harmful chemicals. The next layer is made of reinforcement material embedded with rubber. The reinforcement may be as light as one layer of fabric, to as strong as multiple layers of steel wire. This layer determines how much pressure or vacuum the hose can withstand. The innermost layer or liner of a hose is made of a material that is compatible with the fluid to be carried.

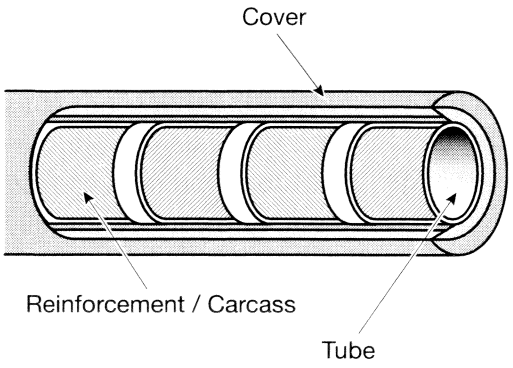


Figure 1. Hose Construction

NOTES

Selecting the correct hose for a particular application requires that you understand the basic construction of hose, including the following:

- material compatibility
- pressure rating
- ability to withstand vacuum
- flexibility
- resistance to abrasion
- hose size

Material Compatibility

The material used to form the inner surface of the hose must be compatible with the fluid that will be flowing inside. For example, diesel fuel will cause rubber to deteriorate. The chemical properties of some fluids can have destructive effects on certain materials. The specifications listed for each type of hose will indicate the substances the hose will tolerate as well as those it cannot.

Pressure Rating

Each different type of hose is designed to withstand a specific range of pressures. Hoses made of the same materials may have different pressure ratings depending on their construction. The pressure ratings are listed as "maximum working pressure" and are given in bar (one atmosphere of pressure) or pounds per square inch (psi). Figure 2 shows several different hose construction designs used to achieve different pressure ratings. Hydraulic hose may be required to withstand 5000 psi or more.

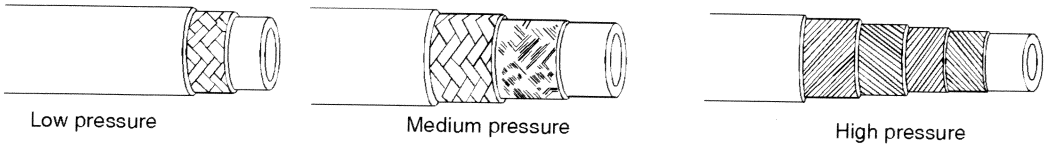


Figure 2. Hoses for Different Pressures

Hose diameter also has an effect on the amount of pressure a hose will withstand. Large hose will withstand less pressure than small hose of the same construction. For example, a ¼ in. medium-pressure hose has a maximum working pressure of 210 bar (3000 psi) while a 2 in. medium-pressure hose has a maximum working pressure of only 24 bar (350 psi).

NOTES

Ability to Withstand Vacuum

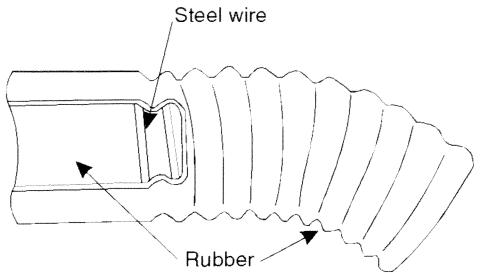


Figure 3. Hose with Steel Wire Coil

Hoses used as "suction hoses" must be able to withstand vacuum (pressures less than atmospheric pressure). To prevent the hose from collapsing, a steel wire coil is incorporated on the inside of the hose. The steel coil provides the hose wall with the resistance to prevent collapse and allows the hose to be bent without kinking. Figure 3 illustrates such a hose.

Thick side walls allow hoses that are not required to bend to withstand negative pressures without collapsing.

When you're selecting a hose, make sure you know the pressures it will be required to withstand and choose a hose that matches or exceeds that pressure.

Flexibility

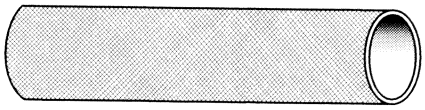
The "stiffness" of a hose has a direct bearing on its ability to withstand repeated bending. Hoses that are stiff are less able to withstand repeated bending than soft, pliable hoses. The materials used to manufacture the hose and the number of reinforcement layers in the hose affects its stiffness. Usually, hoses able to withstand high pressures are stiffer than low-pressure hoses.

Resistance to Abrasion

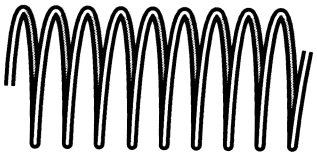
There are several methods used to improve the abrasion resistance of a hose. Some have a fabric exterior bonded to their outer surface, others have a braided wire for an outer covering. Most hoses are able to tolerate some abrasion with an outer layer of synthetic rubber. Protective hose wrap is available for applications where the hose cover is not sufficient. These protective wraps may be made of nylon fabric, hard plastic, or steel wire (Figure 4). Some have to be put over the hose before installation, whereas others can be wrapped around a hose that's already attached to a machine.

NOTES

Plastic spring guard



Textile / Nylon Sleeving



Metal spring guard

Figure 4. Hose Protection

Hose Size

Hose size always refers to the nominal inside diameter of the hose. Several ways are used to express the size of a hose. When ordering hose or reading the outside hose cover, use the "dash number" system. The dash number refers to the hose size in 16ths of an inch and is expressed as a dash (-) followed by a number. For example, a ½ inch hose is 8/16 of an inch and so it is referred to as "dash 8" (-8) hose. Table 1 shows several examples of hose sizes and their dash designations.

When talking about hose, it's often called by its fractional size ("I need a ½ in. hose") or by the dash number ("I need a number 4 hose").

Nominal ID	Dash Number
3/16 in.	-3
1/4 in.	-4
5/16 in.	-5
3/8 in.	-6
1/2 in.	-8
5/8 in.	-10
3/4 in.	-12
1 in.	-16
1 1/4 in.	-20
1 1/2 in.	-24

Table 1. Hose Sizes

NOTES

Determining hose size is not normally done by measuring the inner diameter. The most accurate method is to find the hose size in a parts manual. We can sometimes find the dash number on the hose cover but be sure to not use any fractional numbers found on the cover. If the cover is not marked or the numbers have rubbed off, then you can try to determine the hose size by the size of the hose fittings.

Figure 5 shows the marking on the cover of a hose made by Weatherhead. The "GH781" indicates pressure rating, liner composition, cover material, bend radius, etc. The "8" at the end indicates size so this is a -8 hose (or "number 8" or ½ in.).

Figure 5. Hose Markings

Hose Fittings

Hose fittings provide a method of connecting the end of a hose to a component or to another hose. There are several methods of joining the fitting to the end of the hose. Some types of fittings can be reused while others, such as crimp-on, are designed to be discarded with the worn-out hose. Push-on and reusable hose fittings will be discussed here and the crimp-on or swaged will be covered in the hydraulic section of Competency C-3: Service Hydraulic Components.

Push-on Hose Fittings

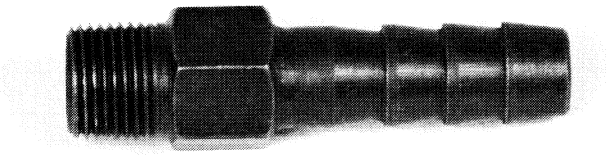


Figure 6. Push-on Fitting

The method used to attach the fitting to the hose depends on the pressure the hose and fitting are required to withstand. Low-pressure systems can use a push-on fitting as shown in Figure 6. Push-on fittings have a barbed stem that is inserted into the hose end.

NOTES

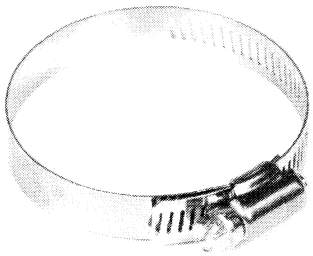


Figure 7. Hose Clamp

The fitting can be made more secure with the addition of a hose clamp. Hose clamps are available in several forms, but the screw-type shown in Figure 7 is popular because it can be reused.

Reusable Hose Fittings

Low- and medium-pressure hoses can use a two-piece reusable fitting that's also called a field attachable coupling. This type of fitting consists of a socket and nipple arrangement (Figure 8) that can be attached to the hose with common hand tools.

The socket component has a smooth hexagonal exterior while the interior of the wider portion receives the hose and has coarse shallow left-hand threads to grip it. The narrower end receives the nipple component and has right-hand threads.

The nipple consists of a long threaded section, a hexagonal nut for tightening, and a shorter threaded section or swivel nut to attach to another fitting. The long threaded portion of the nipple has a smooth and tapered section at its end.

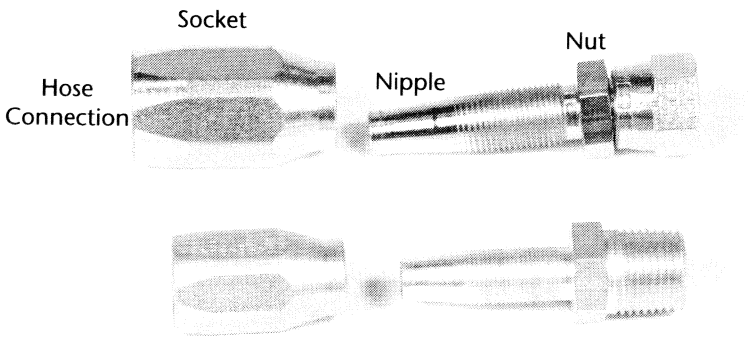


Figure 8. Reusable Hose Fitting

NOTES

To attach the fitting to the hose, the socket is threaded onto the hose in a left-hand direction. The smooth, tapered end of the nipple is inserted into the hose inside the socket and the right-hand threads are engaged. As the nut is tightened, the nipple is drawn into the socket and forced into the hose. The nipple expands the hose and presses it into the coarse threads of the socket. The procedure will be discussed in more detail in the Hose Assembly section of Competency C-2: Service Hydraulic Components.

Medium-pressure hose has one reinforcement layer of braided steel wire. The fitting to be used is shown in Figure 8. For best results, use the hose and fitting made by the same manufacturer.

High-pressure hose has two reinforcement layers of braided steel wire. The fittings to be used with this type of hose are identified by notches on the exterior of the socket (Figure 9). Their basic design is similar to the medium-pressure fitting except that the threads on the inside of the socket are coarser and are designed to bite into the wire mesh reinforcing layer on the hose. The cover near the end of the hose needs to be removed (called skiving) to allow the socket to grip directly onto the wire reinforcement.

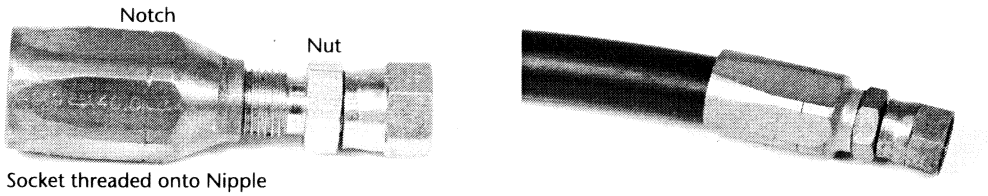


Figure 9. High-pressure Fitting

Calling a two-wire reusable hose fitting a high-pressure fitting is over-stating the pressure capacity of this type of fitting. In the past, a system working at 3000 psi (204 bar) would have been considered a high-pressure system. Today, systems can reach twice that much pressure and more. Hose is made with four-wire and six-wire construction to handle these new high-pressure systems. Reusable fittings would be blown off the end of the hose as soon as the system starts to work. Knowing how dangerous this can be for anyone working close to equipment, you must use good judgement when replacing a hose. There is a strong movement away from reusable hose fittings because of the danger involved with them.

NOTES

Crimp-on Hose Fittings

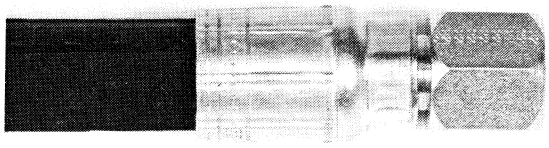


Figure 10. Crimp-on Fitting

Crimp-on (or swaged) hose fittings are a permanent type of fitting that is discarded when the hose fails. These fittings are attached to hoses by crimping (swaging) with the use of a hose press specifically designed for this one purpose. The popularity of this type of reliable fittings has lead manufacturers to make their hose presses very compact so many of them can be taken into the field if required. Crimp-on hose fittings have almost eliminated the use of reusable hose fittings. Figure 10 illustrates a permanent crimp-on hose fitting.

Note: There is one manufacturer of reusable crimp-on fittings which is very specialized (special hose press and tooling) so it's not used except on their equipment.

Hose Fitting Connections

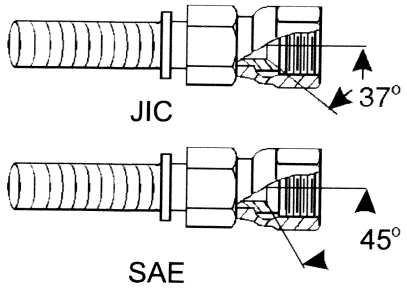


Figure 11. SAE and JIC Fittings

The part of the hose fitting that couples to the hose is only half the story when discussing these fittings. There needs to be a means of coupling this hose fitting to a component or another hose. Common types of threaded fitting are NPT (usually male pipe), SAE, JIC (usually female), and ORFS (which will be discussed in the hydraulic section of Competency C-3: Service Hydraulic Components). It's also possible to couple hose using a few types of flange fittings or many styles of quick-disconnect fittings.

NOTES

Hose Assembling Procedures

The following outlines of hose assembling procedures are general in nature. You should always consult the manufacturer's procedures for specific instructions.

Push-on Hose

Push-on hose fittings use a barbed insert to secure the fitting on the end of the hose.

The procedure to install push-on hose fittings is as follows:

1. Cut the hose to length. Make sure the end is cut square.

2. Clamp the fitting in a mechanic's bench vise with the barbed end of the fitting projecting past the side of the vise (Figure 12).

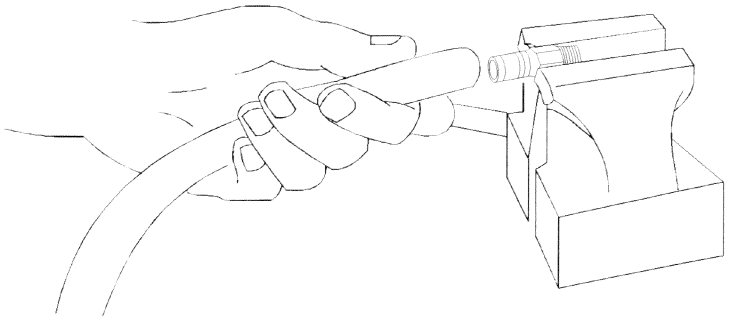


Figure 12. Installing Push-on Hose Fitting

3. Apply a liberal coating of suitable lubricant to the inside of the hose end and to the barbed nipple of the fitting.

4. Push the hose end on the fitting as far as possible. The end of the hose should be up against the flaring on the fitting.

Push-on hose fittings can be made even more secure by adding a hose clamp to the part of the hose that fits over the barbed stem. Place the clamp at the approximate centre of the barbed stem and tighten.

NOTES

Push-on hose fittings are reusable. Removing a fitting is done in the following manner:

1. Remove the hose clamp.

2. Secure the fitting in a vise. Cut a slit in the hose along the length of the barbed nipple (Figure 13).

3. Bend the hose away from the slit and give it a sharp pull to tear it off the nipple. Clean off any pieces of hose left on the nipple's barbs.

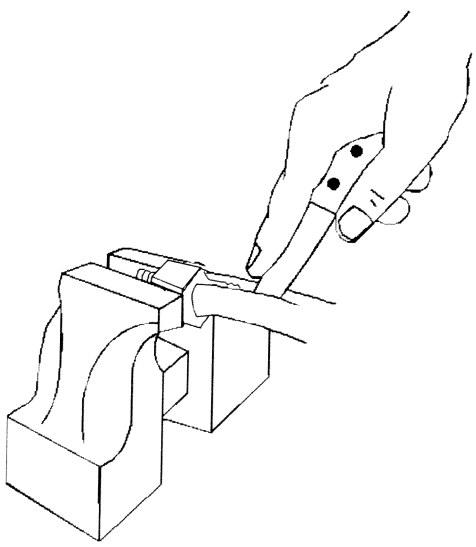


Figure 13. Removing a Push-on Fitting

Reusable Hose Fitting—Medium-pressure

The procedure for installing this type of fitting is as follows:

1. Cut the hose to length with a fine-toothed hacksaw, chop saw, or hose cutter. (Medium-pressure hoses have a layer of braided wire that cannot be cut with a knife.)

2. Select the proper size socket for the diameter of hose. Secure the hose in a vise with four to six inches protruding from the jaws. Tighten the vice only enough to prevent the hose from spinning, tightening too much may damage the hose. Screw the fitting socket counter-clockwise onto the hose until it bottoms, then turn it clockwise a quarter turn (remember it's left-hand thread).

3. Clamp the socket in the vise (again not too tight) so that the end of the hose is accessible through the end of the socket.

4. Apply a coating of hose assembly lube to the inside of the hose and on the section of the nipple that fits inside the hose. Anti-seize lubricant on the threads of the nipple aid in assembly and disassembly (if ever needed).

Do not use oil or grease as a lubricant for hoses that are going to carry oxygen, as this could cause an explosion.

5. Screw the nipple clockwise into the hose until the flange reaches the socket. If the nipple doesn't have a hex drive on it, you will have to jam an appropriate fitting into it to be able to turn the nipple into the socket.

NOTES

Reusable Hose Fitting—High-pressure

Installing high-pressure hose fittings is very similar to the procedures used with medium-pressure hoses. The socket part of this hose fitting will have notches formed on the outside of the socket. These notches not only serve to help identify the fitting as a high-pressure fitting, but are also used to indicate the length of the hose cover to be removed (skiving) at the end of the hose. Note that not all high-pressure hose needs to be skived to install fittings.

To install socket and nipple fittings to high-pressure hoses, follow these procedures:

1. Cut the hose to length with a hacksaw, chop saw, or hose cutter. Use a skiving tool or knife to remove the cover around the hose down to the metal wire reinforcement. The length of the skiving should be equal to the distance from the end of the socket to the notches as shown in Figure 14.

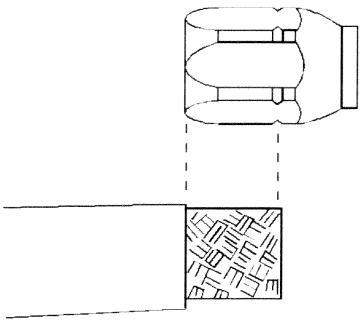


Figure 14. Correct Skiving Length

2. Use a wire brush or soft wire wheel to clean the wire reinforcement. Be careful not to damage the wire.

3. Secure the hose as mentioned previously and screw the socket counter-clockwise onto the hose. Back the hose off a quarter turn after it has bottomed.

4. Lubricate and insert the nipple into the end of the hose in the same manner as for medium-pressure hose fittings.

Removing reusable fittings from hose is the reverse of installing the fittings. Once the fittings are removed, ensure that any hose residue is cleaned off the threads.

Crimp-on Fittings

Crimp-on hose fittings are installed by using a special hose press specifically designed by the manufacturer of the hose and fitting you're dealing with. Consult the manufacturer's procedure for operating their hose press. A trained individual will make the operation of a hose press look simple, but do not be tempted to try it on your own without training. Personal injury or damage to an expensive piece of equipment may result.

NOTES

Quiz A-5

1. Which statement is the best description of a fastener's thread pitch?

   a. angle of the thread flanks
   b. distance between adjacent threads
   c. depth of the thread groove
   d. thread slope in relation to the axis of the bolt

2. Three measurements are commonly used to identify bolt size. One measurement is thread pitch, what are the other two?

   a. thread diameter and thread length
   b. bolt shank diameter and bolt head size
   c. bolt shank diameter and penetration length
   d. crest diameter and root diameter

3. What is the name of a threaded fastener that is used with a nut?

   a. bolt
   b. screw
   c. cap screw
   d. stover

4. Which of the following describes the function of a Stover nut?

   a. it is used as a jam nut
   b. it is used with stove bolts
   c. it is a type of castellated nut
   d. it is a type of self-locking nut

5. What is the grade of the bolt in Figure X?

   a. Grade 2
   b. Grade 6
   c. Grade 8
   d. Grade 12

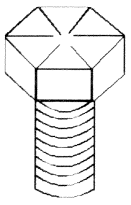


Figure X.

6. What is a thread gauge is used for?

   a. measure thread angle
   b. measure thread pitch
   c. measure thread diameter
   d. measure the slope of the thread faces

7. Which washer prevents a nut from coming loose?

   a. plain washer
   b. flat washer
   c. Woodruff® washer
   d. split-ring washer

8. What prevents a castellated or slotted nut from turning on its bolt?

   a. friction
   b. its oval shape
   c. a cotter pin
   d. a hitch pin clip

9. Which pin is used to align machinery parts during assembly?

   a. dowel pin
   b. shear pin
   c. clevis pin
   d. snap lock pin

10. Which fastener is commonly used to securing a gear or pulley to a shaft?

    a. cotter pin
    b. key
    c. spring pin
    d. rivets

11. Which type of tap should be used first when cutting bolt threads?

    a. bottoming
    b. taper
    c. plug
    d. starter

12. When cutting threads, for which material is lubrication not recommended?

    a. mild steel
    b. bronze
    c. cast iron
    d. aluminium

13. Which tool is used for turning smaller size taps?

    a. T-type wrench
    b. flex bar
    c. nut-driver screwdriver
    d. ratchet

14. How should a die be used when cutting threads?

    a. cut the complete thread in one pass
    b. cut a shallow thread first
    c. cut the threads as you turn it backwards
    d. use lubricant for the final pass only

15. What is the purpose of the tool illustrated in Figure Y?

    a. break the tangs on Heli-Coils®
    b. removes broken taps
    c. cleans the flutes of taps
    d. measures the diameter of threaded holes

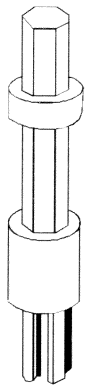


Figure Y.

16. What is used to repair damaged external threads of a bolt?

    a. a thread tap
    b. a thread chaser
    c. a stud extractor
    d. a Heli-Coil®

17. Which procedure is used to bring damaged internal threads back to their original size?

    a. install a Heli-Coil®
    b. weld then re-tap the hole
    c. press in a new thread
    d. use a thread file

18. Which tool is used to remove a cap screw that is broken off flush to the surface of its threaded hole?

    a. a screwdriver
    b. a wrench
    c. vice grip pliers
    d. a stud extractor

19. If rust is the cause of a seized threaded fastener, how may you be able to free it?

    a. apply dry ice to it
    b. soak it in penetrating oil
    c. strike it with a hammer repeatedly
    d. spray heavy weight oil on it

20. Which measurement is the same for steel pipe nipples of the same nominal size but of different schedules?

    a. inside diameter
    b. outside diameter
    c. pressure rating
    d. wall thickness

21. Which schedule is standard steel pipe?

    a. Schedule 10
    b. Schedule 40
    c. Schedule 80
    d. Schedule 160

22. To run a branch line off a piping line, which fitting would you use?

    a. a coupler
    b. a union
    c. a tee
    d. an elbow

23. Which fitting is used to block off the end of a pipe nipple?

    a. a cap
    b. a plug
    c. an elbow
    d. a reducer

24. Which operating condition damages plastic tubing?

a. high vibrations
b. low pressures
c. low temperatures
d. high temperatures

25. On which component is the external threads of an inverted flare tube fitting located?

a. on the body
b. on the nut
c. on the sleeve
d. in the tube

26. Which requirement is followed when compression fittings are used with plastic tubing?

a. the tubing is pre-heated
b. the tubing is flared
c. the fitting has an internal sleeve
d. the fitting threads are wrapped with Teflon tape

27. What are two commonly used types of flares formed on tubing?

a. open and closed
b. soft and hard
c. single and double
d. inverted and plain

28. What is the distance tubing should project above the die bar when you are going to form a double flare?

a. just slightly above the die bar
b. the thickness of the adapter head
c. half the diameter of the tube
d. depends on the tube wall thickness

29. What does the number -12 stamped on the side of a hydraulic hose indicate?

a. it is 12 millimetres in diameter
b. it is 12 layers thick
c. it has an inside diameter of ¾ inch
d. it is able to withstand 12 psi of pressure

30. How are push-on hose fittings made more secure?

a. use sealant on the fitting
b. place a dry lubricant on the fitting
c. apply solvent to the inside of the hose
d. install a hose clamp over the connection

31. How is a vise used when installing a push-on fitting into a hose?

a. it secures the hose
b. it is a guide for cutting the hose
c. it clamps the fitting
d. it tightens the hose clamp

32. Which procedure is used to remove a push-on fitting from the end of a hose?

a. pull the hose straight off the fitting
b. slit the hose and then pull sideways on it
c. soften the hose in hot water then remove
d. grind the hose off the nipple

33. Which procedure is used when assembling a medium-pressure reusable fitting onto a hose?

a. soften the hose end with heat
b. rotate the socket counter-clockwise onto the hose
c. attach the nipple into the hose then the socket
d. turn the hose clockwise into the socket

34. What do the notches indicate on high-pressure hose fittings?

a. the wrench size needed
b. which direction to tighten the fitting
c. the length of the skive required
d. the diameter of hose to use

COMPETENCY A-6

Lift and Support Loads

HEAVY MECHANICAL TRADES:
LINE A—COMMON OCCUPATIONAL SKILLS

Goals

You need to know the safe and correct procedures for using lifting and hoisting equipment so that you will be able to protect both yourself and your co-workers from danger.

When you have completed the Learning Tasks in this Competency, you will be able to:

- apply the Occupational Health and Safety Regulations
- determine load weight
- select, use, and maintain jacks
- select, use, and maintain stands and blocking
- select, use, and maintain wire ropes, chains, and lifting straps
- use fibre rope knots, bends, and hitches
- use visual and sound signals
- select, use, and maintain hoisting equipment
- lift, hoist, and move loads

Learning Task 1

Occupational Health and Safety Regulations

Whenever you're handling materials, remember that you're responsible for your own safety and for the safety of others. The best form of personal protection is to stay alert.

Each circumstance will require you to take different precautions. The following are the minimum safety requirements in any situation.

Personal Protection

Wear a CSA-approved safety hat at all times, especially if there is any risk of falling objects or of receiving a bump to your head.

If the materials you're handling could injure your hands, wear gloves for protection. Gloves should have short cuffs. Gauntlet-type gloves are not safe because the cuffs tend to catch on projections and also funnel dirt and small objects into the glove. If you're handling corrosive or irritating chemicals, wear rubber gloves to prevent skin contact.

When working with materials that are rough and abrasive, wear a protective apron to protect your clothing.

Protect your feet with CSA-approved safety boots that have steel toes and steel insoles (if protruding nails are a hazard).

Always wear CSA-approved eye protection in the form of safety glasses or safety goggles.

Clothing

The clothing you wear should protect you from dirt, cuts, and abrasions. Your clothing should be loose enough to allow free movement, yet not so loose that it poses a danger of getting caught on or in any materials or equipment. Do not wear any jewelry. Tie long or loose hair back and tuck it under a hat or hair net.

NOTES

NOTES

Housekeeping

Your job site housekeeping habits can make material handling safe or dangerous. Keep all traffic areas clear to prevent tripping. Clean up spills immediately to prevent slipping and falling.

Safe Lifting and Carrying

The prevention of back injuries is very important. Follow these basic safe lifting and carrying procedures:

- Always wear good supportive and well-fitting footwear.
- Determine the weight of the load before attempting a lift. If the load is too heavy, get help or use a machine to make the lift.
- Do not try to lift loads that are extremely bulky or awkward. Get help with large, poorly balanced loads.
- Bend at the knees. Do not stoop or bend your back when attempting a lift. Keep your back in a vertical position.
- Place your feet about shoulder-width apart and, if possible, have one foot at the side of the load to be lifted and the other foot behind the load.
- Keep the load as close to your body as possible during the entire lifting and carrying process. Holding a load away from your body puts a tremendous strain on your lower back.
- Do not twist your body while you're supporting a load. To change direction, shift your feet and turn your entire body.
- When lowering a load, bend your knees. Keep your back straight and vertical.

Safe Handling of Loads Supported by Cranes

When using slings to attach a load to a crane, be sure the load is balanced and secure. When the crane begins to take up the slack, keep clear of the load because it could shift and trap you. Be especially careful to avoid getting your fingers caught between the load and the slings. If you must apply a sideways force to a suspended load, always push the load away from you (Figure 1).

NOTES

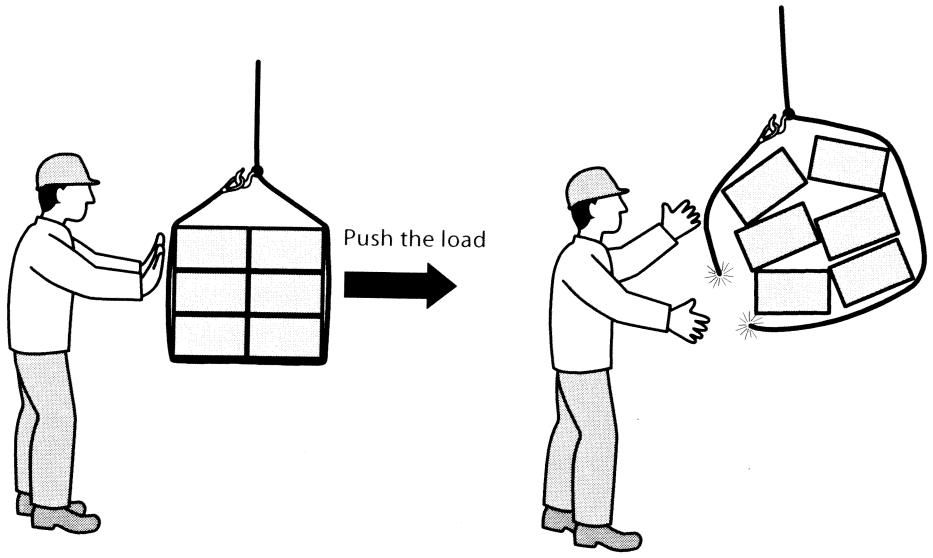


Figure 1. Push a Load

Pulling a suspended load could result in back strain or, much worse, entrapment should the load come loose (Figure 2).

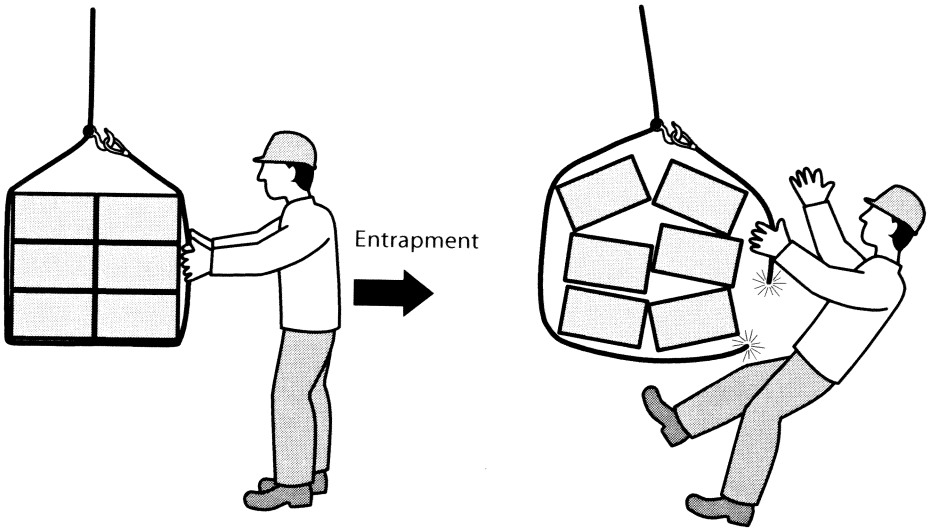


Figure 2. Never Pull a Load

Loads that cannot be adequately controlled must have tag lines attached (Figure 3). Tag lines are usually used when the load is out of reach. Tag lines are necessary in windy conditions. Windy conditions can become so bad that all hoisting operations may be stopped until your supervisor decides it is safe again.

NOTES

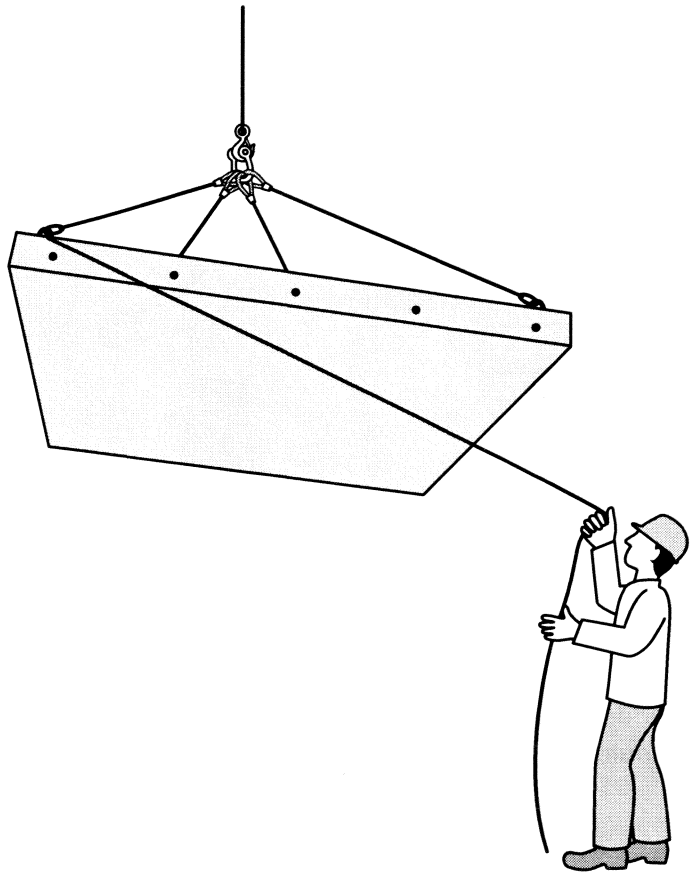


Figure 3. Using Tag Lines

You should be familiar with the standard signals used in hoisting operations so that even if you're not directly involved, you can anticipate the movement of the load. These signals are covered later in this Learning Task.

The Occupational Health and Safety (OHS) Regulation on the WorkSafeBC website is a great resource to keep you informed and up-to-date on information regarding lifting and hoisting procedures:

CAUTION:

- Never work under a suspended load.
- Never move a load over fellow workers. If you must lift a load over their location, tell them they must move out of the way first.
- You should anticipate the danger to yourself in the event a suspended load were to drop. You should mentally prepare a plan of action, including an escape route to safety.

Learning Task 2

Determine Load Weight

NOTES

Load Weight

The first step in any lifting operation is to determine the approximate weight of a load to be lifted. All decisions such as which equipment to use, the best rigging to use, and the best way to secure the load for lifting will be influenced by the weight. The weight may be obtained from shipping papers, design plans, catalogue data, original equipment manufacturer, or from other sources, but will often have to be calculated.

You may also use a portable electronic scale (crane scale) to monitor weight as you lift a load (Figure 1). Some scales can measure up to 45 000 kg (99 000 lbs.). Some scales have an alarm which will sound if the entered maximum weight is exceeded, whereas others will require manual monitoring.

For example, on structural steel erection plans, the size of each steel beam is usually indicated along with its weight per metre and the actual length of each member. This makes it easy to compute the weight of any member to be lifted. If a steel member does not have its weight per unit of length listed, you can calculate the total weight with reasonable accuracy with some basic information and formulas.

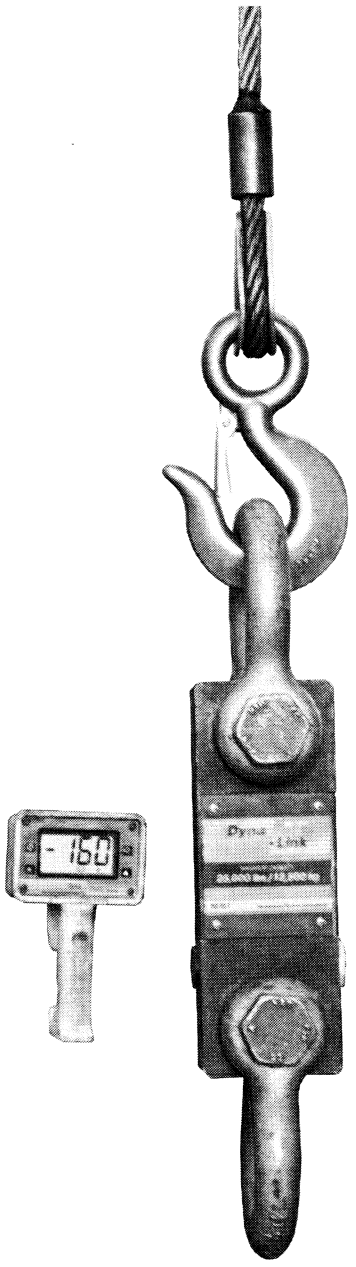


Figure 1. Portable Electronic Scale

NOTES

Steel weighs approximately 7850 kg/m^3 or 40 lbs/ft^2 of one inch thick material. By calculating the metric volume of each piece, you can determine its weight in kilograms as follows:

WEIGHT = VOLUME (in m^3) × 7850 kg

Suppose you have two pieces of steel plate, each measuring 38 mm × 1352 mm × 3 m. You must calculate their volume in m^3 then multiply by 7850 kg.

WEIGHT = 0.038 × 1.352 × 3.0 × 7850 kg × 2 pieces
WEIGHT = 2420 kg

If you are working with the Imperial system, you calculate the total area of each piece (in ft^2) then multiply by its thickness (in inches or fractions of an inch), then multiply by 40 lbs. For example, three pieces of ⅜" plate each measuring 4' × 8' would weigh:

WEIGHT = AREA (in ft^2) × THICKNESS (in inches) × 40 pounds
WEIGHT = 4 × 8 × ⅜ × 40 × 3 pieces
WEIGHT = 1440 pounds

You can calculate the mass of structural shapes by converting their shape into an equivalent flat shape. For example, a 3" × 6" × ¼" angle 10' long would flatten out to a 8¾" x 10' piece of metal (Figure 2).

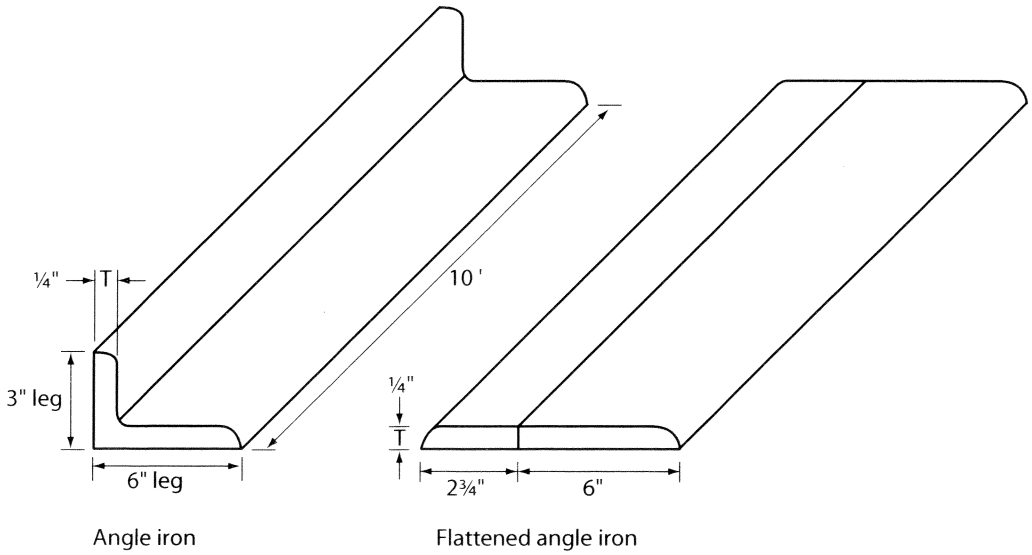


Figure 2. Angle Iron Flattened

NOTES

Since 9" is less than a foot you can still calculate the area in ft^2 by using 9/12 of the width as shown:

$$\text{WEIGHT} = \frac{9}{12} \times 10 \times \frac{1}{4} \times 40 \text{ lbs.}$$

$$\text{WEIGHT} = 75 \text{ lbs.}$$

Most other structural shapes such as I-beams, wide flange, and channels are calculated using the same method. Pipes and cylinders must also be converted to flat shapes in order to calculate their weight. First you mentally "unroll" the pipe into a flat shape (Figure 3).

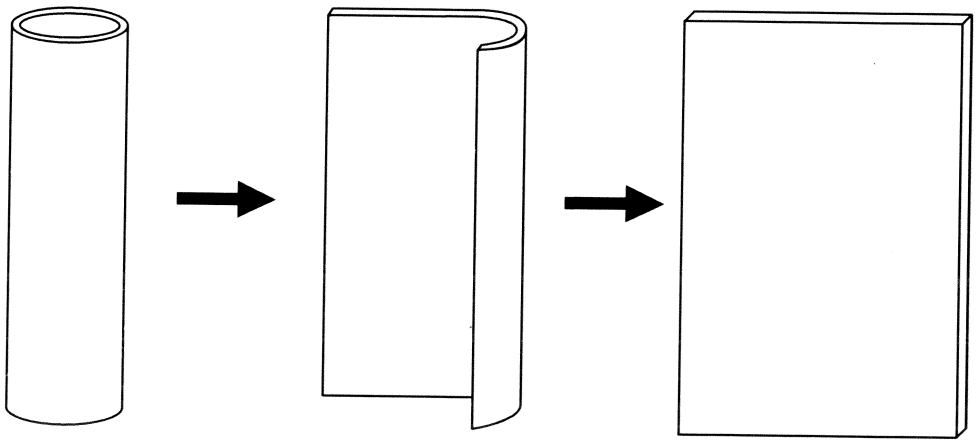


Figure 3. Unrolling a Pipe

For example, a pipe with 13 mm thick walls, a diameter of 250 mm, and a length of 3.8 m will need its circumference converted into a flat surface.

$$\text{CIRCUMFERENCE} = \text{DIAMETER} \times \pi$$
$$\text{CIRCUMFERENCE} = 250 \times 3.14$$
$$\text{CIRCUMFERENCE} = 785 \text{ mm}$$

Using the circumference as the width of the flat, you can now calculate the volume of the material used to make the pipe as follows:

$$\text{VOLUME} = \text{WIDTH} \times \text{LENGTH} \times \text{THICKNESS}$$
$$\text{VOLUME} = 0.785 \times 3.8 \times 0.013$$
$$\text{VOLUME} = 0.038779 \text{ m}^3$$

Having calculated the volume, you then multiply that by 7850 kg to get the mass of the pipe:

$$\text{WEIGHT} = \text{VOLUME} \times 7850 \text{ kg}$$
$$\text{WEIGHT} = 304.4 \text{ kg}$$

NOTES

Cylinders can be calculated in the same manner as pipes except that you must include the area of the two ends in your calculations. The formula for the area of a circle is:

$$\text{AREA} = \pi \times \text{RADIUS SQUARED}$$

or

$$\text{AREA} = \pi^2$$

Once you have the area, you can calculate volume by multiplying the area by its thickness.

Charts are available which show the weight per unit of length of the more commonly used structural shapes as well as the approximate weight of other common materials such as wood, earth, rock, masonry products, and liquids.

Learning Task 3

Select, Use, and Maintain Jacks

NOTES

The most important step in any load lifting operation is to determine the weight of the load so that you can select the appropriate lifting equipment for the move. You must make sure the weight of the load does not exceed the capacity of the lifting equipment selected.

Each make and model of lifting equipment will have its own particular requirements.

Hand-operated Forklifts

Hand-operated forklifts are used over smooth, hard floors for transporting loads which are resting on pallets. The loads must be within the rated capacity of the forklift and the path the forklift travels must be free of rubble. The wheels of this type of forklift are small and hard and cannot negotiate an obstruction as small as an electrical extension cord. Hand-operated forklifts are safe to operate if you follow these basic rules:

- Make sure the load is balanced on the pallet.
- Loose loads should be secured with strapping before being moved.
- Lift loads carefully, making sure the load is not interlocked with adjacent loads.
- Travel at a pace that allows you total control of the load.
- When pulling a load backwards, pay attention to what is behind and beneath you.
- Do not lower a load unless you're certain that everyone's feet and fingers are clear of the load.
- Store a pallet truck so that its forks and handle are out of heavily travelled areas.

Most hand-operated forklifts, sometimes called a pallet jack, raise their loads by the pumping action of the handle (Figure 1). You must close the hydraulic valve (located near the end of the handle) before a lift can be effected. Lowering the load is accomplished by opening the hydraulic valve. Some may be electrically powered for lifting and moving.

NOTES

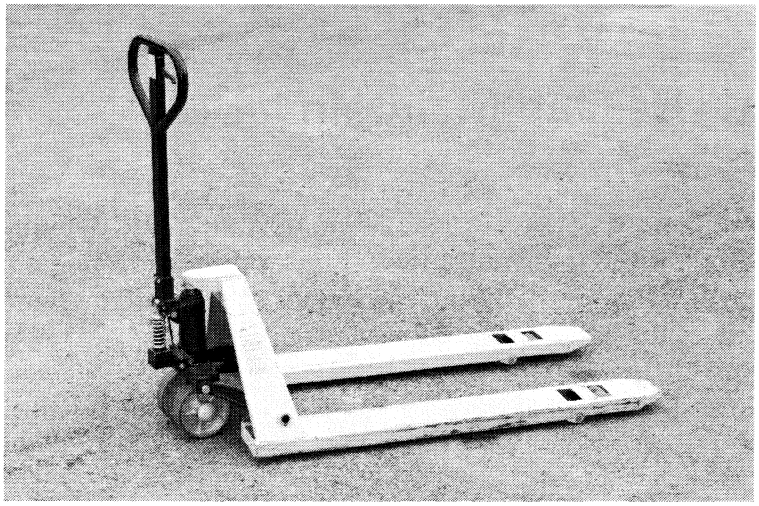


Figure 1. Manual Forklift

Hydraulic Jacks

Hydraulic jacks are relatively safe and easy to use. There are various types of hydraulic jacks: bottle jacks, transmission jacks, floor hoist, or floor jacks.

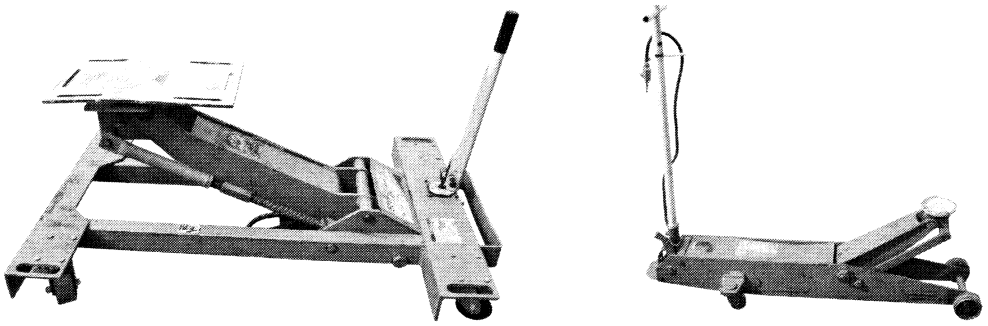


Figure 2. Hydraulic Jacks

Hydraulic jacks gain their mechanical advantage through the use of hydraulics. A relatively small pump piston forces oil against a relatively large lifting piston. The mechanical advantage provided depends on the ratio of the pump piston diameter to the lifting piston diameter.

Hydraulic jacks range in size from 1360–90 000 kg (1½–100 tons). Hydraulic jacks have a relatively short lifting distance of 90–200 mm (3½–8 in.). Some hydraulic jacks have an adjustable screw head which can be used to adjust the total length of the jack prior to the start of a lift.

Hydraulic jacks can be used for any type of lifting or pressing, but they are most useful in situations that require a large lifting capacity rather than the capacity to lift a load to any great height.

Bottle Jack

NOTES

The hydraulic jack shown in Figure 3 is often called a bottle jack and is operated with a detachable handle. The handle is made from a short length of steel tubing and has a pair of notches at one end. This end is used to open and close the valve at the base of the jack.

Figure 3. Bottle Jack

To lift a load with the hydraulic jack, close the valve on the jack, insert the handle into the pump and move the handle up and down.

The pump handle need not move through a full stroke in order to raise the load, however the shorter the stroke of the handle, the smaller the movement of the lifting piston.

To lower loads supported by a hydraulic jack, turn the valve at the base of the jack counter-clockwise. The speed at which the load is lowered is directly proportional to the amount the valve is opened. You must open the valve slowly to avoid lowering the load too quickly.

Do not rely on a hydraulic jack remaining in a loaded position for a long period. Gradual fluid leakage is common which will cause the load to lower.

NOTES

Floor Hoists

A typical hydraulic floor hoist or floor crane is shown in Figure 4. The lifting reach can be changed by moving the boom in or out. However, as the boom extends, the lifting capacity decreases. The lifting capacity of these hoists is rated for lifts with the arm fully extended. Various sizes of floor hoists are available and they may be manually or electrically powered.

Figure 4. Floor Hoist

Hydraulic Jack Safety

You should observe the following precautions when using a hydraulic jack:

- Determine the load to be supported by the jack.
- Select a jack that has adequate capacity to support the load.
- Inspect the jack for signs of leaks, wear, stress, or other defects. Take corrective action as required.
- Use blocking to provide a firm base for the jack. Block the jack as close to the load as possible.
- Secure the load against any horizontal movement.
- Position the jack exactly vertical to prevent the load from being pushed sideways by the jack.
- Raise the load and then block it in its raised position. Never allow the jack to support the load—it must be supported by other means.
- When lowering the load, open the valve slowly so that the load is lowered slowly.

NOTES

Mechanical Jacks

Mechanical jacks gain their mechanical advantage through the use of the screw, the lever, or a combination of both. Mechanical jacks include:

- screw jacks
- lever jacks

Screw Jacks

Screw jacks (Figure 5) range in size from 450–45 000 kg (½–50 tons). Depending on their capacity, screw jacks can be used to raise automobiles, heavy equipment, and large industrial machinery.

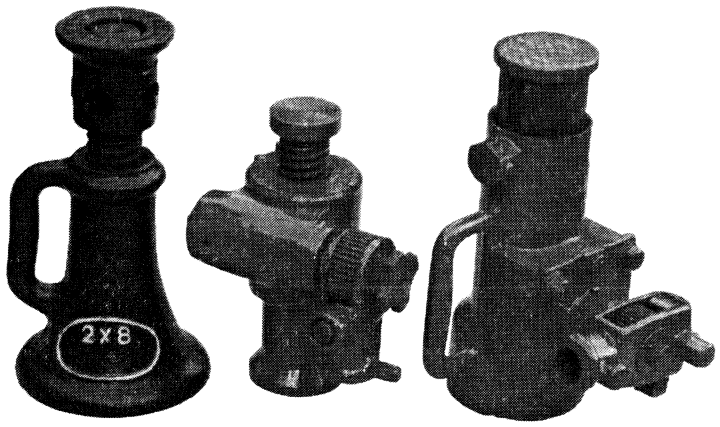


Figure 5. Screw Jack

Some screw jacks are operated by turning the large screw-thread at the top. Others are turned by a crank handle through a gear mechanism at the base of the jack. To use the screw jack shown in Figure 5, insert the handle into a hole near the top of the screw and turn the screw by rotating the top of the jack with the handle. If space permits, turn the handle in a full circle around the jack.

If space is limited, turn the handle as far as possible, relocate the handle in another hole and continue the rotation of the screw.

Lever Jacks

Lever jacks gain their mechanical advantage through the use of a lever. A ratchet permits the lifting to take place in small steps. Each time the lever handle is moved through a full stroke, the lifting mechanism either raises or lowers by one notch along the stem of the jack.

NOTES

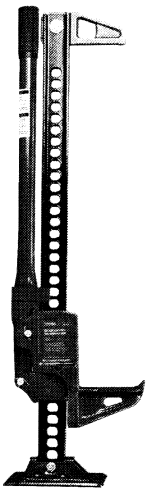


Figure 6. Lever Jack (Jack-all)

A lever jack is operated by moving the handle up and down through a full stroke. The distance the jack moves up or down with each full stroke is determined by the spacing of the notches in the upright. A small lever at the side of the jack controls the direction the jack travels. Usually, when the direction lever is pointing up, the jack will travel up and when the direction lever is pointing down, the jack will travel down.

Due to the room needed to operate the handle, a lever jack is generally placed at the perimeter of the object it is lifting rather than directly underneath. Mechanical jacks, regardless of the type, are more dangerous than hydraulic jacks in the event of failure. When a hydraulic jack fails, the load is lowered gently. When a mechanical jack fails, the load is dropped violently. For this reason, you should inspect mechanical jacks very thoroughly before using them and never exceed their rated capacity.

To improve performance and prevent wear, keep all moving parts of a mechanical jack well-lubricated.

General Safety

The following safety tips must be followed when using any type of jack:

- Wear approved safety footwear.
- If there is any risk of your hands suffering cuts or abrasions, wear gloves.
- Be alert! Try to anticipate load movements in the event something goes wrong. Have an escape plan in mind.

Learning Task 4

Select, Use, and Maintain Stands and Blocking

NOTES

Whenever you lift a load, whether with a mechanical jack, hydraulic jack, or overhead lifting equipment, you must adequately support the load. This is especially important when you're working beneath it or in a position where the load could present a hazard. You should never rely on a jack to support a load—may fail and cause injuries. Loads should be supported by metal support stands or by wooden block bridging. A combination of the two can be used where secondary blocking is required.

Support Stands

Support stands are commercially manufactured and are designed to support a specified load on a stable base, such as concrete or hard ground (Figure 1). They must bear a certification stamp and a rating, either stamped in the metal or embossed. Custom-built stands or support devices must be certified by an engineer indicating how much weight they will safely support.

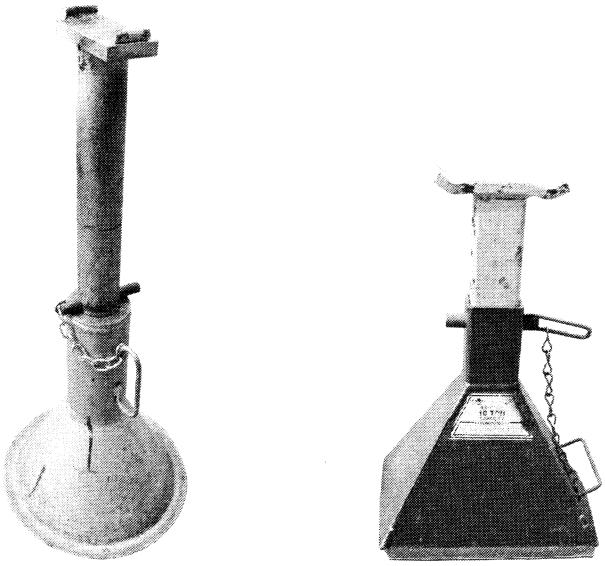


Figure 1. Support Stands

You must examine the support stands carefully for signs of stress or damage. Often, this damage can be seen as paint flaking off or as bend marks on the metal. Only use support stands that are in excellent condition.

NOTES

Position the stands carefully so that they adequately support the load and are stable. Make sure that the base upon which they will rest is firm. If the stand is allowed to sink, this will cause the load to become unstable. Make sure that the load is positioned in the saddle of the jack stand. Never load just the ear of the saddle, as this could cause a jack stand to fail and result in injury. Never place spacers between the jack stand saddle and the load. Always support the load evenly so there is no side load placed on the jack stand.

Bridging

When a load must be supported that is too heavy for jack stands, or is in a position where the ground under the load is too soft to provide adequate support, you can use bridging. Bridging is made of high-quality hardwood of equal sizes, stacked carefully to provide the necessary support. Do not use softwood for bridging material as the load will crush the wood, causing it to crack and drop the load.

Layers of bridging must have the material placed in alternate directions and must be placed so that the length of the material is equal to the width of the bridging. This ensures stability in the load.

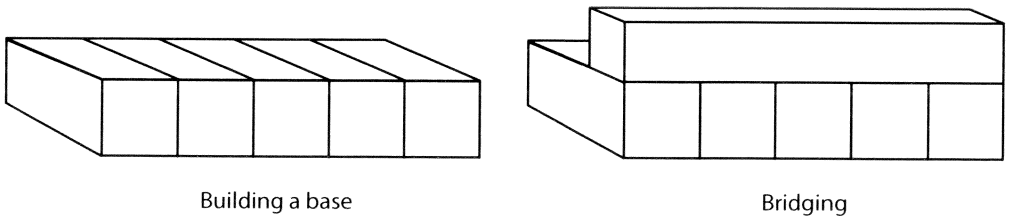


Figure 2. Bridging

Learning Task 5

Select, Use, and Maintain Wire Ropes, Chains, and Lifting Straps

NOTES

There are multiple ways to connect lifting devices to their loads including wire rope, chains, and lifting straps. There are also various rigging and lifting attachments such as hooks, shackles, eye bolts, and turnbuckles. Which type you use will depend on what you're lifting.

Wire Rope

Note: Additional information on wire rope can be found in Competency A-9—Service Winch Wire Rope.

There are many types of wire ropes, each designed for a specific application or use. The manner in which a wire rope is made affects its strength, flexibility, and resistance to abrasion or crushing.

Identifying Wire Rope

Wire rope identification can be found on the storage reel or a tag that is attached to the rope. This information should include the rope's:

- length
- diameter
- composition
- pattern
- formation
- grade

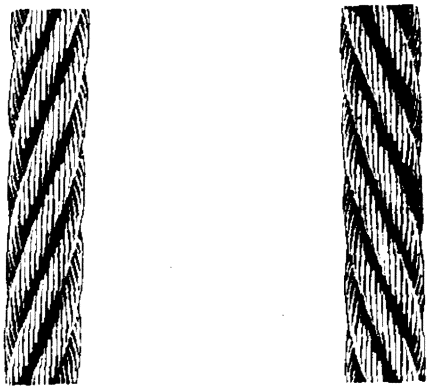
Rope Lay

"Lay" is the direction the wires and the strands are wound to make the rope. Both regular and lang lay (described below) are available in right or left styles. Right lay has the strands wound in a clockwise direction along the length of the rope, while left lay has the strands wound in a counter-clockwise direction. There is also rope called "non-rotational" or "antirotational." This wire rope has an outer layer of strands wound in one direction and an inner layer wound in the opposite direction. Non-rotational wire rope is designed so it will not spin when a load is applied to it.

NOTES

Regular Lay

Regular lay rope has the wires of the strands wound in one direction while the strands are wound in the opposite direction (Figure 1).

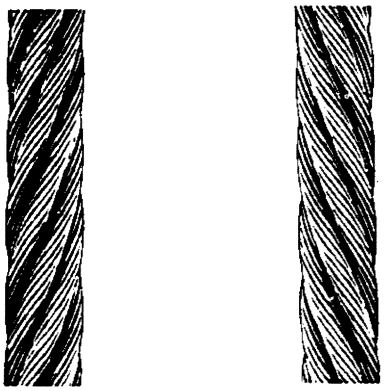


Right Regular Lay Left Regular Lay

Figure 1. Regular Lay

Lang Lay

Lang lay rope has both the wire and the strands wound in the same direction (Figure 2).



Right Lang Lay Left Lang Lay

Figure 2. Lang Lay

Never use lang lay wire rope as a sling, as the lay of the rope may cause the load to rotate.

NOTES

Working Load Limit for Wire Rope

The working load limit (WLL) is a rating given to all rigging hardware, including fibre and wire rope. The rope type and diameter are the basis for calculating the working load limit. Working load limits for ropes are calculated by dividing the rope's breaking strength by the design factor set by WorkSafeBC. The design factor for any rigging assembly used to hoist or support workers must be at least 10 (*OHS Regulation, Part 15.6.3*).

If a wire rope's WLL for hoisting materials is 1200 kg with a design factor of 5, you can calculate the rope's WLL for supporting workers as follows:

breaking strength = WLL for hoisting materials × design factor
breaking strength = 1200 kg × 5
breaking strength = 6000 kg

Now that you've calculated the breaking strength of the rope, you can calculate the WLL for hoisting workers:

WLL for hoisting workers = breaking strength ÷ design factor
WLL for hoisting workers = 6000 kg ÷ 10
WLL for hoisting workers = 600 kg

Wire Rope Inspection

A wire rope used for lifting must be replaced if there are six or more randomly distributed broken wires in one rope lay, or three or more broken wires in one strand in one rope lay. (A rope lay is the length along the rope in which one strand makes a complete revolution around the rope.)

A rope must also be replaced if there are one or more broken wires near an attached fitting. Breaks that occur near attached fittings are usually the result of fatigue stresses concentrated in these localized sections. If you find wire breaks of this type, replace the rope or redo the attachment to remove the locally fatigued area.

Once broken wires appear in a rope operating under normal conditions, many more will show up within a relatively short period. Using a wire rope with more than the allowable number of broken wires is a hazard.

Making a Decision

If you are not sure that the rope is safe for lifting, tag it so that it will not be used by another worker and notify your supervisor that you suspect the rope to be substandard. Have your supervisor arrange for inspection or testing of the wire rope before it is returned to service.

Never use a sling for hoisting unless it bears a manufacturer's WLL identification attached to it.

NOTES

Chain

Chains are preferred in hoisting operations where the ability to withstand high temperatures and abrasion is required. Chains can take rough handling, store easily, and grip the load well. They resist abrasion and corrosion better than wire rope and are good for lifting rough loads such as heavy castings. Chains have no elasticity and are very poor at withstanding shock loads.

The working load limits (WLL) for chains apply when they are used as a single vertical sling.

Grades

There are several grades of chain available. Chain is identified by the grade and by stock diameter (size). Chain size is the diameter of the rod that is used to form each link of the chain. The minimum grade acceptable for overhead hoisting is system 8 chain grade A. Each link must bear an "8" stamped into its surface (Figure 3). It may also bear the letter "A" along with the number 8. The standards for chain are established by the National Association of Chain Manufacturers.

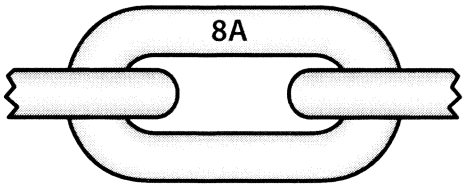


Figure 3. Grade A Link

Inspection

Chains should have a frequent link-by-link inspection. You should also immediately inspect any chain that has sustained a shock load. Check each link for cracks, bends, twisting, chips, or cuts. Bends and twists may also occur (Figures 4 and 5).

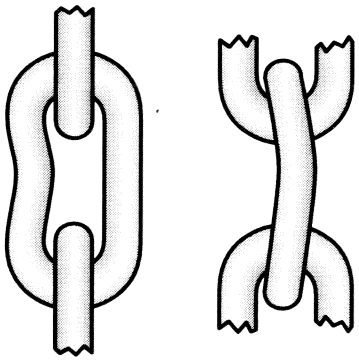


Figure 4. Bent Links

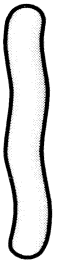


Figure 5. Twisted Link

NOTES

Chains tend to show signs of wear at the bearing surfaces of each link (Figure 6). When the amount of wear equals 5% of the link diameter for chains less than 25 mm (1 in.), or 10% for chains over 25 mm (1 in.), you must stop using the chain for hoisting.

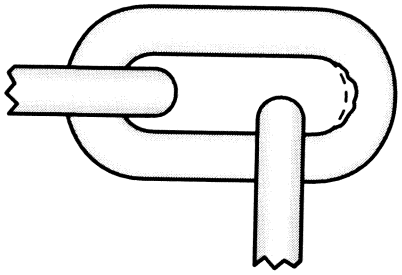


Figure 6. Worn Link

When using chain in any hoisting operation, never place a load on a twisted or knotted chain. If at all possible, avoid sharp bends as they tend to overload the links at the bend. Chains that are overloaded will also stretch. If any link shows stretching of 3% over its original size, do not use the chain for lifting.

Heat will also have an adverse effect on the lifting capacity of a chain. As temperature increases, there will be a temporary and possibly permanent effect on the chain's capacity. *WorkSafeBC, OHS Regulation, Part 15.51* states, "A chain sling must not be exposed to a temperature above 260°C (500°F) unless otherwise permitted by the manufacturer." Figure 7 shows a typical manufacturer's chart for effects of heat on chain working load limits.

Chain temperature	Reduction of working load limit while heated	Permanent reduction in working load limit
260°C (500°F)	None	None
315°C (600°F)	10%	None
370°C (700°F)	20%	None
425°C (800°F)	30%	None
480°C (900°F)	40%	10%
540°C (1000°F)	50%	15%

Figure 7. Effects of Heat on WLL

NOTES

Making a Decision

Inspect the chain carefully and make a decision. If you're not sure that the chain is safe, tag it so that it will not be used by another worker and notify your supervisor about your decision. Have your supervisor make the necessary arrangements to have the chain inspected for safety before it is returned to service.

Never use a chain for hoisting unless there is a manufacturer's WLL identification attached to it (Figure 8).

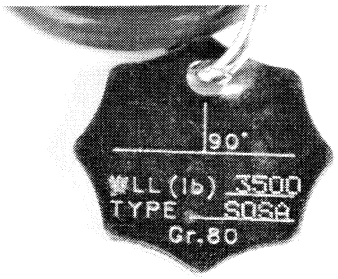


Figure 8. Chain Tag

Chains will usually stretch under heavy load, giving you some warning of possible failure. But if the overload is great, the chain will fail instantly, without warning. Chains have less resistance to shock load than wire rope and can break without warning. A wire rope that has been overloaded might not show any obvious signs of stretching, but a chain will display elongated links.

Chains used as slings should be supplied with a master ring at one end and a hook at the other (Figure 9). The large master ring is designed to fit over a crane's main hook. The chain's own hook is hooked directly to loads that have attachment points. The chain can also be wrapped around the load and its hook secured to the master ring (Figure 10).

NOTES

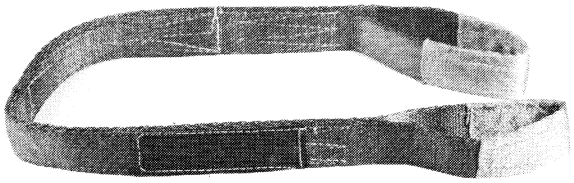
Figure 9. Chain with Master Ring and Hook

Figure 10. Chain Hook Secured to Master Ring

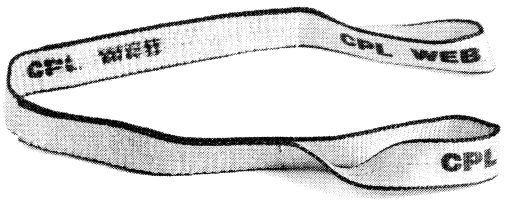
NOTES

Synthetic Web Slings

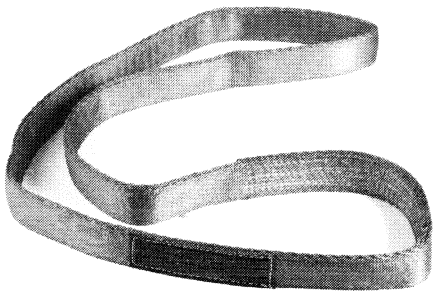
Synthetic web slings are available in a variety of shapes and widths. They are softer and wider than most other slings and so better protect the load against marring and scratching. Synthetic web slings come in several common shapes (Figure 11).



Standard Eye Web Sling



Twisted Eye Web Sling



Endless Web Sling

Figure 11. Synthetic Web Slings

Some web slings have metal end fittings instead of sewn eyes. There are two types of metal end fittings. A basket web sling has metal triangles of equal size at each end of the webbing (Figure 12). A choker web sling has a larger triangle containing a slot at one end and a smaller triangle at the other end (Figure 13). The smaller triangle can be passed through the slot of the larger triangle to form a choker hitch.

NOTES

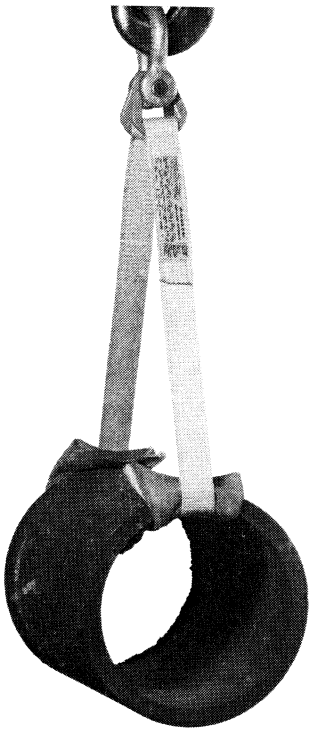


Figure 12. Basket Web Sling

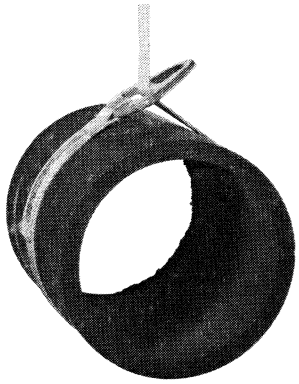


Figure 13. Choker Web Sling

Synthetic web slings must bear a tag indicating the working load limit of the sling (Figure 14).

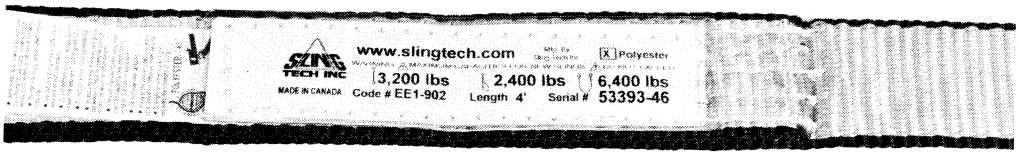


Figure 14. Synthetic Web Sling Safe Working Load Limit Tag

NOTES

Metal Mesh Slings

Slings made of metal mesh are used when a load is too abrasive or too hot for synthetic webbing. These metal mesh slings usually have triangle ends that permit the use of either a basket or a choker hitch.

Inspection

Before using any web sling, inspect it for:

- worn or distorted fittings
- cuts
- holes
- punches
- tears
- frayed material
- broken stitching
- burns from acid, caustic chemicals, or heat

Making a Decision

Inspect every sling carefully to determine whether it is in usable condition. If you're not sure that the sling is safe, tag it so that it will not be used by another worker and notify your supervisor about your decision. Have your supervisor make the necessary arrangements to have the sling inspected for safety before it is returned to service.

Never use a sling for hoisting unless there is a manufacturer's WLL identification attached to it.

Rigging and Lifting Attachments

For some situations, slings alone are not enough to rig a load for hoisting. In these situations you'll need to use hardware to match the lifting requirements.

This hardware includes:

- hooks
- choker hooks
- shackles
- wire rope clips
- eye bolts
- welded lugs
- turnbuckles
- spreader and equalizer bars

NOTES

Hooks

Of the many types of hooks available, the most commonly used ones include slip, grab, and sorting hooks with standard eye (Figure 15).

Slip Hook | Grab Hook | Sorting Hook

Figure 15. Various Standard Eye Hook Types

The standard eye slip hook with safety catch is commonly used to lift loads that have been rigged, as is the variation that includes a swivel base (Figure 16).

Figure 16. Slip Hook with Swivel Base and Safety Catch

Slip and grab hooks are usually attached to the ends of the chains to pick up or pull a load. Sorting hooks are also called "shake-out hooks." Sorting hooks are mainly used at the end of slips for picking up steel plate and other steel structural shapes. The long, thin hook can slide in between closely stacked steel shapes. When you use a sorting hook to lift a heavy load, make sure that the load sits squarely in the bottom or saddle of the hook. To protect chains from the stress of twisting while under load, all hoisting hooks should be equipped with swivels (Figure 17).

NOTES

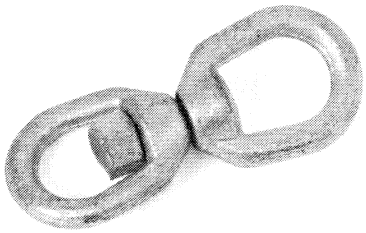


Figure 17. Chain Swivel

Hook Inspection

Like all rigging hardware, hooks must be inspected frequently. You must be alert for signs of wear, especially in the saddle, the throat opening, and other areas of a hook most subject to wear (Figure 18). Measure the throat opening to make sure it's not widening. Widening is a sign that the hook has been overloaded and weakened. Check for cracks, corrosion, and distortion.

If you discover evidence of wear, immediately discard the hook. Destroy the hook before throwing it away to prevent someone else from using it. *WorkSafeBC, OHS Regulation, Part 15.29, Hook Rejection Criteria* states that a worn or damaged hook must be permanently removed from service if:

- the throat opening, measured at the narrowest point, has increased by more than 15% of the original opening
- the hook has twisted more than 10 degrees from the original plane of the hook
- the hook has lost 10% or more of its cross-sectional area
- the hook is cracked or otherwise defective
- wear or damage exceeds any criteria specified by the manufacturer

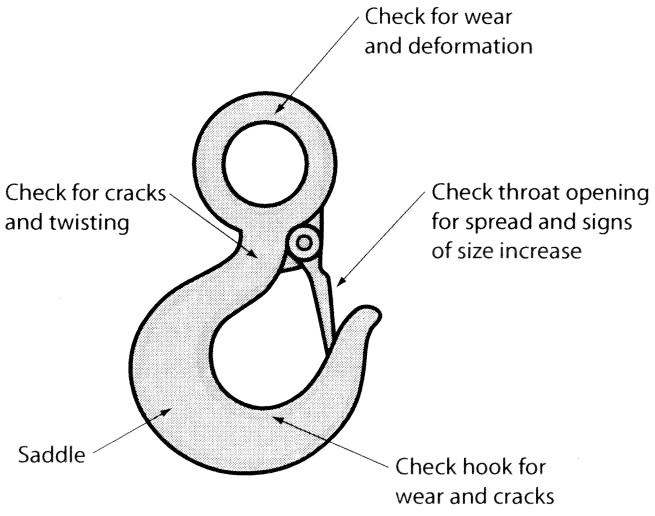


Figure 18. Parts of Hook to Check

NOTES

All hoisting hooks must have safety catches. Exceptions are grab and sorting hooks.

Hook Capacity

Hooks are usually made of alloy steel. Their working load limit (WLL) should be stamped on them. It's important to remember that the WLL applies only when the load sits in the saddle of the hook. If the load is off centre or sits between the saddle and the tip, the WLL is significantly reduced (Figure 19).

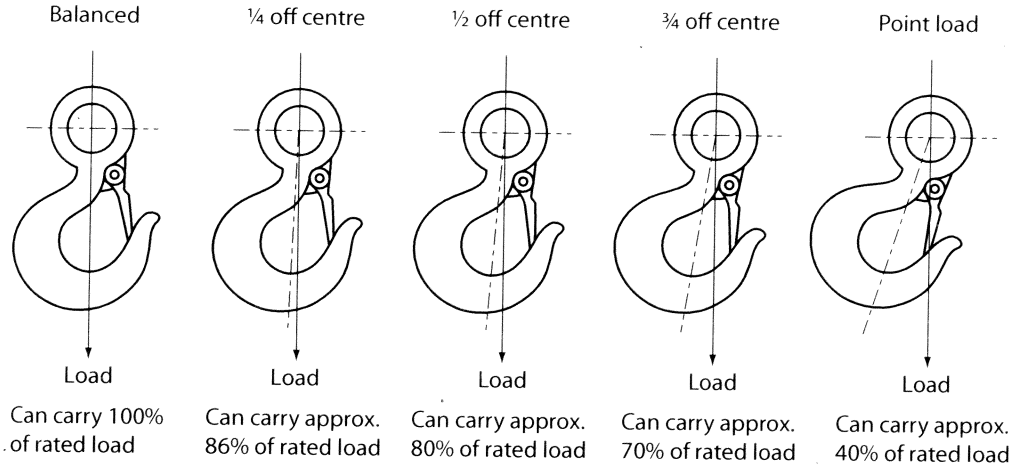


Figure 19. Effect of Off-centre Loads on Hook Capacity

Choker Hooks

Choker hooks are used at the end of a sling, where their width protects the rope from sharp bends. They can also be used to form choker hitches. The standard choker hook is attached to the end of the sling. The sling is then passed around the load and the wide surface of the hook is hooked over the standing part of the sling.

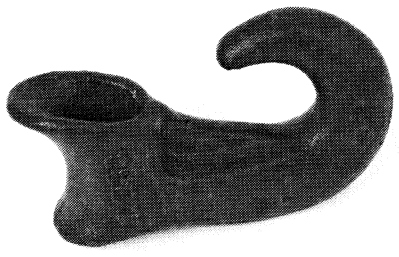


Figure 20. Standard Choker Hook

NOTES

A variation of the standard choker hook, the adjustable or sliding choker hook, is mounted on a sling that has a loop at each end. The sling is passed around a load and the end loop is hooked over the choker hook.

Figure 21. Adjustable Choker Hook

Shackles are used to connect a sling to a load (Figure 22). Use shackles whenever two or more ropes are to be placed over a hook. The shackle should have a throat large enough to avoid crowding and pinching the ropes. The working load limit (WLL) of a shackle must be shown as a stamped or embossed number on the body of the shackle. Do not use shackles that do not have a WLL.

Figure 22. Shackle

Figure 23. Ropes on Shackle Over Hook

NOTES

Never replace the pin of a shackle with an ordinary bolt. Shackle pins are made of hardened steel. Ordinary bolts will bend under load and will damage the shackles. In many applications, the shackle pin must be secured for safety. The pin may be wired to prevent it from turning out, or the pin may be seized in place.

When placing a shackle on a lifting hook, position it so that the pin is on the hook. Placing the pin on the sling could cause the pin to become loose (Figure 24).

Figure 25 shows the correct method for attaching a shackle to a lifting hook. Note that if the shackle's opening is considerably wider than the thickness of the hook, you should use packing washers to centre the hook on the shackle.

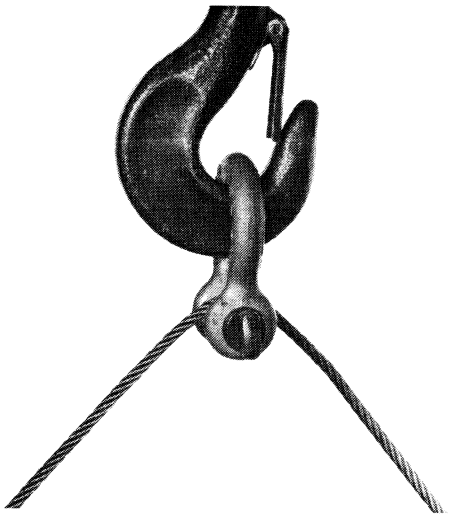


Figure 24. Incorrect Shackle Attachment

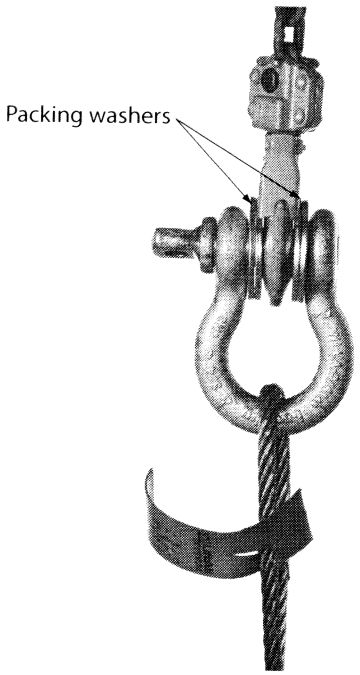


Figure 25. Using Packing Washers

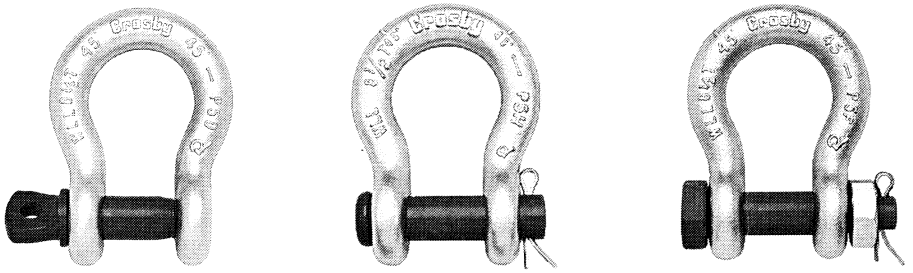
Never attach a shackle so that the load is applied to the sides of the shackle. This is called "cross-bow loading." Always apply the load on the pin and on the end of the shackle (Figure 25). To prevent cross-bow loading, never use a shackle with slings if the angle between the two slings (included angle) at the shackle will be more than 90°.

NOTES

There are three basic types of pins available for shackles:

- screw pins
- round pins
- bolt type pins

The screw-type shackle is most commonly used.



Screw Round Bolt

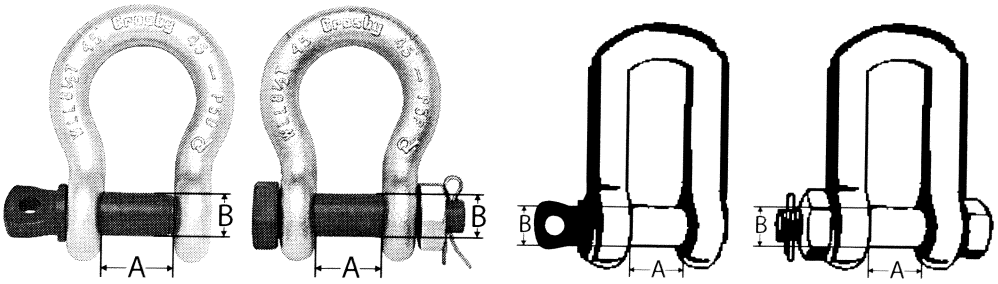
Figure 26. Shackle Pin Types

The shackle is rated for lifting capacity and size. The chart in Figure 27 shows how to measure a shackle and what the weight ratings are for each.

NOTES

SHACKLES

Screwpin G-209 | Bolt Anchor G-2130 | Screwpin Chain G-210 | Bolt Chain G-2150



SHACKLE SIZE INCHES	WORKING LOAD LIMIT TONS	DIMENSION A	DIMENSION B
3/16	1/3	0.38	0.28
1/4	1/2	0.47	0.31
5/16	3/4	0.53	0.38
3/8	1	0.66	0.44
7/16	1 1/2	0.75	0.50
1/2	2	0.81	0.63
5/8	3 1/4	1.06	0.75
3/4	4 3/4	1.25	0.88
7/8	6 1/2	1.44	1.00
1	8 1/2	1.69	1.13
1 1/8	9 1/2	1.81	1.25
1 1/4	12	2.03	1.38
1 3/8	13 1/2	2.25	1.5
1 1/2	17	2.38	1.63
1 3/4	25	2.88	2.00
2	35	3.25	2.25
2 1/2	55	4.13	2.75
3	85	5.00	3.25
3 1/2	120	5.25	3.75
4	150	5.50	4.15

Figure 27. Shackles and Weight Ratings

NOTES

Shackles can be used to form a choker hitch (Figure 28), but you must make sure the pin is not bearing on any moving part of the rope. The rope could cause a screw pin to turn and become loose.

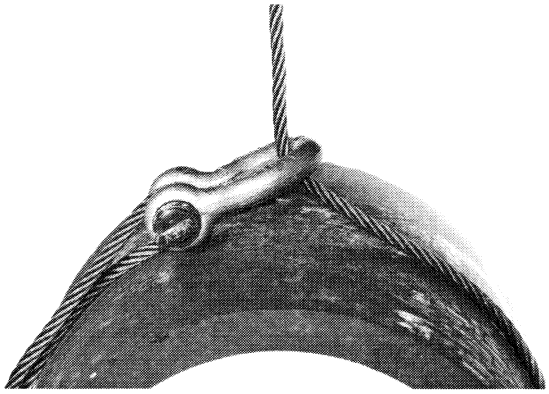
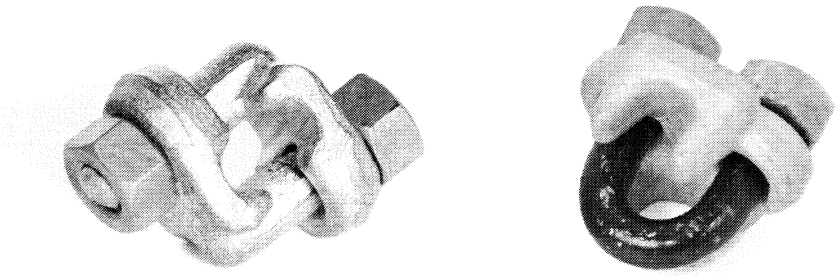


Figure 28. Correct Use of a Shackle for a Choker Hitch

Wire Rope Clips

Wire rope clips are used to fasten the end of a wire rope back onto its standing part to form a loop. Wire rope clips provide a relatively quick and easy method for fastening wire rope. However, they significantly reduce the breaking strength of wire rope (up to 20%) because they crimp the rope.

The two most popular types of wire rope clips are the U-bolt clip and the fist grip clip (Figure 29).



Fist Grip Clip U-bolt Clip

Figure 29. Cable Clips

NOTES

Installing Wire Rope Clips

The number of wire rope clips required and their spacing are directly related to the diameter of the wire rope. The number of clips required, the spacing between them, and the torque specifications are calculated and listed in *WorkSafeBC, OHS Regulation, Table 15-2* (Figure 30).

Example:
The number of clips for a 13 mm (½ in.) wire rope is 3, the spacing is 76 mm (3 in.) and the torque specification is 88 N•m (65 lb•ft).

Diameter of rope		Number of clips	Spacing between clips (centre to centre)		Torque	
mm	in.		mm	in.	newton metres	foot pounds
6	1/4	2	38	1 1/2	20	15
8	5/16	2	51	2	41	30
10	3/8	2	57	2 1/4	61	45
11	7/16	2	64	2 1/2	88	65
13	1/2	3	76	3	88	65
16	5/8	3	102	4	129	95
19	3/4	4	114	4 1/2	176	130
22	7/8	4	133	5 1/4	305	225
25	1	4	152	6	305	225
29	1 1/8	5	178	7	305	225
32	1 1/4	5	203	8	488	360
38	1 1/2	6	229	9	488	360
44	1 3/4	7	267	10 1/2	630	465
51	2	8	305	12	881	650
54	2 1/8	8	330	13	881	650
57	2 1/4	8	356	14	881	650

Figure 30. *WorkSafeBC, OHS Regulation, Table 15-2*: Installation and Use of Wire Rope Clips

Wire rope has a tendency to stretch a small amount when first put into service. As it stretches, its diameter will decrease. After you have correctly applied and torqued the clips, place the connection under load to allow the wire rope to stretch. Then lower the load to release the tension on the connection and retorque the nuts. If the wire rope clip connection is under heavy strain, check the nuts at regular intervals until you no longer find any change in their tightness.

NOTES

The correct procedure for installing wire rope clips is as follows:

1. Calculate the length of wire rope required to complete the loop. This includes the loop, the length to accommodate the number of clips, and the length of dead end extending beyond the first clip. Install the first clip six wire rope diameters from the rope end (Figure 31). Tighten the nuts to the recommended torque using a torque wrench.

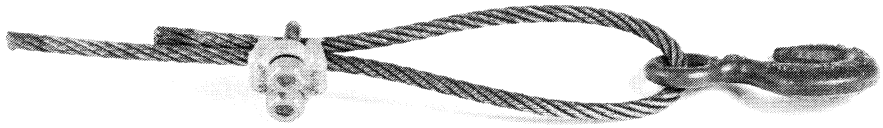


Figure 31. Installing First Wire Rope Clip

2. Install the second clip as near the thimble as possible (Figure 32). Tighten the nuts but do not torque.

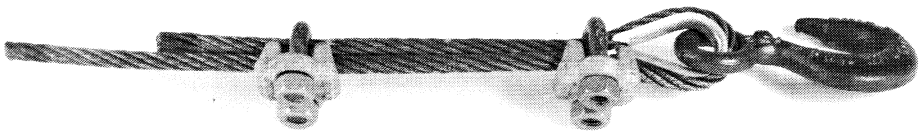


Figure 32. Installing Second Wire Rope Clip

3. Install all other clips at equal spacing, apply tension to the rope, and then torque all the nuts (Figure 33).

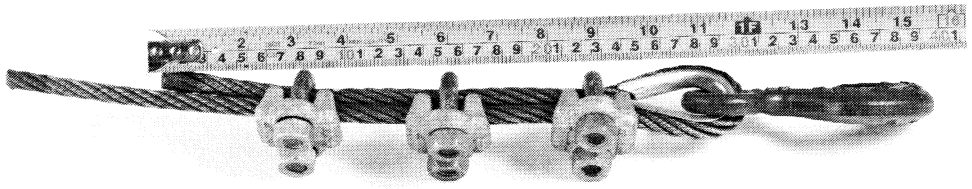


Figure 33. Installing Centre Cable Clip

Never put the saddle of the cable clip on the dead end of the wire rope (Figure 34).

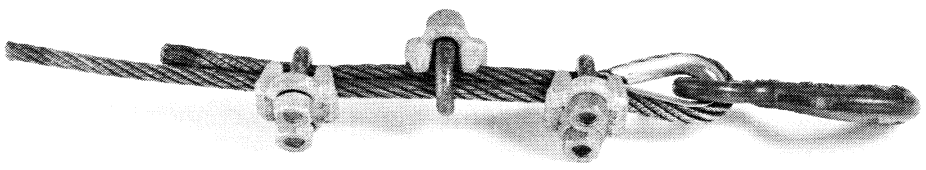


Figure 34. Incorrect Installation of Wire Rope Clips

Correctly installed cable clips reduce the breaking strength of wire rope by 20%. Incorrectly installed cable clips can reduce the breaking strength by up to 50%.

NOTES

Eye Bolts

Eye bolts are used to provide a point of attachment for hoisting. There are two types: shoulderless and shoulder. Never use shoulderless eye bolts in overhead hoisting. Force applied from any angle but the vertical will break the stem of the bolt (Figure 35).

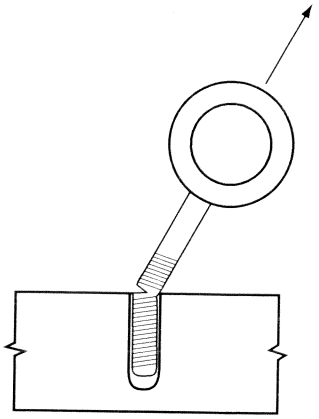


Figure 35. Incorrect Use of Shoulderless Eye Bolt

Shoulder-type eye bolts are able to withstand pulls up to 45° from vertical, providing the pull is applied along the plane of the eye (Figure 36). Pulling at an angle that is not in the same plane will bend or break the eye. Always make sure that the eye bolt is properly installed so that the shoulder is bottomed against the load. Do not use an eye bolt if there is any space between the shoulder and the load, because it will act as a shoulderless eye bolt and could break off under stress.

NOTES

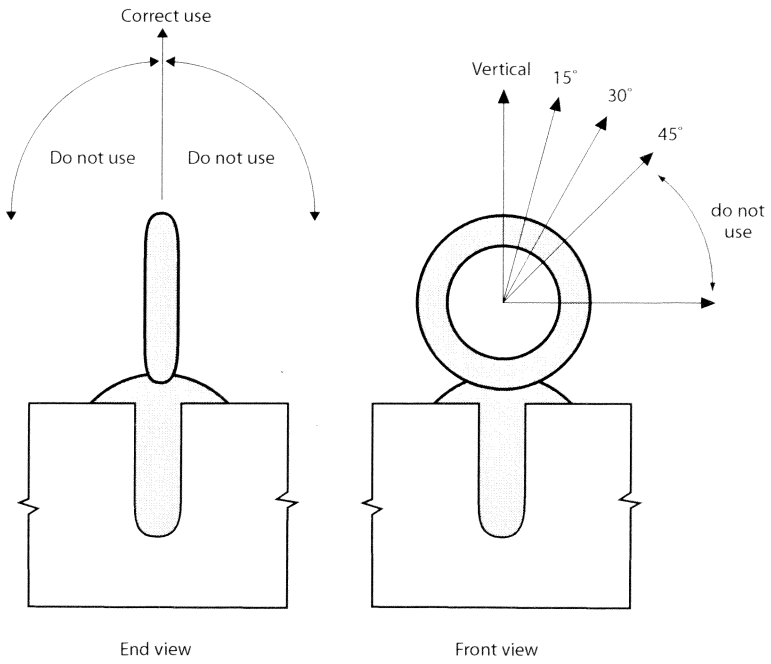


Figure 36. Angle of Pull on Shoulder-type Eye Bolt

The working load limits (WLL) for eye bolts are given for vertical pulls. When lifting at an angle, you must reduce the WLL of the eye bolt as follows:

Vertical pull = No reduction in WLL
15° from vertical = 45% reduction in WLL
30° from vertical = 65% reduction in WLL
45° from vertical = 75% reduction in WLL
over 45° from vertical = NOT RECOMMENDED

Welded Lugs

On many occasions, lugs are welded to the object to be lifted (Figure 37). The dimensions of the lugs and the methods of welding them vary. Unlike eye bolts, the pull may be applied to welded lugs from vertical to 90° from vertical when the force is applied along the plane of the lug. Depending on the thickness of the lug, pulls may be applied across the plane of the lug at 15° to 20° from vertical.

NOTES

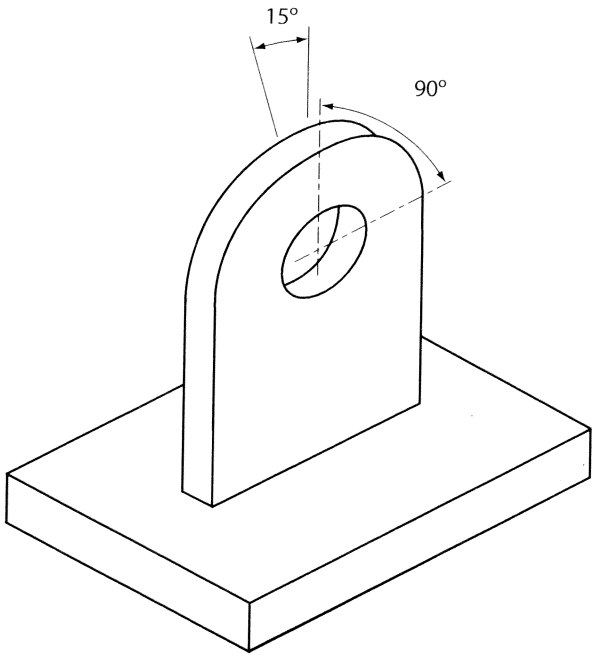


Figure 37. Range of Pull Angles on Welded Lug

All welded lugs must welded by a qualified welder and certified by a professional engineer before they can be used for hoisting.

Turnbuckles

Turnbuckles are used to adjust the lengths of slings so that loads that have uneven attachment points can be lifted in a level position (Figure 38).

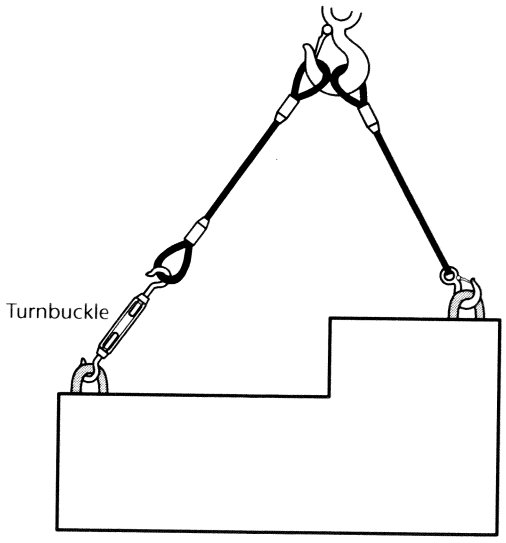


Figure 38. Turnbuckle Used to Adjust Length of Sling

NOTES

Turnbuckles are metal sleeves with left-hand internal threads at one end and right-hand internal threads at the other. Threaded metal rods are fitted into each end (Figure 39).

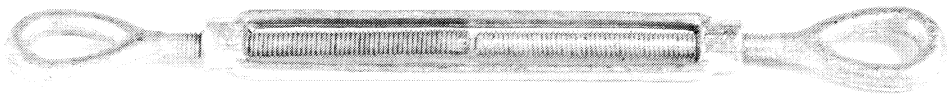


Figure 39. Turnbuckle

The ends of these threaded rods are available as eyes, jaws, or hooks (Figure 40). Note: Turnbuckles with hooks have a reduced capacity and if used for overhead lifting, must be equipped with a safety catch.

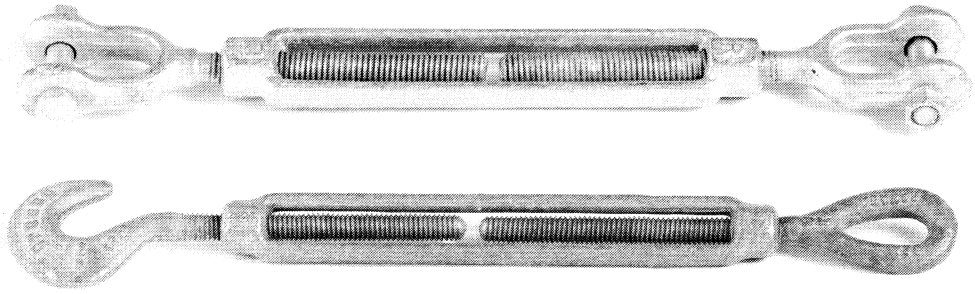


Figure 40. Turnbuckle Ends

It's important to prevent turnbuckle ends from rotating. Rotation can be caused by vibration or by tension on the rope attached to the turnbuckle. If there is any chance that the ends of the turnbuckle could rotate within the sleeve, the ends should be wired to the sleeve with a lock wire (Figure 41).

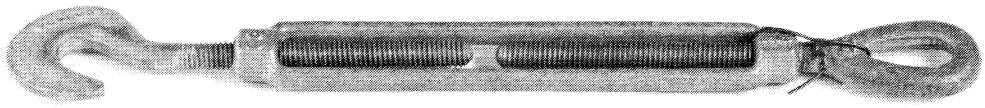


Figure 41. Turnbuckle End with Lock Wire

Spreader and Equalizer Bars

NOTES

Long loads are often attached to spreader bars (beams) before they're hoisted in order to prevent the load from tipping or sliding out of the rigging. Equalizer bars ensure that the load is distributed evenly between the legs of a sling or between the hoist lines when more than one is used. Figure 42 shows spreader and equalizer bars and how they are used to keep loads evenly balanced.

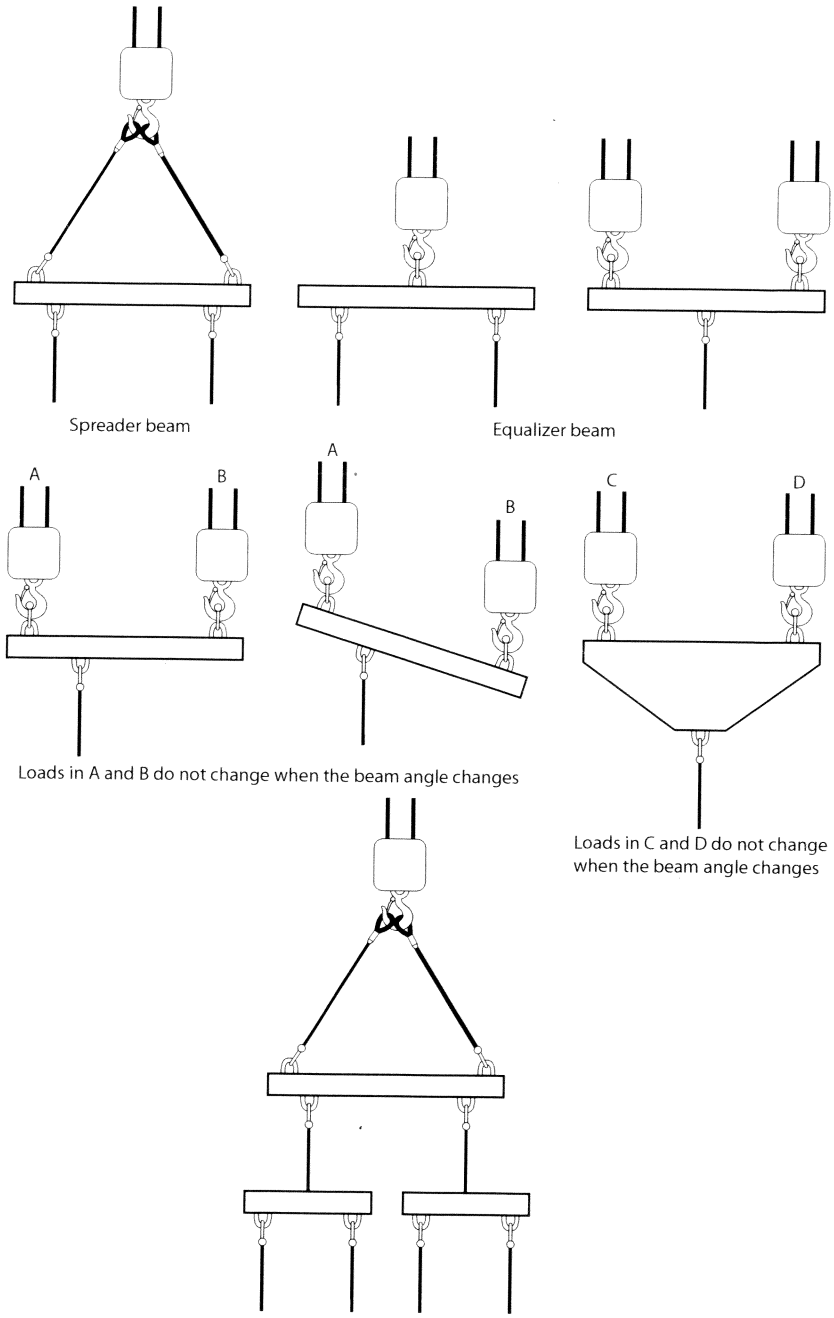


Figure 42. Spreader and Equalizer Bars

NOTES

Equalizer bars, spreader bars, and all lifting devices must be professionally designed and manufactured. They must be certified by a professional engineer, stamped with the certification, and marked with a working load limit (*WorkSafeBC, OHS Regulation, Parts 15.57,15.58,* and *15.59*). Homemade lifting devices, such as S-hooks, are only permitted if they're certified by a professional engineer.

Learning Task 6

Use Fibre Rope Knots, Bends, and Hitches

NOTES

Fibre Rope

Fibre rope can be made from either natural or synthetic fibres. Natural fibres include manila and sisal. Synthetic fibres include nylon, polyester, and polypropylene. Each of these fibres has unique properties. A newly purchased coil of rope will generally have a breaking strength rating attached to it. Fibre ropes are not the same as fibre slings. Fibre slings are specially designed and commercially fabricated for lifting purposes. Their working load limit will be indicated on a tag sewn to the sling.

The construction of rope begins with fibres that are twisted into yarns. Yarns are twisted into strands, and stands are twisted into lays. This construction is commonly called "laid" or "twisted" rope (Figure 1).

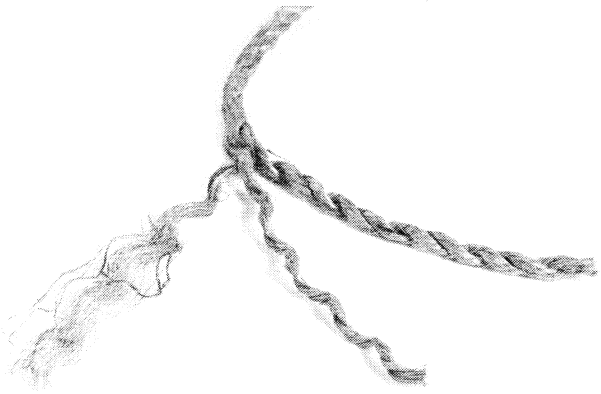


Figure 1. Rope Construction

The term "lay of the rope" means the direction that the lays turn. In a right-hand lay rope, the lays are twisted in a clockwise direction, while in a left-hand lay rope the lays will be twisted in a counter-clockwise direction (Figure 2).

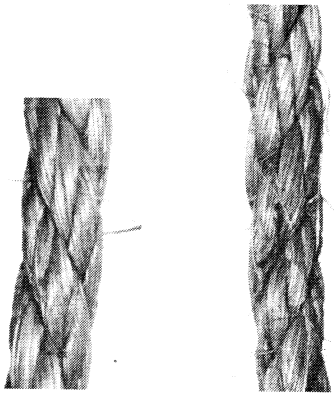


Figure 2. Rope Lay

NOTES

Natural Fibre Rope

Manila Rope

Manila rope is light yellow and has a smooth, waxy surface. Manila rope is about 35% as strong as nylon and is available in six grades (Figure 3).

Grade	Description
Yacht rope	Considered to be the highest quality manila rope, yacht rope is a very pale yellow colour. It is expensive and because of this it is used only on special jobs.
Bolt rope	This is a high-grade, pale yellow rope. In strength it falls between yacht rope and No. 1 grade.
No. 1 grade	Usually containing one or more coloured strands as identification, No. 1 grade is light yellow and is the lowest grade suitable for overhead lifting.
No. 2 grade	This type is slightly darker than No. 1 rope and does not have coloured identity strands. It loses strength more rapidly than No. 1 grade.
No. 3 grade	Considerably darker than either No. 1 or No. 2 grade, No. 3 grade loses strength very rapidly when in service.
Hardware store rope	This is the darkest and poorest grade of manila rope. Since it is constructed with a high percentage of short fibres, it has little strength, a short life and a much rougher texture with many fibre ends sticking up from the surface.

Figure 3. Grades of Manila Rope

Sisal Rope

Sisal rope is almost white in colour and has a coarse texture that is rough to the touch. Sisal rope is weaker than manila rope and should be used only where cost rather than strength is the major factor. Under WorkSafeBC regulations, sisal rope is not acceptable for construction rigging and hoisting.

Synthetic Fibre Rope

Nylon Rope

Nylon rope is about three times stronger than manila rope. Nylon rope is usually pure white, soft, pliable, and smooth to the touch. It has an elastic quality and will stretch up to 40% of its original length.

Nylon rope loses about 10% of its strength when wet, but regains its original strength when dried. Nylon does not rot, is unaffected by mildew, and can withstand temperatures up to 150°C (300°F) without being damaged. It will be damaged by acids and alkalines.

NOTES

The highly elastic nature of nylon rope makes it capable of withstanding repeated shock loads. However, this same elasticity can be a hindrance if you're trying to lift loads in areas with restricted headroom.

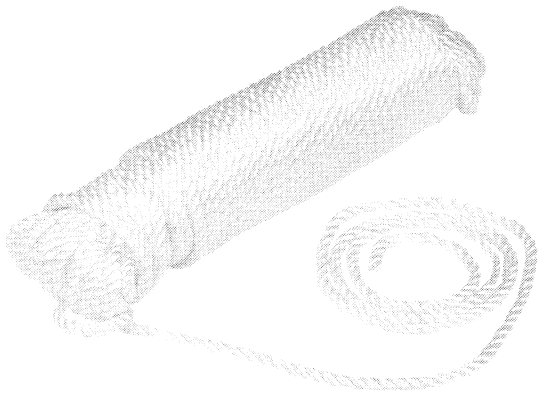


Figure 4. Nylon Rope

Polyester Rope

Polyester rope is similar to nylon rope in appearance, but is not as elastic. It will only stretch 5% before breaking.

Polyester rope is 87% as strong as nylon, but because it's not elastic, it can sustain only 60% of the shock load nylon rope can.

Polyester does not lose any strength when wet, and unlike nylon, it's not affected by acids or alkalines. For your own protection, however, you should wash polyester ropes and slings with cold water whenever they have been exposed to any chemicals.

Polypropylene Rope

Polypropylene rope, commonly called "poly rope" is the most popular general-purpose synthetic fibre rope available in hardware stores. Polypropylene rope is available in a wide range of colours, but yellow is the most common. Polypropylene rope is smooth and somewhat slippery. It's lightweight and floats on water.

Polypropylene gradually softens as temperatures increase and loses 40% of its strength at the temperature of boiling water (100°C or 212°F). Higher temperatures will eventually cause polypropylene to melt. Polypropylene rope is 60% as strong as nylon but is capable of absorbing only 40% of the shock load of nylon. Of all the rope types mentioned, polypropylene has the best insulating properties against electrical shock. It should be noted that only dry ropes should be used near sources of high voltage.

NOTES

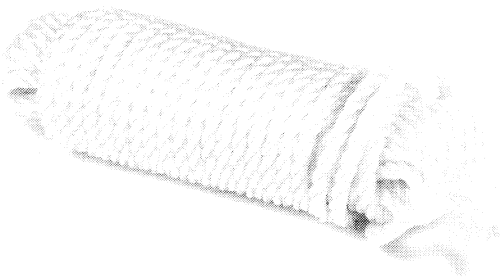


Figure 5. Polypropylene Rope

Working Load Limit for Rope

The working load limit (WLL) is a rating given to all rigging hardware, including fibre and wire rope. The rope type and diameter are the basis for calculating the working load limit. Working load limits for ropes are calculated by dividing the rope's breaking strength by the design factor set by WorkSafeBC. The design factors for fibre rope slings can be found in *WorkSafeBC, OHS Regulation, Part 15, Table 15-1* (Figure 6). Natural fibre rope must not be used for hoisting with a powered hoist (*Part 15.8*). The design factor for any rigging assembly used to hoist or support workers must be at least 10 (*Part 15.6.3*).

Component	Design factor
Nylon fibre rope sling	9
Polyester rope sling	9
Polypropylene rope sling	6
Alloy steel chain sling	4
Wire rope sling	5
Metal mesh sling	5
Synthetic web sling	5
Chain fittings	4
Wire rope sling fittings	5
Other fittings	as specified by manufacturer
Nonrotating wire rope	as specified by manufacturer but not less than 5
Conventional wire rope	5

[Amended by B.C. Reg. 381/2004, effective January 1, 2005.]

Figure 6. *WorkSafeBC, OHS Regulation, Part 15, Table 15-1*: Design Factors for Rigging

NOTES

Examples:
If the manufacturer rates a polypropylene rope's breaking strength at 770 kg, you can calculate the rope's WLL for hoisting materials as follows:

WLL = breaking strength ÷ design factor
WLL = 770 kg ÷ 6
WLL = 128 kg

If the rope is used to lift or support workers, the WLL is:

WLL = breaking strength ÷ design factor
WLL = 770 kg ÷ 10
WLL = 77 kg

If a polypropylene rope's WLL for supporting workers is 550 kg, you can calculate the rope's WLL for hoisting materials as follows:

breaking strength = WLL for supporting workers × design factor
breaking strength = 550 kg × 10
breaking strength = 5500 kg

Then:

WLL for hoisting materials = breaking strength ÷ design factor
WLL for hoisting materials = 5500 kg ÷ 6
WLL for hoisting materials = 917 kg

Never use rigging hardware, including fibre and wire rope, for hoisting unless it has a manufacturer's WLL identification attached to it.

Never use fibre rope with power lifting equipment. They can only be used with hand lifting equipment such as a block and tackle.

Basic Care and Maintenance of Fibre Rope

The life of any type of fibre rope can be greatly extended if you follow the basic care and maintenance procedures listed below.

Whipping

Whipping is a wrapping applied at the end of a rope to prevent the rope strands from unraveling. Whenever a rope is cut to a new length, the ends of the rope should have whipping applied before the rope is put into service.

Whipping is more than just a tidy decoration. It prevents the strands of the rope from slipping in relation to each other. Such slipping would cause one strand to carry more (or less) than its fair share of the load. .

NOTES

To apply whipping to a rope, use a strong, non-slipping twine. If the twine tends to slip, pulling it over soft tar, beeswax, or pine pitch will usually correct the problem. Tape may be used as whipping if applied tightly. Always apply whipping or tape with the lay of the rope. Replace whipping when it shows signs of fraying or loosening.

How to Apply Whipping

1. Begin by holding one end of the whipping twine at the end of the rope. Then form a long loop along the rope.

2. Hold the end of the whipping twine (A) and the left end of the loop with your left hand and begin wrapping the other end of the whipping twine (B) around both the rope and the long loop.

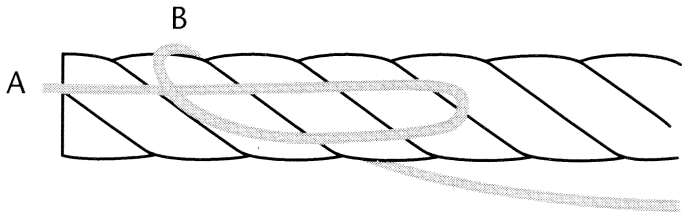


Figure 7. Loop the Twine

3. Continue to apply wraps as close to each other as possible until you have covered a distance approximately 1½ times the rope diameter.

4. Pass the whipping twine end (B) through the loop.

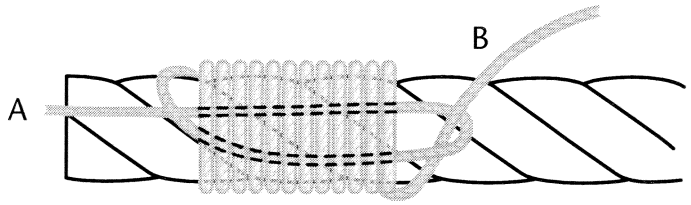


Figure 8. Pass the End Through the Loop

5. Pull on the whipping twine end (A) until you feel that the crossover of the twine is centered under the whipping.

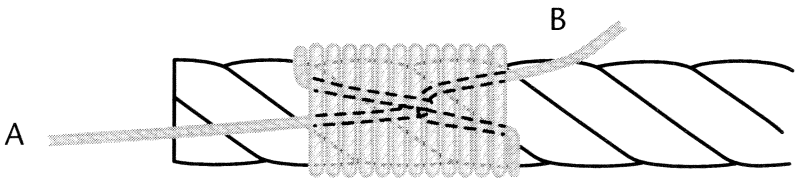


Figure 9. Pull the Crossover to the Centre of the Whipping

6. Trim both ends of the whipping twine as close as possible to the whipping. Then trim the end of the rope so that a length about half the rope's diameter projects beyond the whipping.

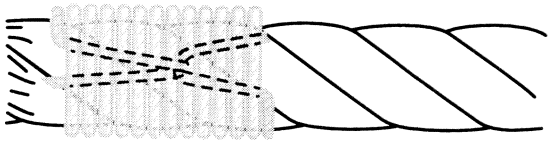


Figure 10. Trim the Ends

For nylon, polyester, or polypropylene ropes, instead of using whipping, you can melt the fibres together with a hot iron or flame. Roll the end of the melted rope between two flat surfaces (scraps of wood) while the rope cools or the end might wind up larger than the diameter of the rope. When the ends of the rope are larger than the rope diameter, they make rigging and knot untying more difficult.

When you are using a hot iron or flame to melt the synthetic rope fibres, be careful not to burn yourself.

Care and Storage

Rope should be kept clean. Soil embedded in the fibres acts as an abrasive, wearing it down. Soiled rope should be washed in cool water, loosely coiled, and hung in a well-ventilated area to dry before storage. Apart from this cleaning, rope requires very little maintenance.

Ropes should not be overloaded—the maximum load should never be more than one-fifth of its breaking strength.

Avoid exposing rope to direct sunlight for long periods of time. Too much exposure causes its fibres to break down.

Do not use frozen rope. If you must handle rope that is frozen, do so very carefully, as any bending may break the strands. To prevent rope from freezing, dry it well before exposing it to cold weather.

Avoid making sharp bends in rope. Sharp bends, including those made by knots, can reduce the rope's strength by 50%. Carefully remove any kinks or small loops before pulling a rope taut. Always pad or soften the sharp corners of a load before applying the rope.

When attaching a small-diameter object such as a hook or ring to a rope, use a thimble to protect the eye of the rope (Figure 11).

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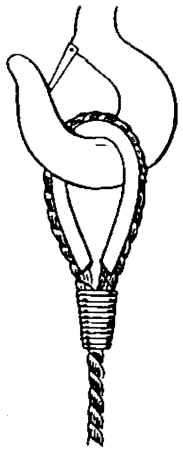


Figure 11. A Thimble Protects the Eye

To remove new rope from its shipping coil: place the coil on its side, reach down inside and pull the rope up from inside the coil. Leave the outer wrapping intact.

To store a rope: coil it in a clockwise direction, then hang it on large diameter pegs in a cool, dry room with good air circulation to prevent mildew. Improper storage of fibre rope leads to rot, brittleness, crushed fibres, kinks, and many other defects.

With basic care and proper storage, fibre rope will provide many years of service. If left lying around on the ground or stored in musty, dank areas, fibre rope could rot, become brittle, develop kinks, or become defective in many other ways.

Give the rope a thorough visual inspection before performing any lifting tasks. When inspecting a fibre rope, look for:

- broken strands
- wear and abrasion
- heat damage, such as melting
- contamination with petroleum products
- evidence of rot or damage from exposure to the elements
- crushing, twisting, or kinking
- loose, broken, or damaged thimbles
- any damage that will affect the lifting capacity of the rope

Basic Knots, Bends, and Hitches

NOTES

To use any rope effectively, you must first be able to choose the correct knot, bend, or hitch for a given situation. The knot, bend, or hitch must support the load placed on it, be quick and easy to tie, and be easy to untie once the load has been removed.

Parts of a Rope

To better understand the following instructions on knot tying, you will need to know the parts of a rope.

The starting point for most knots is a loop (Figure 12). The portion of the rope that forms the loop is called the "bight." The long portion of the rope is called the "standing part." The end of the rope is called just that, "the end." This is the part that moves when you tie most kinds of knots.

The overhand loop is formed by passing the end of the rope over or in front of the standing part of the rope. When the end of the rope passes under or behind the standing part of the rope, it's called an "underhand loop" (Figure 13).

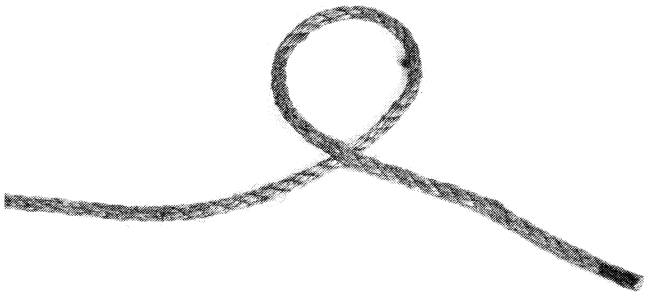


Figure 12. Overhand Loop

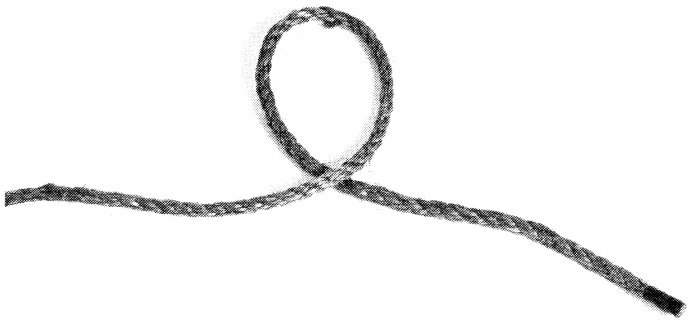


Figure 13. Underhand Loop

NOTES

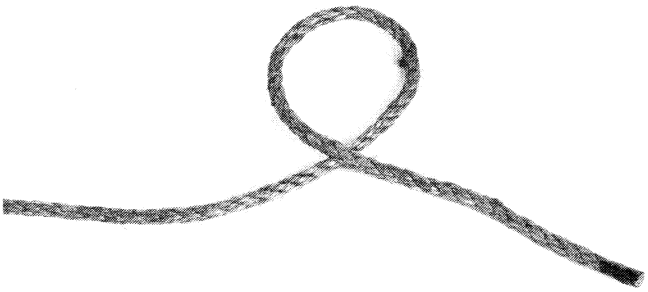
Basic Knots

Animated illustrations of the following eight knots, bends, and hitches are available on the Internet. It may be helpful to view these animations as you read through the descriptions on the following pages.

Bowline

The bowline knot forms a non-slip loop at the end of a rope (Figure 14).

To tie a bowline, form a small loop by passing the end of the rope over the standing part. Pass the end under the bight and pull it up through the loop. Pass the end behind the standing part, and then back down through the loop. Tighten the knot by holding both the end of the rope and the loop in one hand and the standing part in the other. Pull until the knot is tight.



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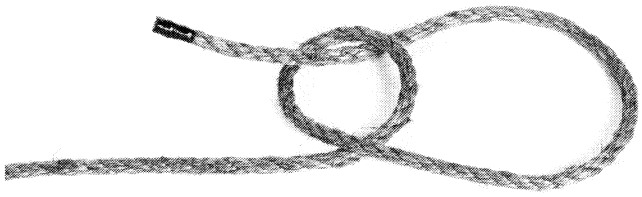

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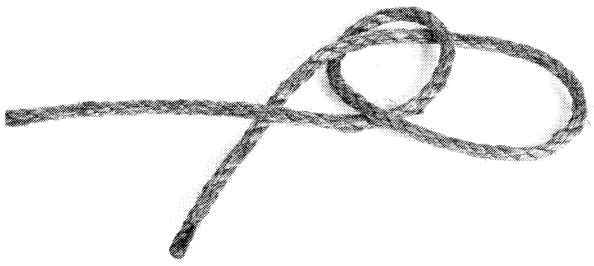

Step 3

Figure 14. Bowline Knot
(continued on the next page)

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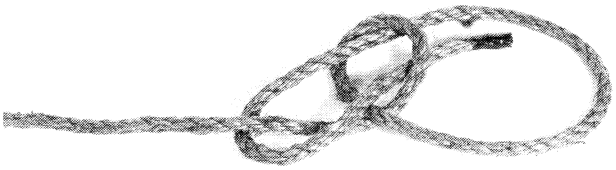

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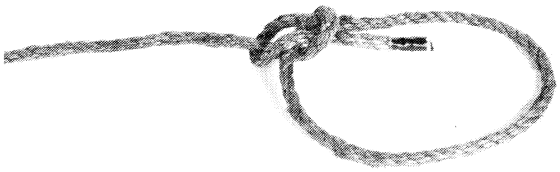


Step 5

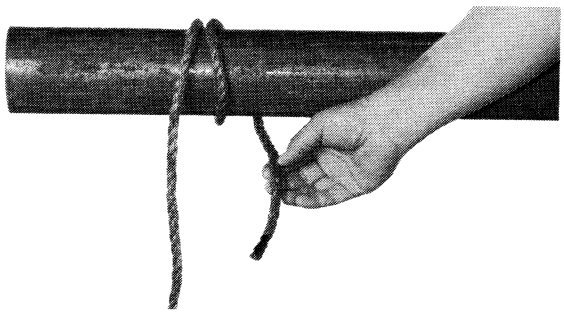
Figure 14. Bowline Knot

To untie the bowline, loosen the knot by pushing the loop that is around the standing part of the rope away from the knot. Once the knot is loosened, it's easily untied.

Use the bowline when you need a slip-proof loop.

Round Turn with Two Half Hitches

To make a secure fastening, a half hitch is often tied to the standing part twice (Figure 15). To make this round turn with two half hitches, you must first pass the rope completely around the object being attached. Then pass the end of the rope around the standing part and pull the end between the object and the rope.



Step 1

Figure 15. Round Turn with Two Half Hitches
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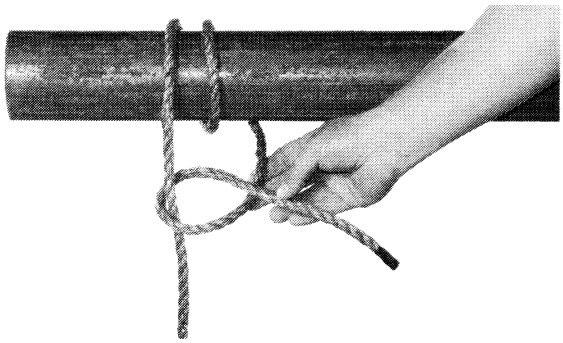

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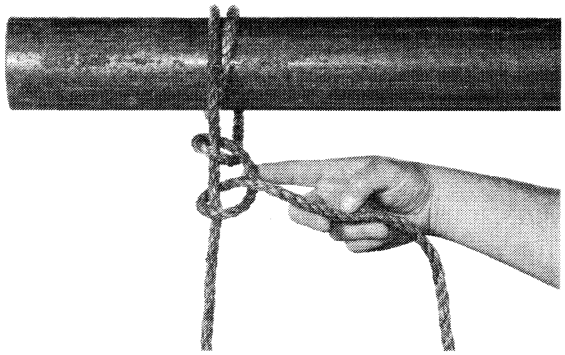

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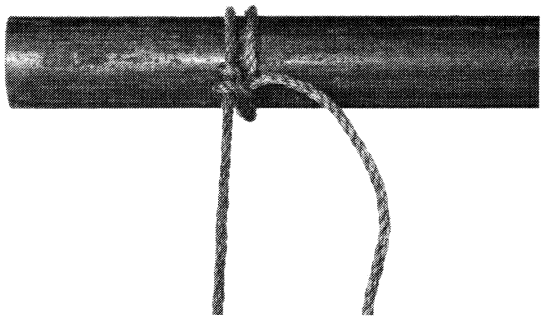


Step 4

Figure 15. Round Turn with Two Half Hitches

Continue with a second loop around the standing part of the rope, making sure both loops are made in the same direction. (If one loop is clockwise and the other counter-clockwise, the hitch will be difficult to untie.)

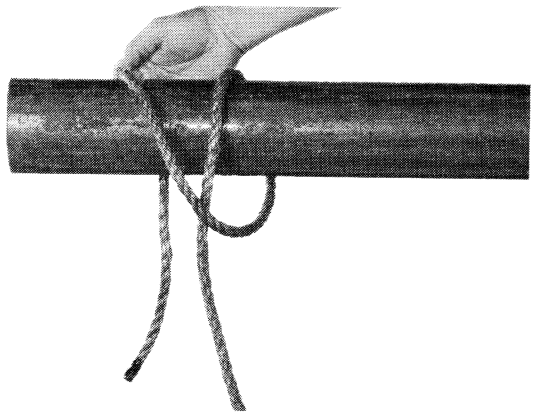
Finish by passing the end of the rope between the standing part and the two loops. As the standing part is pulled tight, the loop around the object will slip until the two half hitches have jammed tightly to the object. They will not come untied if the pull on the standing part is relaxed.

NOTES

Clove Hitch

Use the clove hitch to secure a rope to a fixed object, such as a post.

To tie a clove hitch, make two wraps around the object. Make the first wrap to one side of the standing part and the second wrap to the opposite side of the standing part. Then pass the end of the rope between the object and the second wrap. Pull the two wraps close to each other. Pull the standing part and the end in opposite directions. You can make the clove hitch even more secure by tying the end to the standing part with a single half hitch.



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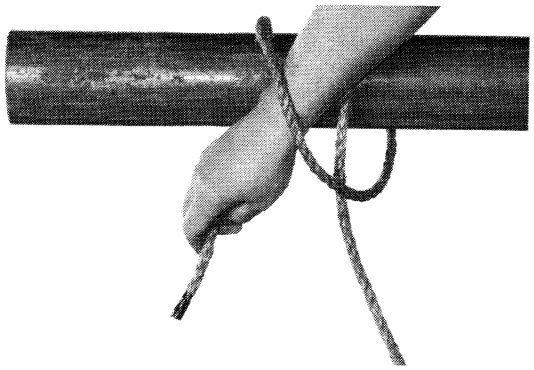

Step 2

Figure 16. Clove Hitch
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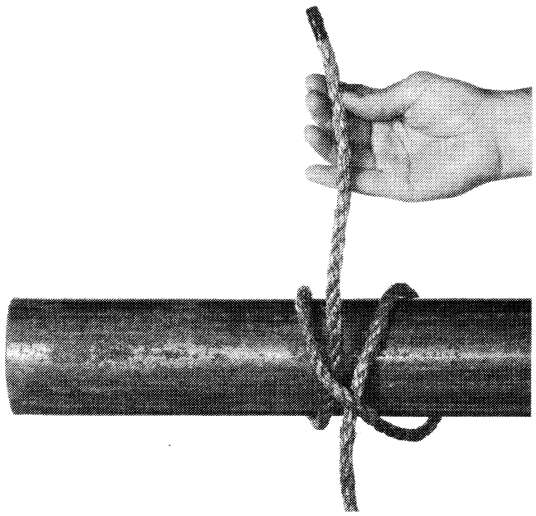

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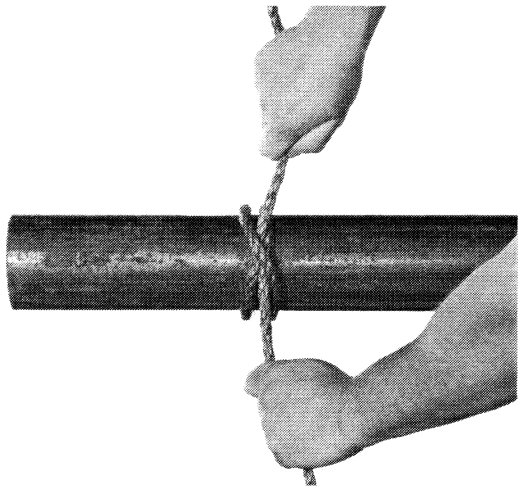


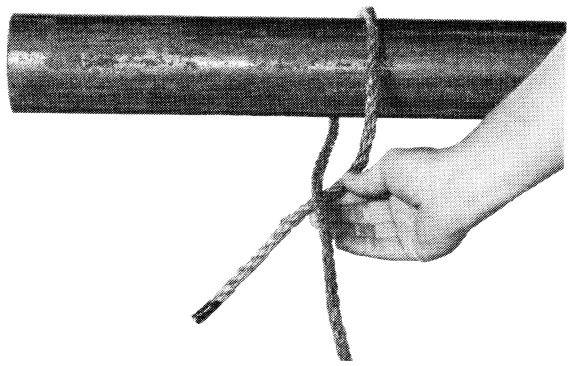
Step 4

Figure 16. Clove Hitch

Timber Hitch

Use the timber hitch to secure a rope to a plank, timber, post, tube, or pipe when you want to lift that object in a vertical position.

The timber hitch is a series of modified half hitches. To tie a timber hitch, begin by tying a single half hitch around the object. Then pass the free end of the rope between the object and rope two more times.



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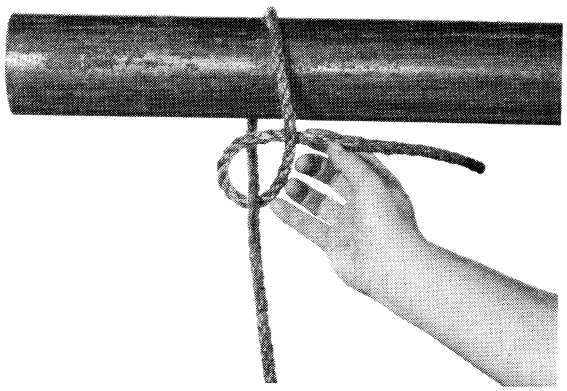

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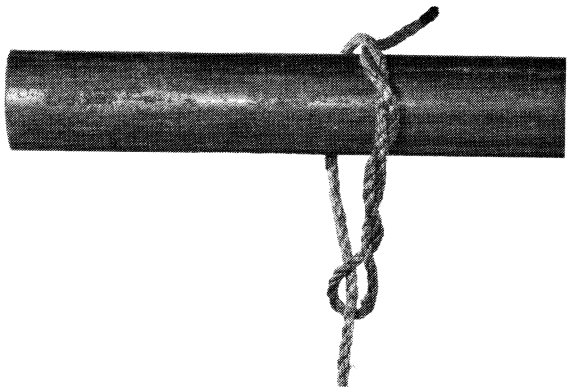

Step 3

Figure 17. Timber Hitch
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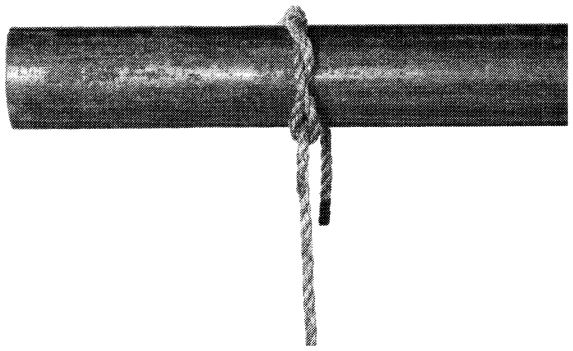


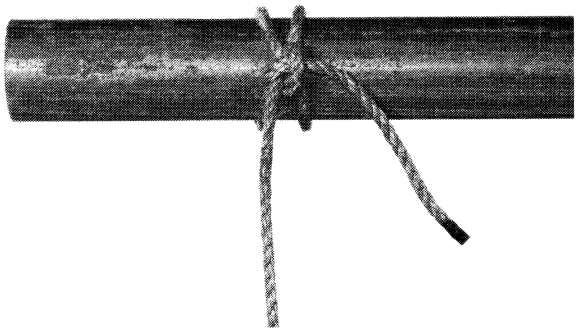
Step 4

Figure 17. Timber Hitch

Pull the hitch tight by pulling the standing part of the rope at 90° to the object. It is common to tie one or more half hitches along the length of the object with the standing part of the rope as seen in Step 4 of Figure 17.

Running Half Hitch

A running half hitch is often used together with the round turn and two half hitches, the clove hitch and the timber hitch. This gives the knot a much better grip on an object being lifted in a vertical position. In this example, we will use a clove hitch as the main knot and add two running half hitches (Figure 18).



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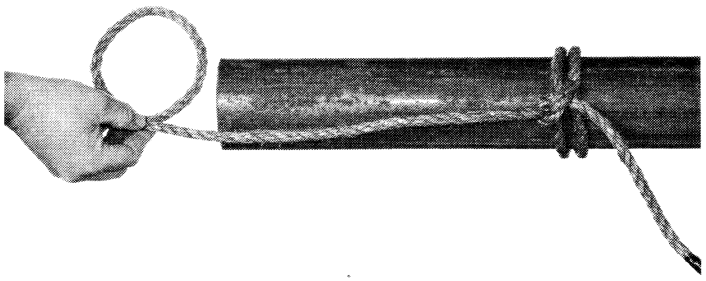

Step 2

Figure 18. Running Half Hitches
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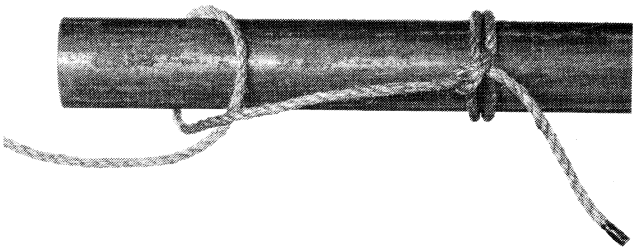

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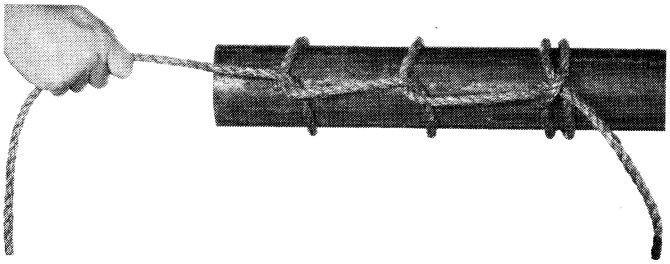


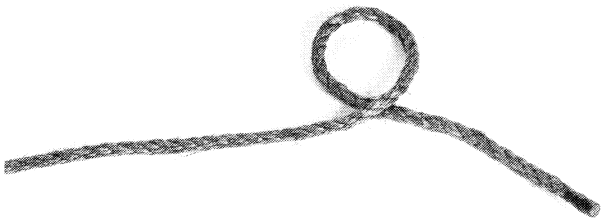
Step 4

Figure 18. Running Half Hitches

Simply make an underhand loop and slip it on the end of the object being lifted about 30–60 cm (12–24 in.) from the original knot. Repeat for a better grip.

Single Dutchman

The single Dutchman is a very useful knot for tying down a load. The knot forms a slip-resistant loop that acts like a pulley in a block and tackle system. You can generate almost three times as much tension on a rope using the single Dutchman as you would if you just pulled on a straight rope.



Step 1

Figure 19. Single Dutchman
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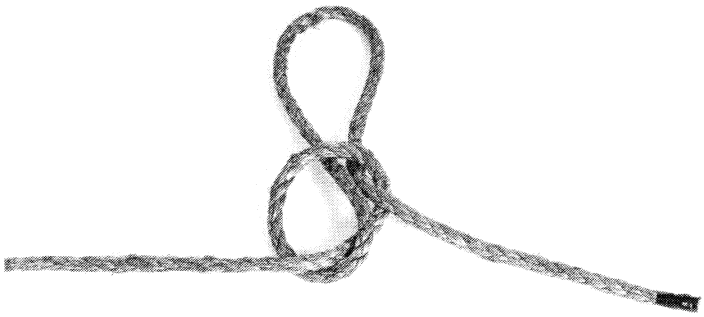
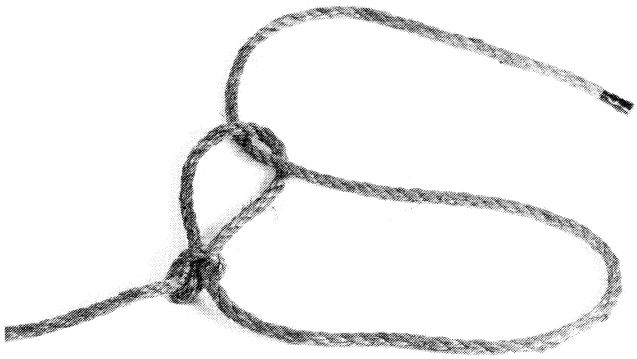


Step 2

Step 3



Step 4

Figure 19. Single Dutchman

To tie the single Dutchman, form a loop on the standing part of the rope about 1 metre (3 ft.) from the second point of anchorage (Step 1, Figure 19).

Place the bight end of the rope end through the loop (Step 2, Figure 19), creating a slip knot.

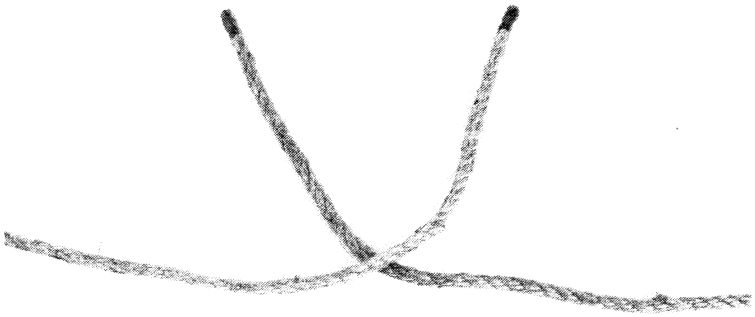
Tighten the slip knot by pulling on both the bight that you pulled through the loop and the free end of the rope (Step 3, Figure 19). Both the bight and the free end are pulled away from the standing part of the rope.

NOTES

To create the Dutchman, take the end of the rope and run it around the anchor point and back up through the loop formed by the slip knot. Once the end is through the bight of the slip knot, pull it towards the anchor point, away from the standing part (Step 4, Figure 19). When enough tension is applied, tie off with one or two half hitches.

Reef or Square Knot

Use the reef knot or square knot to fasten together two ropes of equal diameter. To tie the knot, cross the ends of the ropes and turn one rope around the other. Then cross the ends again and turn one end around the other end, making sure the second turn is done in the opposite direction to the first.



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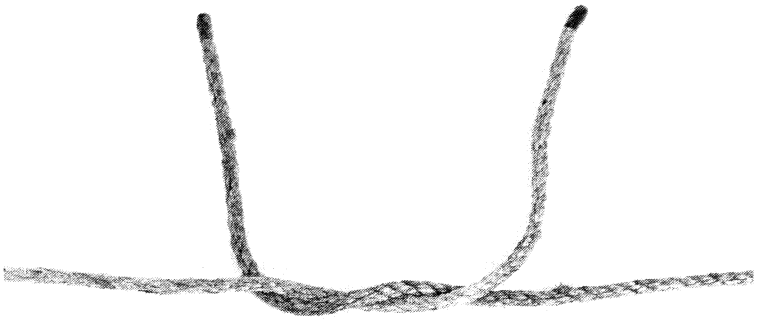

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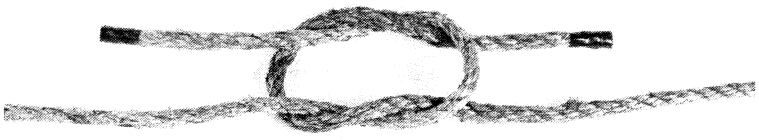

Step 3

Figure 20. Reef or Square Knot
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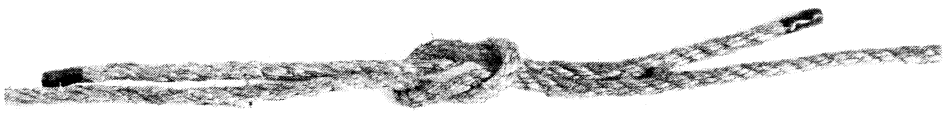


Step 4

Figure 20. Reef or Square Knot

You can remind yourself how the reef knot is tied by using the following verse:

left over right
then
right over left

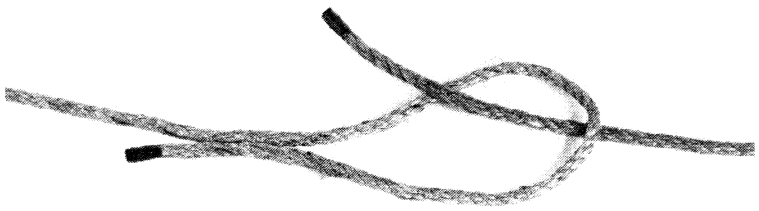
Regardless of which method you use to remember this, be sure that your reef knot has both the standing part and the end of each rope on the same side of the loop formed by the other rope.

Sheet Bend

Use the sheet bend to attach two ropes of unequal diameter to each other.

To tie the sheet bend, form a loop or eye with the larger diameter rope. Then pass the end of the smaller diameter rope through the loop, around the back of the end and standing part of the larger rope, and then under the section of the smaller rope where it first came through the loop.

Continue with the small end until it lies across the top or face of the loop formed by the larger rope. Hold both the standing part and the end of one rope in each hand and pull in opposite directions to tighten the sheet bend.



Step 1

Figure 21. Sheet Bend
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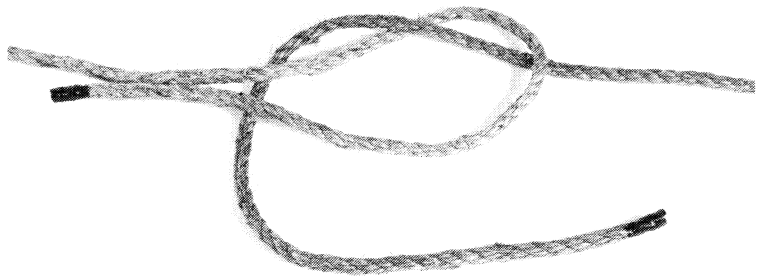

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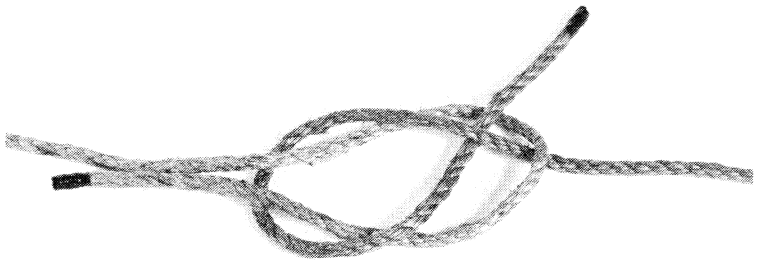
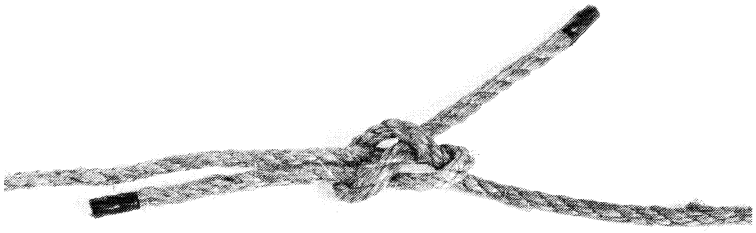


Step 3



Step 4

Figure 21. Sheet Bend

Remember: Any knot bend or hitch will reduce the rope's WLL by 50%. Do not join ropes for overhead lifting, use only single-piece ropes.

NOTES

NOTES

Learning Task 7

Use Visual and Sound Signals

Operator Qualifications

WorkSafeBC, OHS Regulation, Part 14.34:

(1) A crane or hoist must only be operated by a qualified person who has been instructed to operate the equipment.

Qualified Riggers

WorkSafeBC, OHS Regulation, Part 15.2:

Rigging and slinging work must be done by or under the direct supervision of qualified workers familiar with the rigging to be used and with the code of signals authorized by the Board for controlling hoisting operations.

Whenever the operator of lifting or hoisting equipment is unable to obtain a clear view of the path of the load or of the path of the equipment, a competent signaler must be stationed in a position with a clear view of the operation and the operator. That signaler must direct all movements of the load from this vantage point.

Sound or Light Signals

When the lifting apparatus is a hoist capable of moving only up or down and not sideways, the only signals used are: "RAISE," "LOWER," "STOP," and "ALL CLEAR."

Hoists of this kind usually have safety gates that, when open, prevent operation of the hoist. Nevertheless, a hoist operator must not operate the hoist until the "ALL CLEAR" signal has been given.

The "ALL CLEAR" signal tells the operator that the workers using the hoist are finished with it, and that the hoist operator can again operate it safely.

NOTES

Since the operator of such a hoist might not always be able to see the signalers, a system of sound signals or light signals has been devised. The sound signals are short bursts from a horn or rings of a bell, and the light signals are short flashes from a light source. Both use the same code:

- "STOP"—one bell or flash
- "RAISE"—two bells or flashes
- "LOWER"—three bells or flashes
- "ALL CLEAR"—four bells or flashes

During poor operating conditions, light and sound signals can be used together.

An easy way to remember light and sound signals is to consider the urgency of each signal.

- "STOP" could be an emergency, so it is the shortest—one bell.
- "RAISE" could have more urgency than "LOWER," so it gets two bells.
- "LOWER" is left with the signal three bells.
- There is no urgency attached to the signal "ALL CLEAR," so it is the longest—four bells.

Hand Signals

Hand signals can be found in *WorkSafeBC, OHS Regulation, Part 15.20.*

Cranes that are capable of more than just up and down movement of their hook are controlled by the following hand signals:

To Signal "UP" or "HOIST"

With your forearm vertical and your forefinger pointing up, move your hand in small horizontal circles (Figure 1).

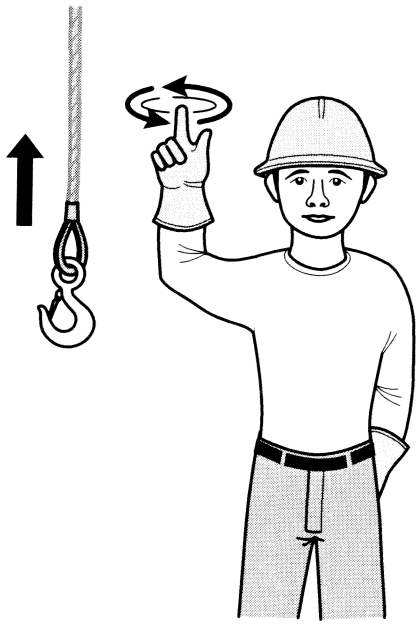


Figure 1. Up or Hoist

NOTES

To Signal "LOWER"

With your forearm extended downward and your forefinger pointing down, move your hand in small horizontal circles (Figure 2).

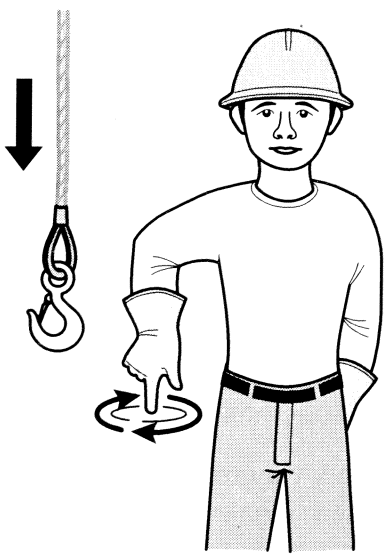


Figure 2. Lower

To Signal "STOP"

If both your hands are free, extend both arms horizontally with your fingers outstretched (Figure 3A). If only one hand is free, signal "STOP" by facing the palm of your hand toward the operator with your fingers outstretched and waving your hand from side to side (Figure 3B).

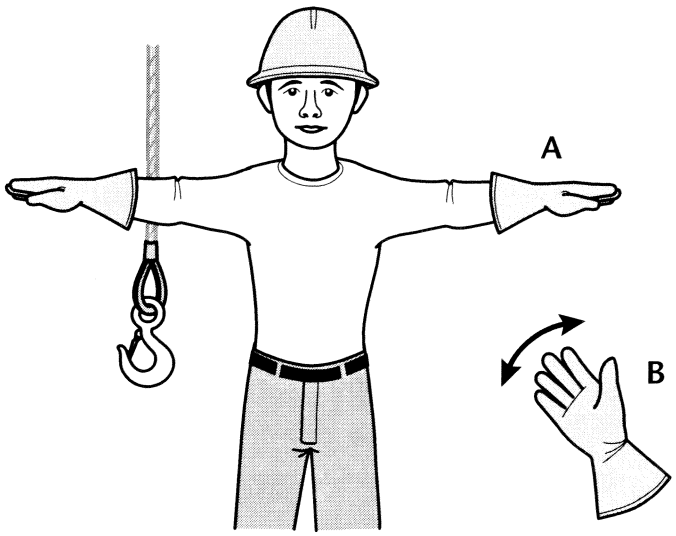


Figure 3. Stop

Boom Signals

NOTES

Raising or lowering the boom is signaled with the arm extended, the fingers closed and the thumb indicating whether you want the boom raised or lowered (Figure 4).

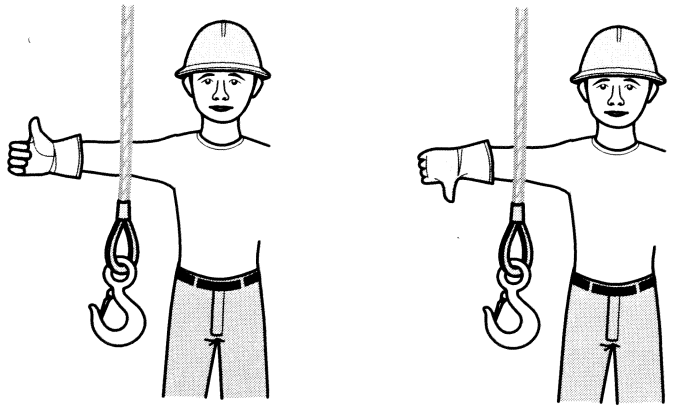


Figure 4. Raise Boom and Lower Boom

Cranes that are equipped with an extendible (telescoping) boom can be signaled to lengthen or shorten the boom. You do this by holding your fists in front of your body and pointing your thumbs inward (to retract the boom) or outward (to extend the boom) (Figure 5). These signals may be done with only one hand when required.

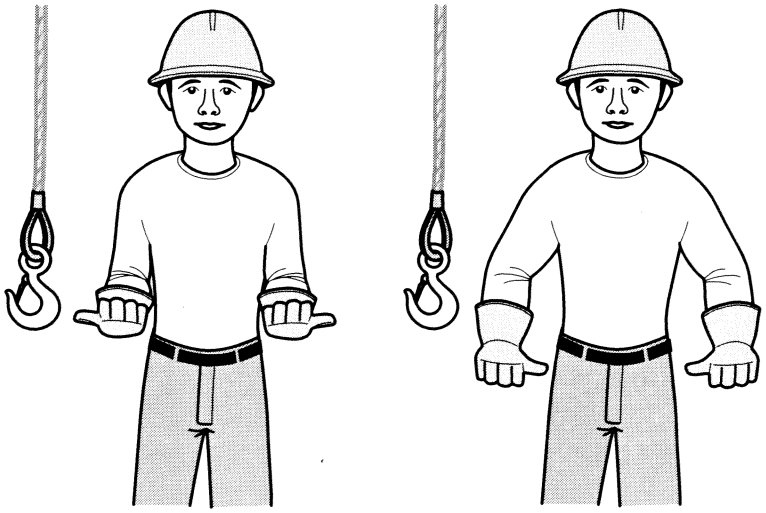


Figure 5. Extend Boom and Retract Boom

NOTES

To signal the crane operator to swing the boom, extend one arm and point with the index finger to indicate the direction of the swing (Figure 6).

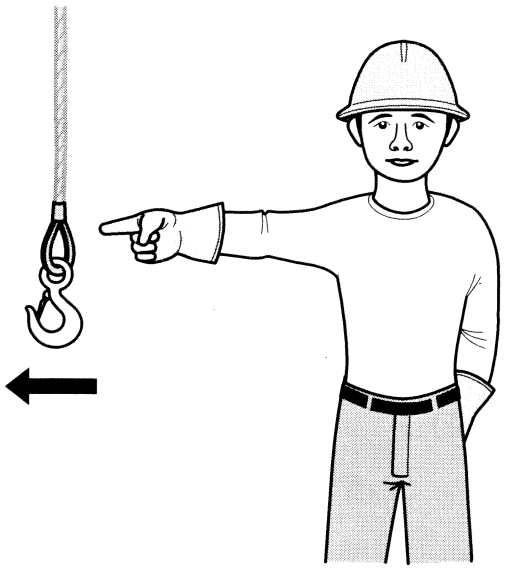


Figure 6. Swing Boom

Dual motions can be signaled to the crane operator. You can signal the operator to lower the boom while raising the load (which causes the load to move away from the crane) or to raise the boom while lowering the load (which moves the load closer to the crane). You can do this with one or both hands. When you are using only one hand, your thumb indicates the direction of the boom and flexing your fingers indicates the movement of the hook (Figure 7B).

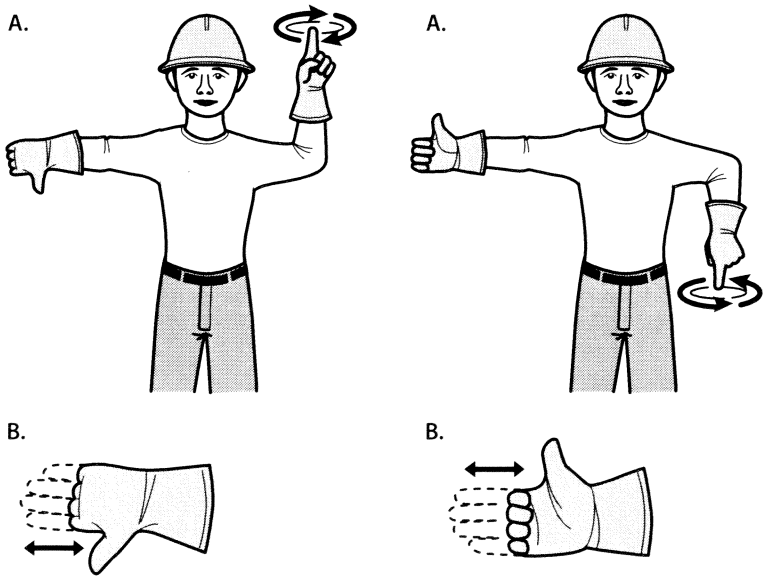


Figure 7. Lower the Boom-raise the Load and Raise the Boom-Lower the Load

NOTES

Line Signals

Some cranes have a jib to extend the crane's reach (Figure 8). A whip line or auxiliary hoist is attached to the jib while the main line is suspended from the boom.

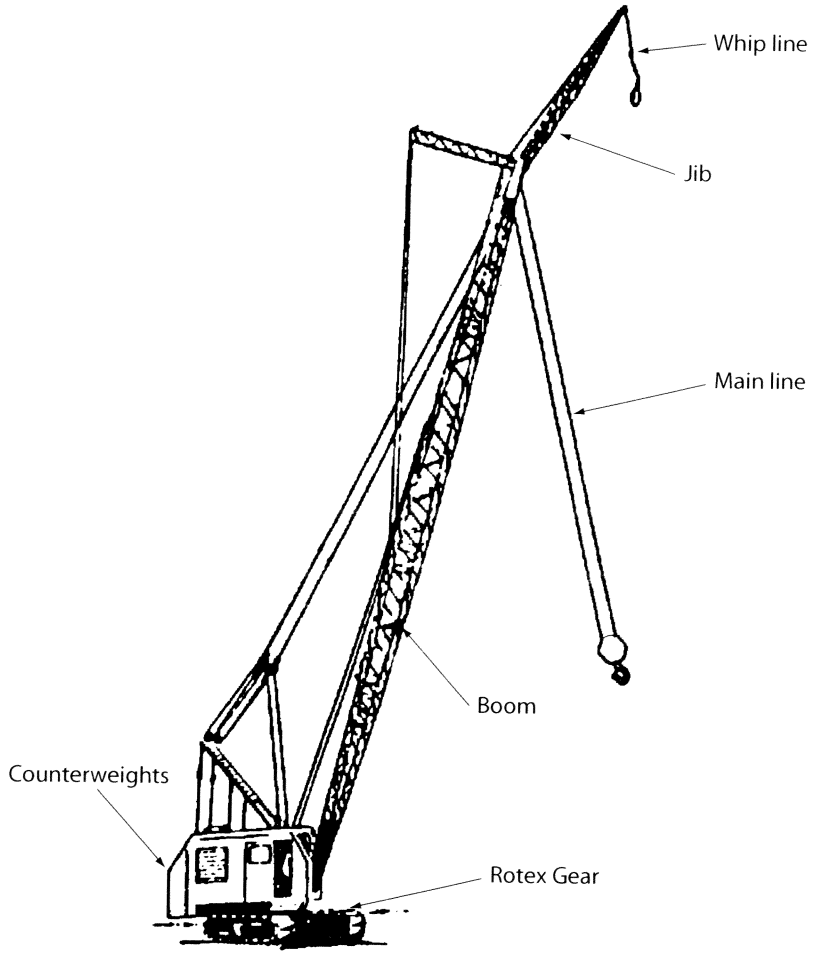


Figure 8. Crane Equipped with Jib

The following signals tell the crane operator which line to use:

- To signal the operator to use the main line, tap your fist to your head (Figure 9A). Then use regular signals to direct further movement.
- To signal the operator to use the whip line, tap your elbow with one hand or point to your shoulder (Figure 9B). Then use regular signals to direct further motion.

NOTES

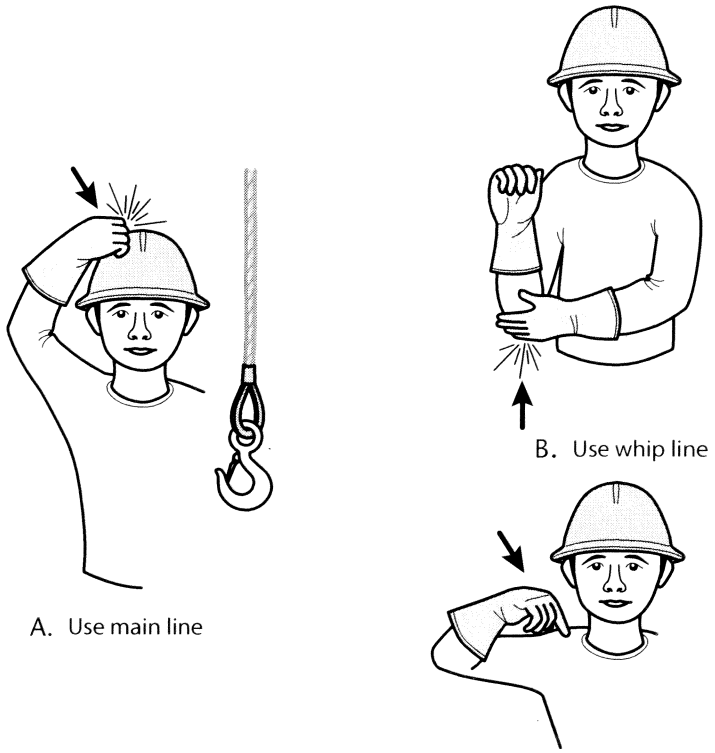


Figure 9. Use Main Line and Use Whip Line

To Signal "MOVE SLOWLY"

To signal slow movement, hold the palm of your free hand motionless in front of your other hand as it is giving the signal for the required movement (Figure 10).

Figure 10. Hoist Slowly

To Signal "DOG EVERYTHING"

The "DOG EVERYTHING" signal is given by clasping your hands in front of your body (Figure 11). The crane operator locks all crane functions at this signal.

Figure 11. Dog Everything

Practice these signals until they become almost automatic to you. They're used by the crane signaler to communicate with the crane operator. They're also used by workers to communicate with the crane signaler. These signals are common to all trades and work sites.

NOTES

NOTES

Learning Task 8

Select, Use, and Maintain Hoisting Equipment

No person shall operate any lifting or hoisting equipment without training. All training must be provided by a qualified instructor.

Manual Lifting Devices

Manual lifting devices include:

- block and tackle
- chain hoist/fall
- come-along
- Griphoist (Tirfor)

Block and Tackle

A block and tackle uses fibre ropes rather than wire rope. A block and tackle is capable of increasing lifting capacity. This increase can be calculated by counting either the number of ropes that leave the travelling block or by counting the number of pulleys.

For example, a block and tackle with six pulleys (Figure 1), three on the fixed block and three on the movable block, could lift a 1200 kg load by exerting a pull of only 200 kg. This is important because the load being lifted could be considerably greater than the breaking strength of the rope.

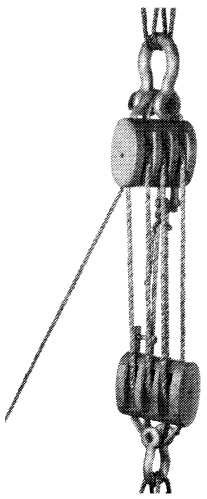


Figure 1. Block and Tackle

A block and tackle has no braking device or safety system. It cannot support a load unless the line is anchored.

Chain Hoist

Chain hoists, commonly called "chain falls," are lifting devices that move loads either up and down or sideways, but never both at the same time. Chain hoists are most often used for vertical lifts, but some can be used for horizontal pulls. Chain hoists are hand operated and are available in a variety of capacities from 450–9000 kg (1000–20 000 lb.). The lifting capacity of a chain hoist must be clearly marked on the hoist. Never exceed this capacity.

Movement of the load is slow and distance per lift is limited by the length of the lifting chain. A chain hoist operates by pulling on the endless hand chain, which turns the drive pulley. The drive pulley is connected to the lifting chain by a series of reduction gears that multiply the amount of force the operator exerts on the hand chain. To lower loads, you simply pull the hand chain in the opposite direction.

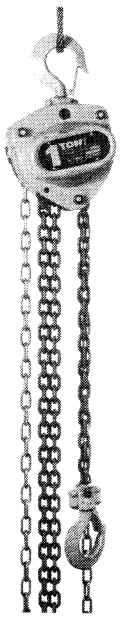


Figure 2. Chain Hoist

Come-alongs

Come-alongs (or hand winches) are similar to chain hoists except that they are activated by a ratchet lever rather than by an endless chain. They're more convenient for horizontal pulls than chain hoists, although they usually have a smaller capacity than chain hoists. As with chain hoists, their capacity should be clearly marked and never exceeded.

Come-alongs are very useful in fabricating shops for pulling structural members into position before tacking and welding. Come-alongs can use either a chain or a cable. The inspection procedures for come-alongs include the inspection of the lifting medium, whether chain or cable. The requirements for safety with cable, chain, hooks, or other attaching devices are the same for all lifting devices. Never substitute regular chain for the original lifting chain supplied with the come-along. Do not use any extensions on the handle to apply greater force.

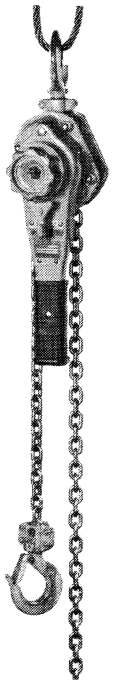


Figure 3. Come-along

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NOTES

Griphoists (Tirfors)

Griphoists, or Tirfors, are hand-operated lifting or pulling devices that have an unlimited amount of rope travel. Griphoists work by direct pull on a wire rope, with the pull applied by means of two pairs of self-energizing smooth jaws that exert a grip on the rope in proportion to the load being lifted or pulled. The initial pressure that causes the jaws to grip the rope and starts the self-energizing action is provided by springs. This initial pressure is about 800 kPa (120 psi).

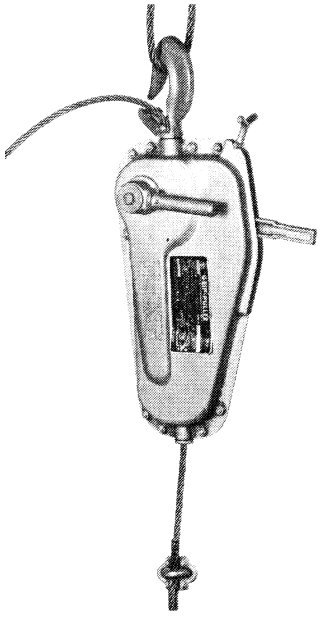

Figure 4. Griphoist (Tirfors)

The two levers that activate these jaws provide a forward or backward motion to the rope, depending on which lever is used. A removable pipe handle is used to operate these levers. The griphoist can be attached directly above the load or it can be anchored near the ground.

Griphoists are available in various capacities. Three common sizes are 750 kg (1650 lb.), 2400 kg (5300 lb.), and 3000 kg (6600 lb.). All griphoists have built-in overload protection, which consists of a shear pin that breaks when the load is heavier than the rated capacity. This prevents the load from moving any farther.

Always replace the griphoist wire rope with another piece of wire rope that has the same specifications as the original.

Hoists

NOTES

Electric Hoists

Electric hoists are much more efficient than manual hoists. They usually have a push-button control suspended from a chain or wire rope.

Both manual and electric hoists can be stationary or movable. The movable types are used on overhead runways, gantry cranes, jib cranes, and overhead travelling cranes.

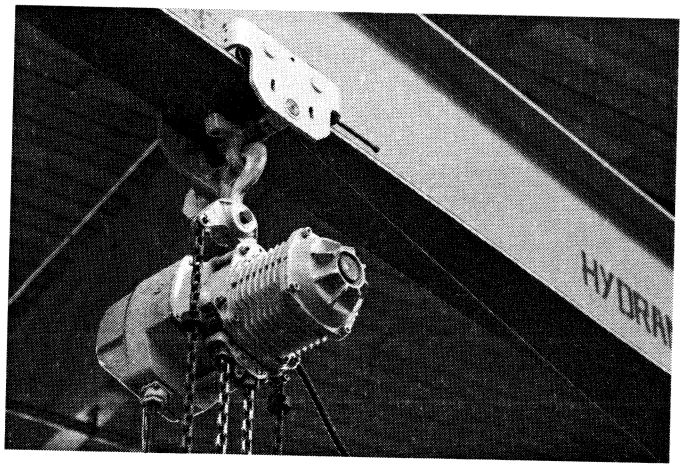

Figure 5. Electric Hoist

Some hoists are manually pulled along the overhead runway or boom, while others may be motor driven. Hoists are manufactured in many capacities from less than 900–11 000 kg (2000–24 000 lb.) and more.

WorkSafeBC, OHS Regulation, Part 14.19 requires that all hoists be equipped with drop stops.

Superstructures for Hoists

Cranes and Hoists Standards (*WorkSafeBC, OHS Regulation, Part 14.2*)

(1) Except as otherwise required by this Regulation, a crane or hoist must be designed, constructed, erected, disassembled, inspected, maintained, and operated as specified by the manufacturer or a professional engineer, and to meet the requirements of the applicable standard listed in subsections (2) to (15).

NOTES

Hoists are usually suspended from an overhead support. The overhead support might be stationary and provide for vertical lifting only, or it might also provide a means for moving the load from one area to another. These support structures must have rated capacities greater than that of the hoist. The rated capacity must be clearly marked on these superstructures. All superstructures must be certified for rated capacity by an engineer or the manufacturer.

Gantry Cranes

A basic support structure that also provides mobility is the gantry crane (Figure 6). With this superstructure, the load can be lifted and then the entire crane assembly and the load can be moved.

Figure 6. Gantry Crane

Overhead Runways

Runways usually consist of "W"-type or "S"-type structural steel beams that are either fastened to heavier crossbeams on the ceiling or mounted on floor supports. The hoist is attached to rollers or trolleys that run along the bottom flange of the beam.

Runways are used extensively in fabricating shops to move materials. They often extend from outside loading, unloading, and storage areas into the shop. Switches, loops, and drop arms can be provided to move material to several locations within a shop.

NOTES

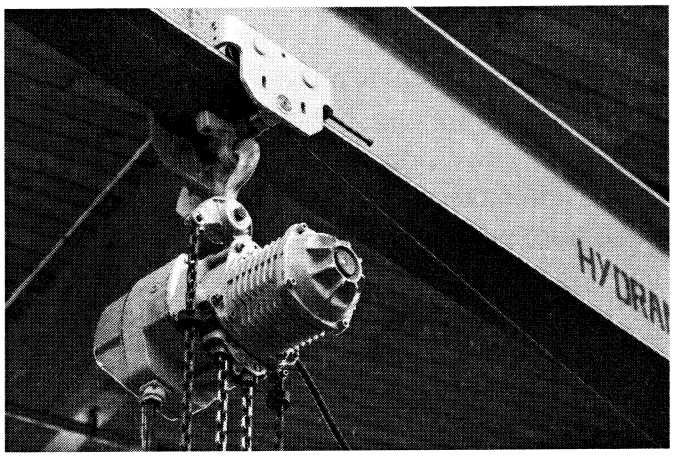

Figure 7. Overhead Runway

Overhead Travelling Cranes

Overhead travelling cranes are also called "gantry" or "bridge" cranes. They can be classified as either over-slung or under-slung, depending on where the hoist assembly is actually mounted. The over-slung type generally has a greater load-carrying capacity. The beam on which the hoist assembly moves is mounted on top of trolleys that move along parallel runways. Under-slung travelling cranes are used for lighter loads, usually not more than 900 kg (2000 lb.). The hoist-carrying bridge or beam is mounted below the trolleys.

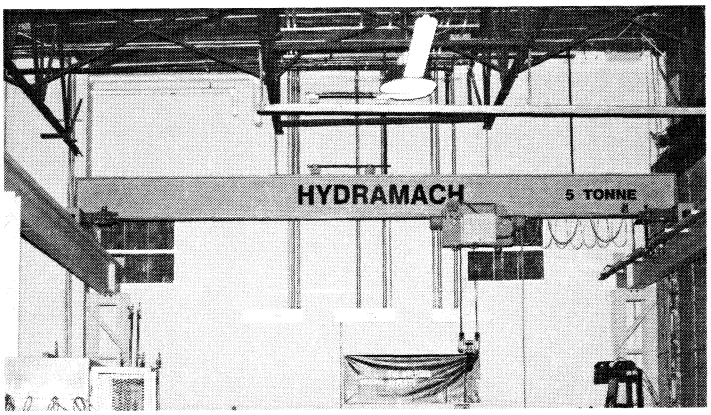

Figure 8. Overhead Travelling Crane

NOTES

Jib Crane

Another type of support structure is the jib crane. The main identifying feature of the jib crane is a rotating boom that is attached to a vertical member (Figure 9). Jib cranes may be wall mounted or they can be mounted on a pedestal. The entire crane assembly can also be mounted on rails for moving materials from one area of a shop to another.

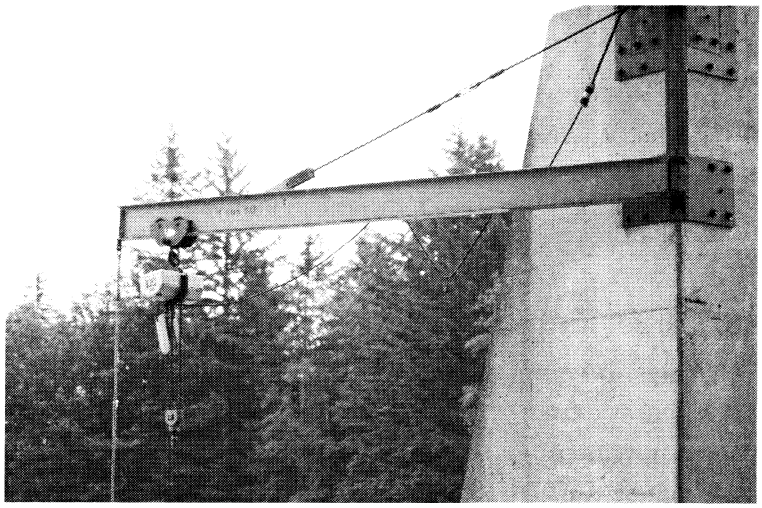

Figure 9. Jib Crane

Learning Task 9

Lift, Hoist, and Move Loads

NOTES

Before you attempt to lift, hoist, or move any type of load, there are facts you must consider:

- What is the estimated weight of the load?
- Is your lifting device rated to handle that weight?
- Is the load balanced so that it won't tip?
- How high are you lifting the load?
- Do you have enough room?
- Do you have to roll the object over? How can this be done safely?
- Are you lifting alone or with co-workers?
- Do you know the hand signals when co-workers are operating the lifting device?

A well-thought-out plan will result in a safe and successful lift.

Centre of Gravity

The centre of gravity is the point at which an object will balance regardless of its orientation. A suspended object will always move so that its centre of gravity is located directly below its point of support.

This must be considered whenever you rig any load, but is particularly important when hoisting with a crane. You must estimate the location of the centre of gravity of the object to be hoisted, then use a sling arrangement that will position the lifting hook directly above this point (Figure 1). Another important consideration when hoisting with a crane is the deflection of the boom. This means that as the load is lifted, the boom will bend downward, and therefore the hoisting line will be at an angle. The load will then have a tendency to swing away from the crane.

NOTES

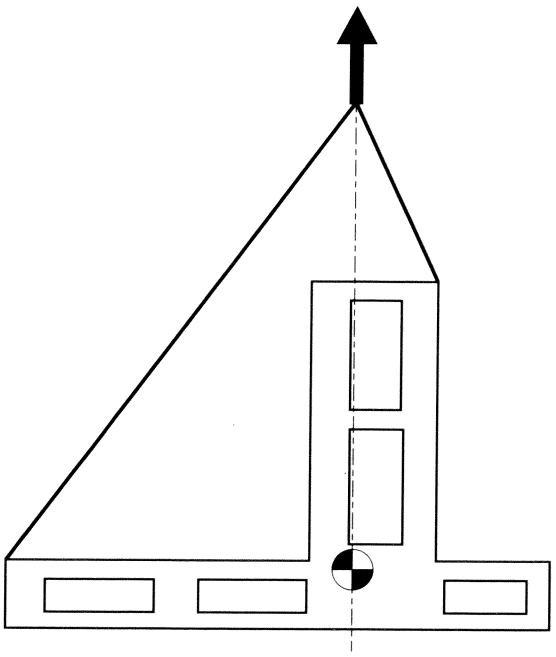

Figure 1. Stable Load

If a load is rigged with the hook offset from the centre of gravity, it will shift or tilt once lifting commences (Figure 2).

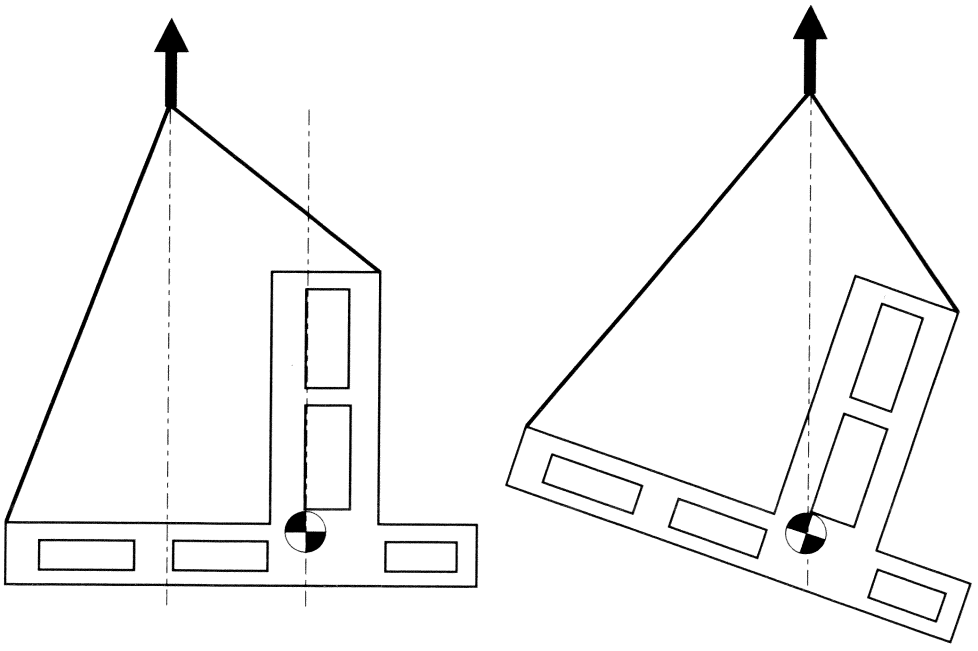

Figure 2. Unstable Load

NOTES

If a load is rigged such that the centre of gravity is above the hoisting points (as shown in Figure 3), there is a danger of the load flipping over.

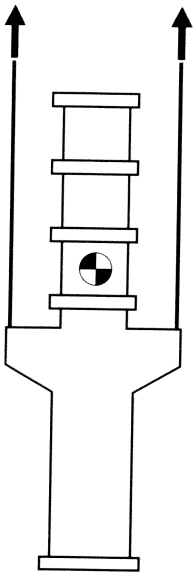

Figure 3. Load Could Tip Over

When considering a double basket sling, make sure that the centre of gravity is located between the two slings. If the centre of gravity is located beyond the slings, the load will topple over at the start of the lift. Rigging loads with their centre of gravity near one sling in a double basket sling arrangement is considered poor practice because of the risk of the load toppling. Always use a sling arrangement that places the centre of gravity below the sling's point of attachment to the load. A correct sling arrangement would be a bridle hitch (Figure 4).

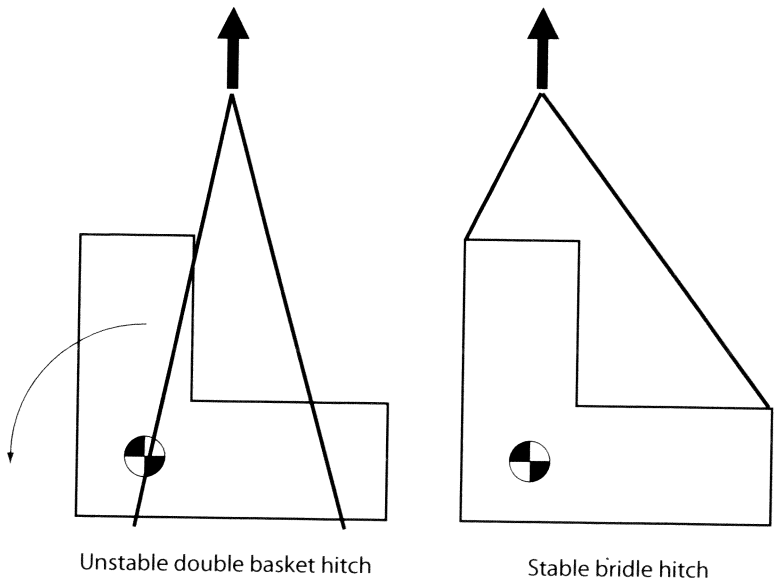

Figure 4. Sling Arrangement

NOTES

Whenever you're hoisting loads with a crane, check that the main load line is perpendicular from two points 90° from each other. Start the initial lift very slowly, watching the load for any signs of tilting or shifting. If the load tilts more than 5°, lower the load and rearrange the rigging.

Rigging the Load

Most items that require hoisting have no place to attach the load to the lifting device. In these cases, slings are used to connect the load to the lifting device. Slings may be made of fibre rope, wire rope, chain, or webbing. Slings may be attached to loads in a variety of ways. These are some commonly used sling configurations, their names, and how they are used.

To protect both the load and the sling, place padding/softeners between the sling and any sharp corners on the load (Figure 5). The simplified diagrams in the following pages do not show the padding, but it's essential that you use them in practice.

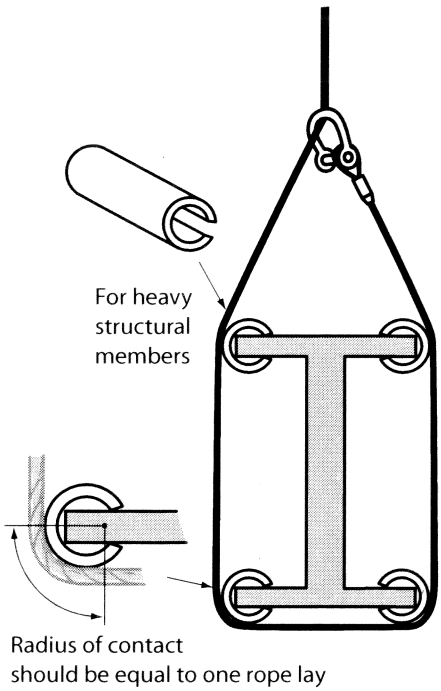

Figure 5. Use Softeners

Three Common Sling Configurations

There are three types of sling in common use:

- Vertical hitches—When used in a straight pulling fashion, the single vertical hitch will safely hoist 100% of its rated WLL.
- Basket hitches—When the legs of the basket hitch are in the vertical position, the basket hitch will safely hoist 200% of its rated WLL.
- Choker hitch—When used in a straight pulling fashion, the choker hitch will safely hoist 75% of its rated WLL.

NOTES

Vertical Hitches

Single Vertical Hitch

The single vertical hitch consists of a single leg of sling material with a hook or an eye at each end (Figure 6).

The working load limit of a sling is the load that the sling can safely hoist while being used as a single vertical hitch. When used in a straight pulling fashion, the single vertical hitch will safely hoist 100% of its rated WLL.

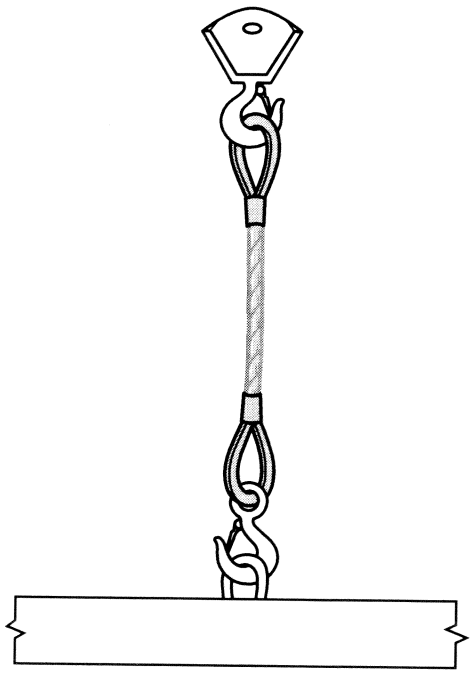

Figure 6. Single Vertical Hitch

NOTES

Bridle Hitch Configurations

Two, three, or more legs may be used together to form a bridle hitch (Figure 7). Bridle hitches are generally used on loads that have suitable attachment points. The load will be stable because the attachment points are above the load's centre of gravity.

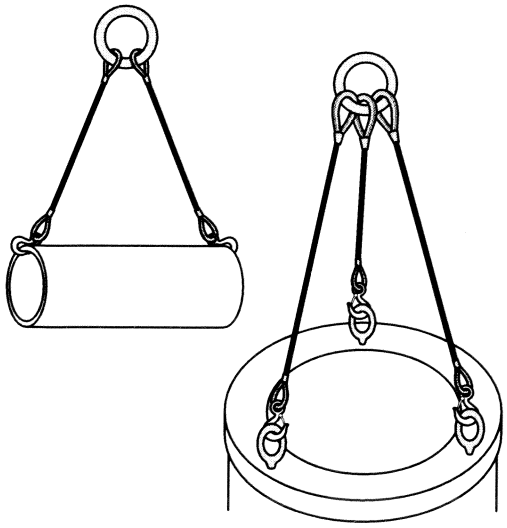

Figure 7. Bridle Hitches

When a bridle hitch has more than two legs, you cannot assume that all legs are sharing the load equally. Regardless of the total number of legs, the full weight of the load might be shared by only two legs. The other legs might simply be balancing the load (Figure 8).

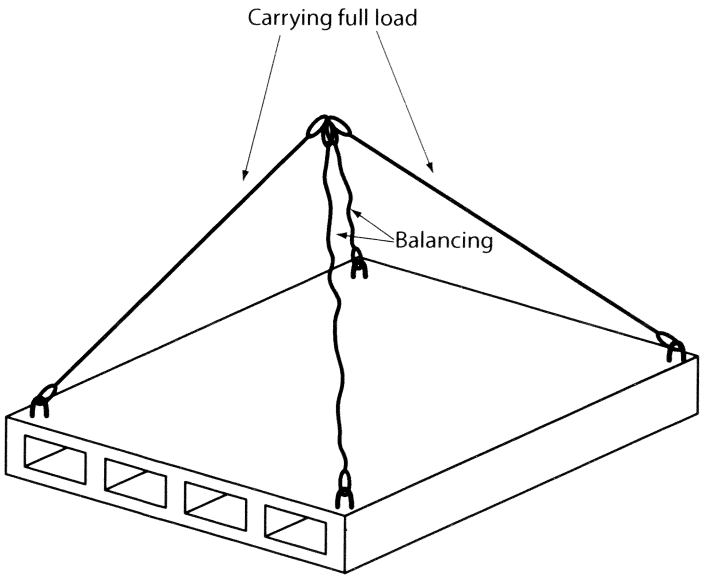

Figure 8. Bridle Hitch with Four Legs

Basket Hitches

NOTES

Single Basket Hitch

Single basket hitches are made from a single length of sling material passed through a load, with both ends of the sling attached to the main hook (Figure 9). When the legs of the basket hitch are in the vertical position, the basket hitch will safely hoist 200% of its rated WLL. Never use single basket hitches on loads that could tilt and slide.

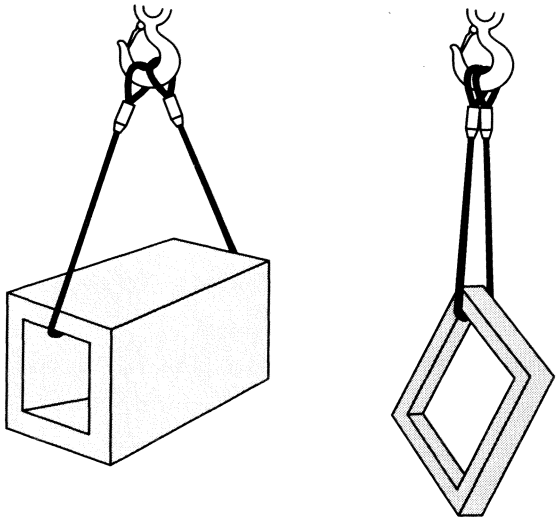

Figure 9. Single Basket Hitches

Double Basket Hitch

Loads that require support from underneath can be lifted with a double basket hitch (Figure 10). The double basket hitch has to be located so that the load is balanced between the two points of support. The two points must also be far enough apart to prevent the load from tipping and sliding out.

NOTES

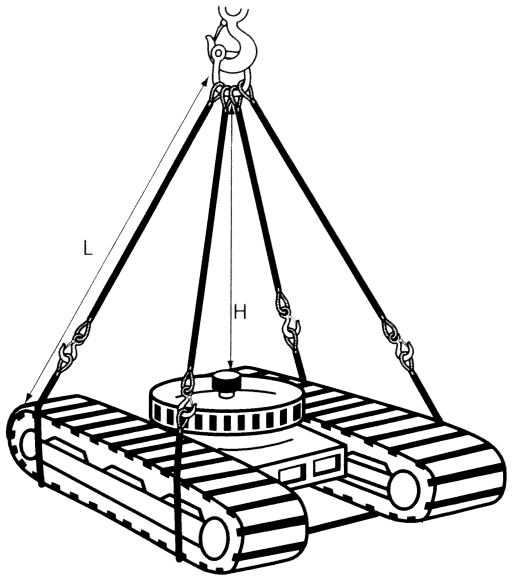

Figure 10. Double Basket Hitches

The legs of a double basket hitch should be inclined at an angle of at least 60° to the horizontal in order to prevent the legs from sliding toward each other. By using longer slings, you can spread the legs farther apart and still maintain the 60° slope.

Double-wrap Basket Hitches

Loose loads can be securely rigged for hoisting with double basket hitches if you wrap the sling completely around the load (Figure 11A). This double wrapping compresses all the components together (Figure 11B) so that even the top pieces will not slide out of the rigging.

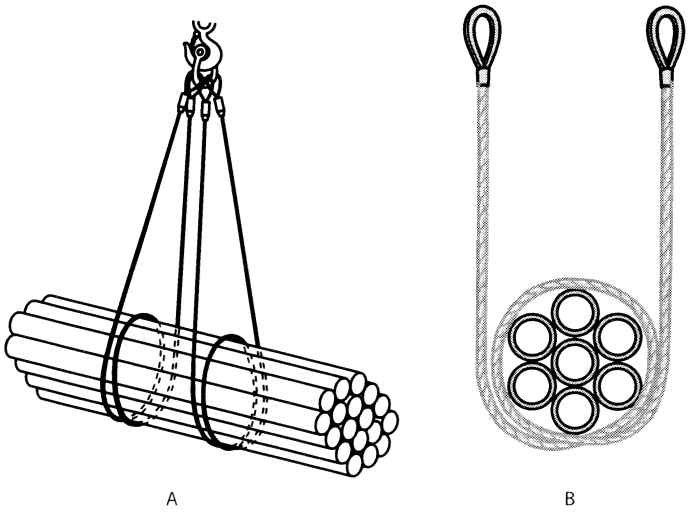

Figure 11. Double-wrap Basket Hitch

Choker Hitches

When used in a straight pulling fashion, the choker hitch will safely hoist 75% of its rated WLL.

NOTES

Single Choker Hitches

Single choker hitches are made with a single length of sling material hooked back to itself just above the load (Figure 12).

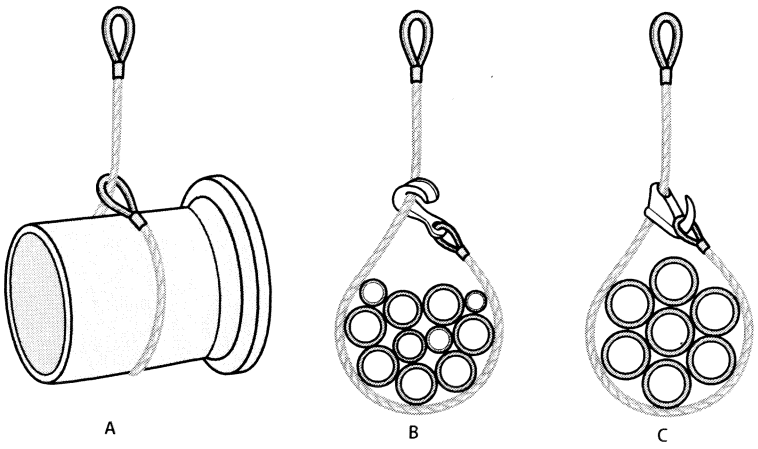

Figure 12. Single Choker Hitches

There are several methods of securing one end of the sling back upon itself to form the choker, but none will totally secure the top of loose loads (Figure 12B and C).

Double Choker Hitches

Double choker hitches must be used on all horizontal loads that contain two or more pieces of material that are over 3 m (10 ft.) in length (Figure 13).

NOTES

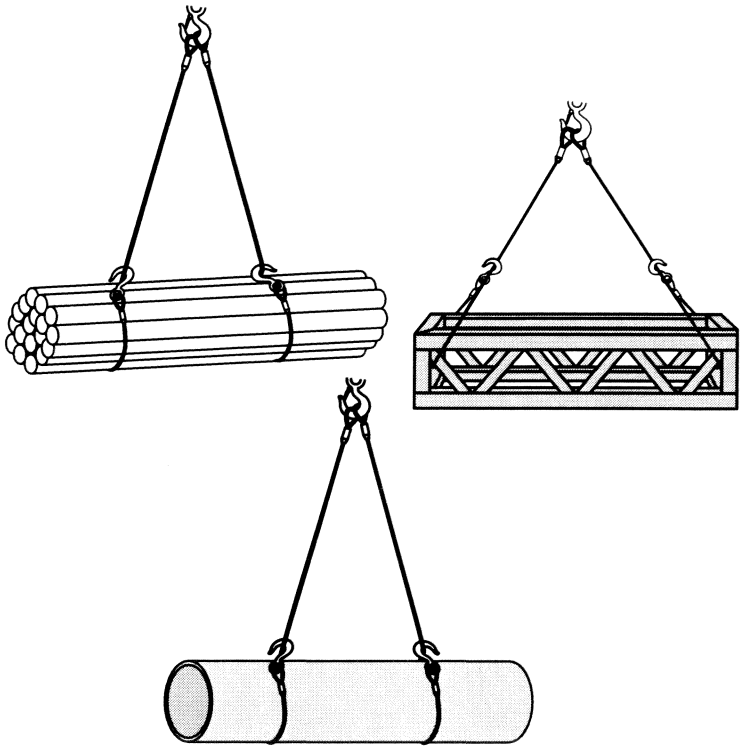

Figure 13. Double Choker Hitches

Double-wrap Choker Hitch

The double-wrap choker hitch is similar to the double-wrap basket hitch in that both squeeze the load from all sides. Double-wrap choker hitches can be used singly or in pairs (Figure 14).

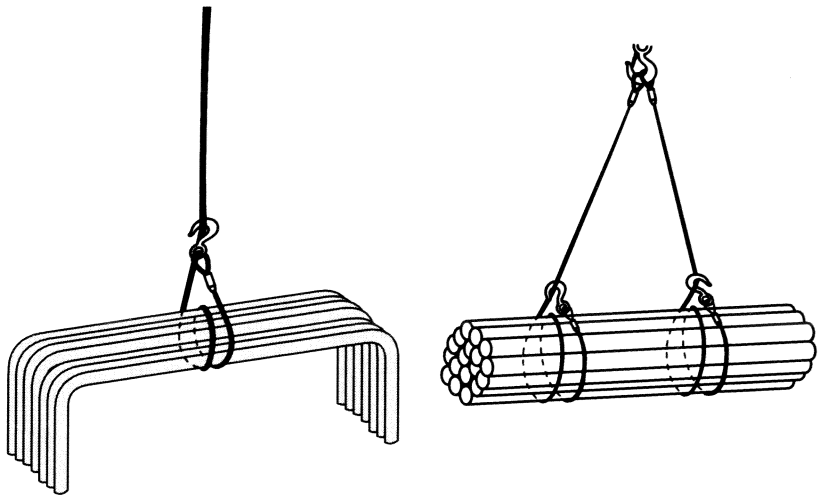

Figure 14. Double-wrap Choker Hitches

Endless Slings

Endless slings (also called "grommet slings") can be used in a variety of configurations (Figure 15).

NOTES

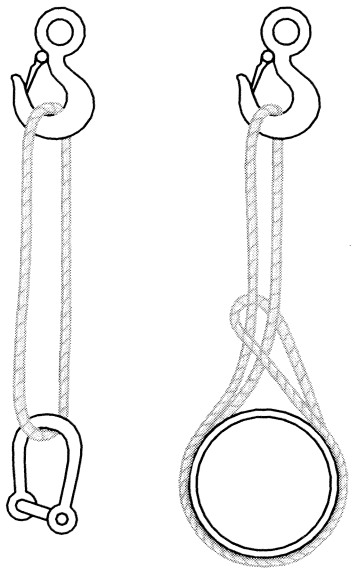

Figure 15. Endless Slings

Endless slings are usually made of fibre rope or synthetic webbing. They are light to handle and do not damage the loads, but because they're subjected to sharp bends, they tend to deteriorate more rapidly than do most other types of slings.

Working Load Limit of Slings

Slings are almost always used in hoisting operations and can be used in many different configurations. The WLL capacity of the sling will be reduced in most configurations. The following shows how to calculate the WLL when the slings are attached to the load in different ways and are on an angle.

Calculating WLL for Sling Angles

The WLL capacity is reduced simply by the angle of the sling configuration putting more tension on the sling. This is called "the sling angle." The greater the angle or incline, the greater the tension. Below are some simple formulas you can use for bridle hitch, basket hitch, and choker hitch configurations.

NOTES

Bridle Hitch Configurations

WLL = WLL of single bridle hitch × H × number of legs ÷ L

Where:

- H = the vertical height from the top of the load to the hookup point
- L = the length of the sling

Note: Each of the examples uses slings with a single vertical hitch WLL of 2000 kg unless otherwise noted.

Example:
The slings in Figure 16 have a WLL of 2000 kg each. The vertical height (H) is 3 m. The sling length (L) is 3.7 m. Calculate the WLL as follows:

WLL = WLL of single bridle hitch × H × number of legs ÷ L
WLL = (2000 kg) × (3 m) × (2) ÷ (3.7 m)
WLL = 3243 kg

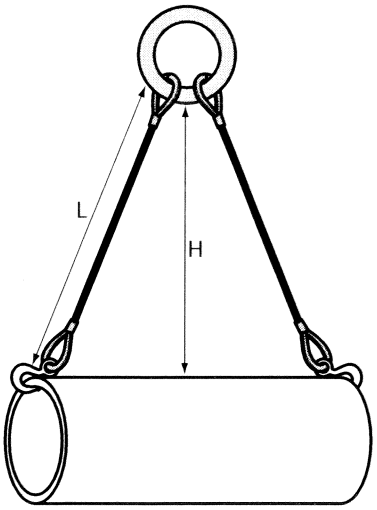

Figure 16. Bridle Hitch with Legs of Equal Length

NOTES

To calculate the WLL of bridle hitches with legs of unequal length or with load attachments of unequal height, use the smallest height and length figures as the H and L dimensions.

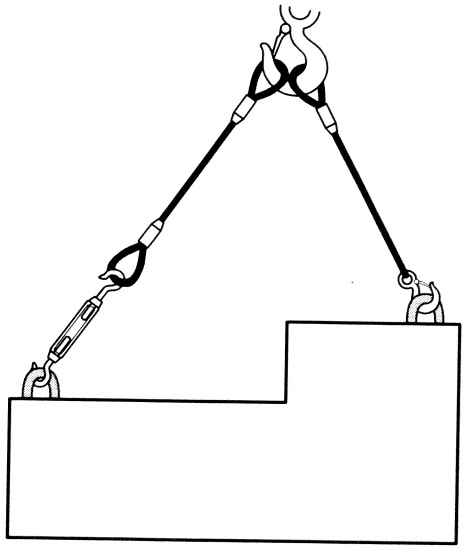

Figure 17. Bridle Hitch with Legs of Unequal Length

For bridle hitches with three or more legs, use the same formula as for bridle hitches with only two legs, because you cannot assume that all legs share the load equally. A four-leg bridle hitch could have all the weight carried by two legs (Figure 18).

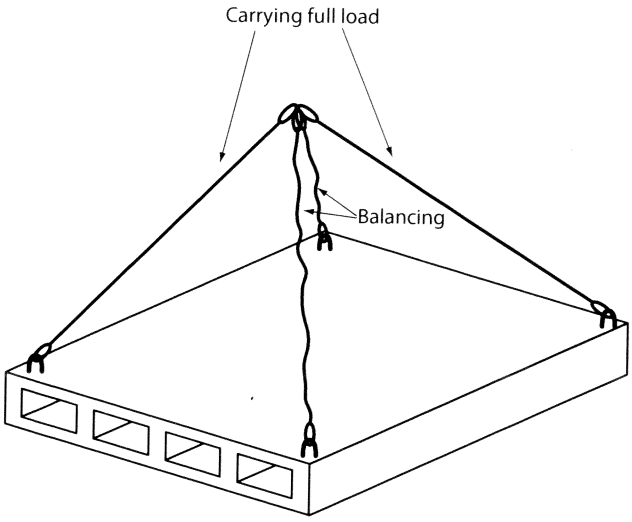

Figure 18. Bridle Hitch with Four Legs

NOTES

Basket Hitch Configurations

The same sling used in a basket hitch configuration, with each leg held in a vertical position during the lift, doubles the WLL of the sling:

WLL = WLL of single vertical hitch × 2

Example:

WLL = WLL of single vertical hitch × 2
WLL = (2000 kg) × 2
WLL = 4000 kg

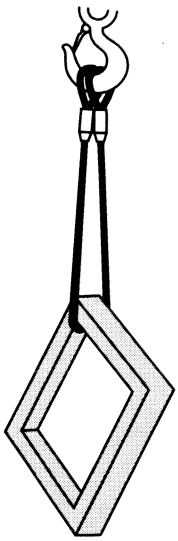

Figure 19. Basket Hitch with Vertical Legs

NOTES

The WLL will be reduced if the legs of the basket hitch are inclined (Figure 20). Use the following formula:

WLL = WLL of single vertical hitch × H × 2 ÷ L

Example:

The sling in Figure 20 has a WLL of 2000 kg. The vertical height (H) is 1 m. The sling length (L) is 1.5 m. Calculate the WLL as follows:

WLL = WLL of single vertical hitch × H × 2 ÷ L
WLL = (2000 kg) × (1 m) × 2 ÷ (1.5 m)
WLL = 2666 kg

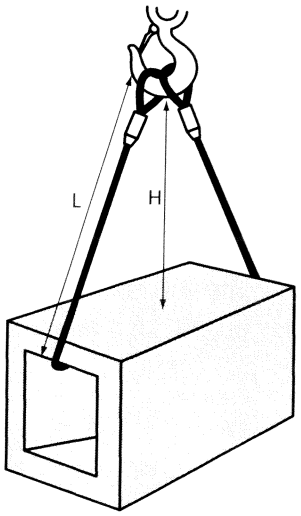

Figure 20. Basket Hitch with Inclined Legs

Double Basket Hitches

Double basket hitches are self-adjusting, since each leg carries its share of the load. Use the following formula:

WLL = WLL of single vertical hitch × H × 4 ÷ L

Example:
Each sling in Figure 21 has a WLL of 6000 kg. The vertical height (H) is 6 m. The sling length (L) is 9 m. Calculate the WLL as follows:

WLL = WLL of single vertical hitch × H × 4 ÷ L
WLL = (6000 kg) × (6 m) × 4 ÷ (9 m)
WLL = 16 000 kg

NOTES

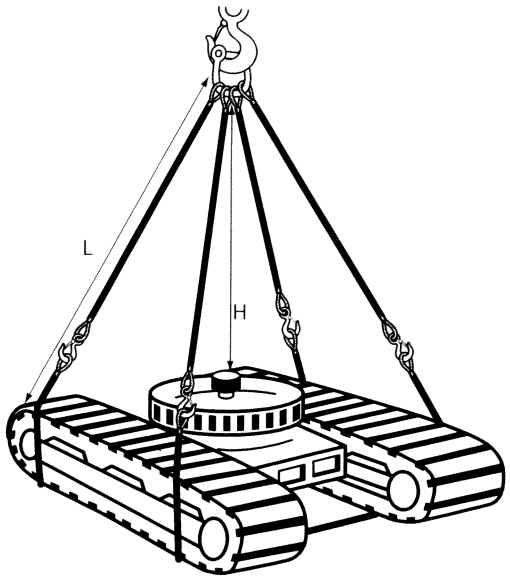

Figure 21. Double Basket Hitch

Single Choker Hitches

Single choker hitches use a similar formula except that the ratio is never less than ¾. When the choker angle is greater than 45° (Figure 22), use the following formula:

WLL = WLL of single vertical hitch × ¾

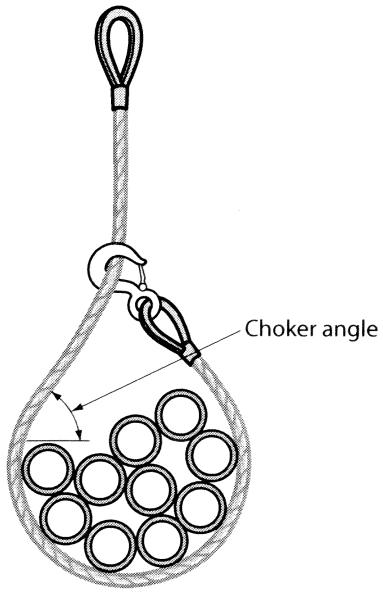

Figure 22. Choker Angle Greater Than 45°

NOTES

Example:

WLL = 2000 kg × ¾
WLL = 1500 kg

When the choker angle is less than 45° (Figure 23), calculate the WLL as follows:

WLL = WLL of single vertical hitch × A ÷ B

Where:

- A = the vertical height from the top of the load to the hookup point
- B = the length of the sling from the hookup point to the edge of the object (the hypotenuse length).

Example:
The sling in Figure 23 has a WLL of 2000 kg. The vertical height (A) is 0.3 m. The hypotenuse length (B) is 1 m. Calculate the WLL as follows:

WLL = WLL of single vertical hitch × A ÷ B
WLL = (2000 kg) × (0.3 m) ÷ (1 m)
WLL = 600 kg

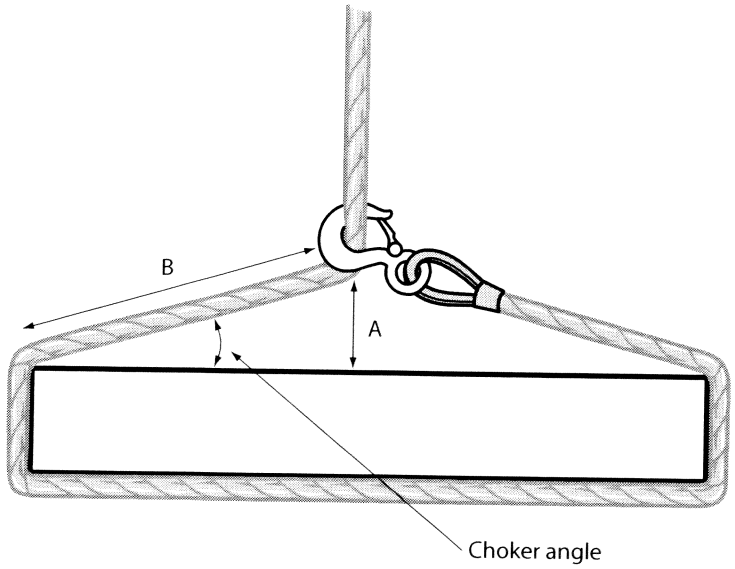

Figure 23. Choker Angle Less Than 45°

NOTES

Chokers are often used in pairs to lift loads in a horizontal position (Figure 24.) To calculate the WLL of such sling configurations, use the following formula:

WLL = WLL of single vertical hitch × A ÷ B × H × 2 ÷ L

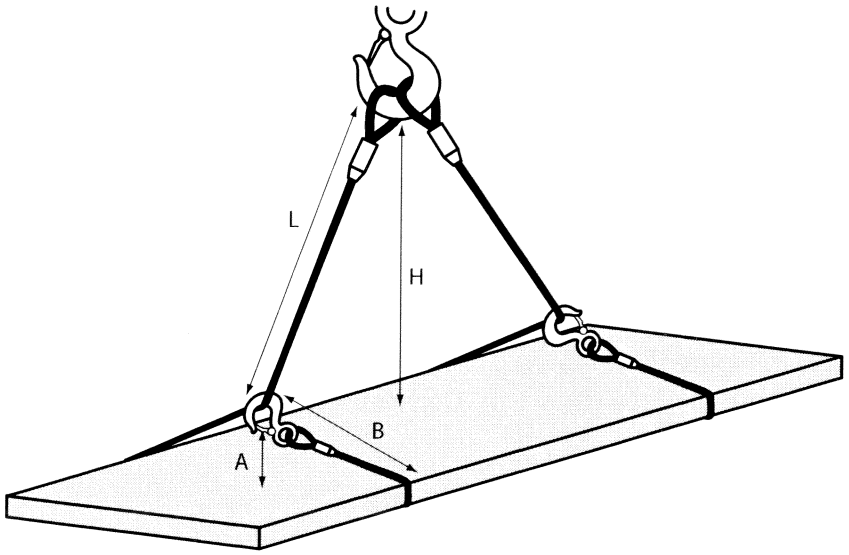

Figure 24. Pair of Choker Hitches

Example:
The slings in Figure 24 have a WLL of 2000 kg. The vertical height (A) is 1 m. The hypotenuse length (B) is 3 m. H equals 10 m and (L) equals 15 m. Calculate the WLL as follows:

WLL = WLL of single vertical hitch × A ÷ B × H × 2 ÷ L
WLL = (2000 kg) × (1 m) ÷ (3 m) × (10 m) × 2 ÷ (15 m)
WLL = 889 kg

If you use either fibre rope or wire rope to make slings, you must remember that:

- A knot can reduce the breaking strength of fibre rope by up to 50%.
- Cable clips correctly attached to wire rope reduce its breaking strength by 20%.
- Sharp corners of a load should be padded to reduce abrasion on the rope.

Rigging Structural Shapes

NOTES

Before lifting loose bundles of round stock, double wrap them with slings to secure the pieces on top of the load. When setting them down, place them on blocking that has side-restraining chocks to prevent the pieces from spreading (Figure 25).

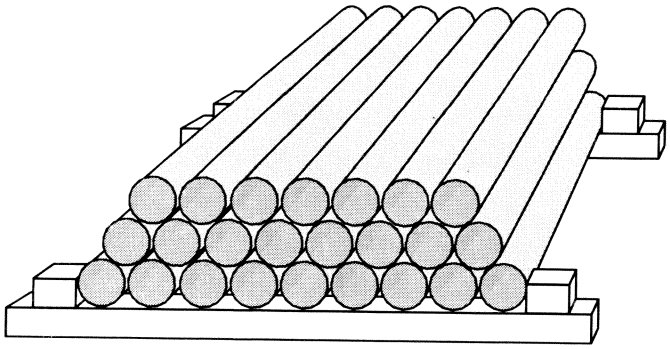

Figure 25. Blocking for Round Stock

When rigging long loads, use slings that are long enough so that the dimension "L" (Figure 26) is always greater than dimension "S." This will ensure that your slings' angles are always greater than 60° from horizontal.

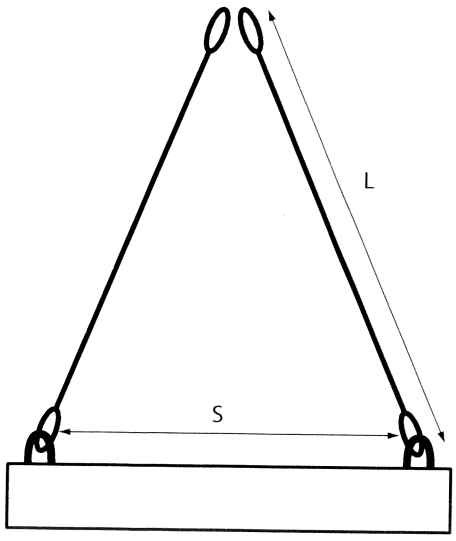

Figure 26. Correct Sling Angle

NOTES

When using endless slings or slings with both ends attached to the load, you may be tempted to wrap the sling on the lifting hook to prevent movement (Figure 27). This is not considered good rigging practice, because it weakens the sling considerably.

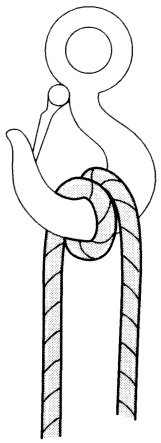

Figure 27. Never Wrap a Hook

You can form a choker hitch from a looped rope as long as the loop contains a metal thimble (Figure 28). Rope loops without thimbles can suffer severe abrasion by the cutting action of the line running through the eye.

Figure 28. Choker Hitch

NOTES

If you're rigging a choker with the aid of a shackle, you must make sure that the shackle pin bears on the eye of the sling. If the pin is allowed to bear on the running line, the movement of the running line could loosen the shackle pin, causing the load to drop.

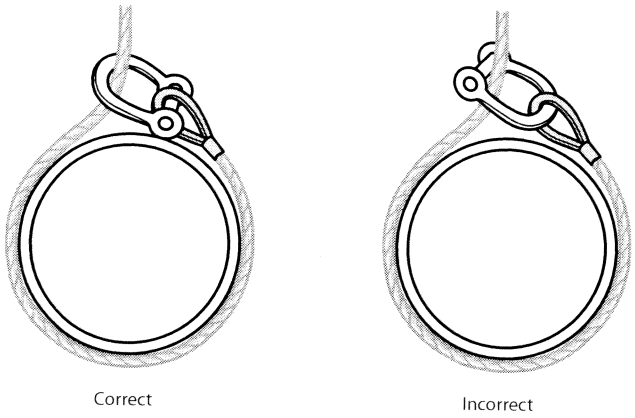

Figure 29. Shackle Use

Always use tag lines to control a load (Figure 30). Tag lines permit you to control the load from a safe distance. Should the load shift or drop, you'll be out of danger.

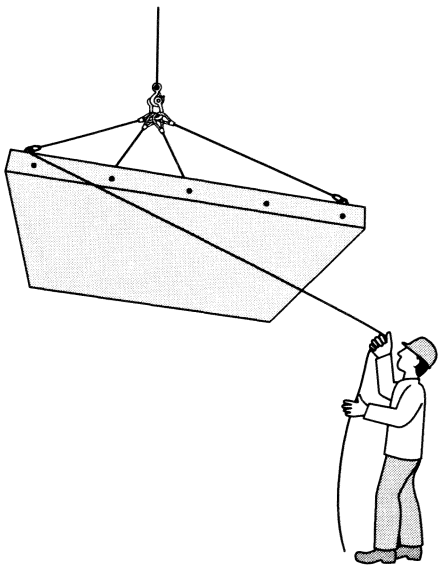

Figure 30. Use Tag Lines

When working near power lines with large cranes, use a power line spotter to avoid hitting the lines with the crane or the load. Electric shock can kill!

NOTES

Whenever two or more ropes are to be attached to the lifting hook, use a shackle to connect the ropes to the hook. The shackle should have the pin bearing on the hook (Figure 31).

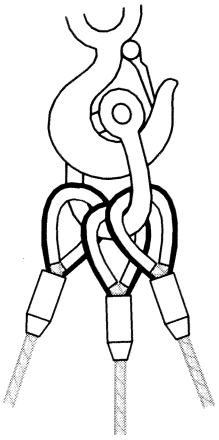

Figure 31. Use Shackles

Many structural shapes have sharp edges and corners that can damage slings. To prevent damaging the slings, always place padding between the sling and the sharp corners of the load (Figure 32).

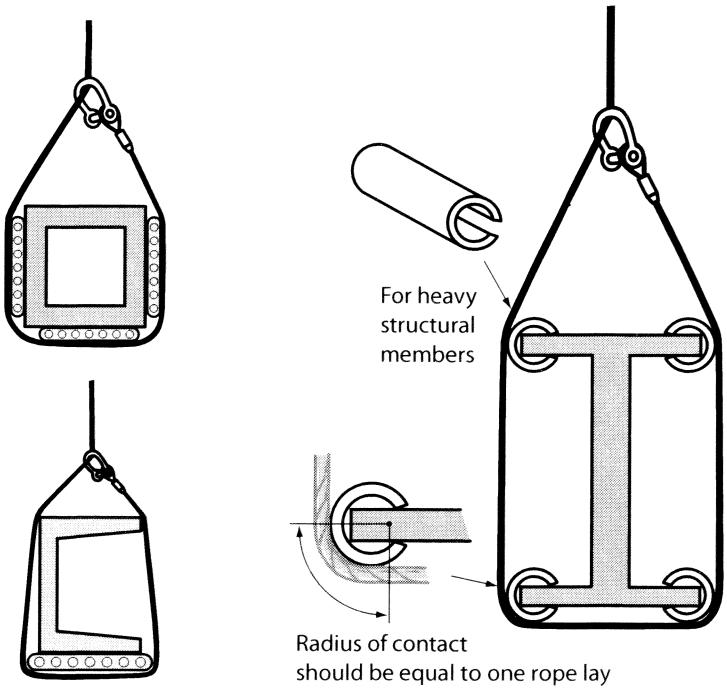

Figure 32. Protective Padding

Turning Structural Shapes

NOTES

When using a crane or hoist to turn heavy structural shapes onto their sides, attach your rigging so that you have full control of the load at all times. Avoid violent or jerky movements.

To roll a load onto its side, first rig the load off centre as shown in Figure 33. Start the roll by lifting the load. Being off centre, it will automatically start to roll as it is hoisted. Once it has rolled, gently lower the load and continue the roll. In this way you can maintain full control.

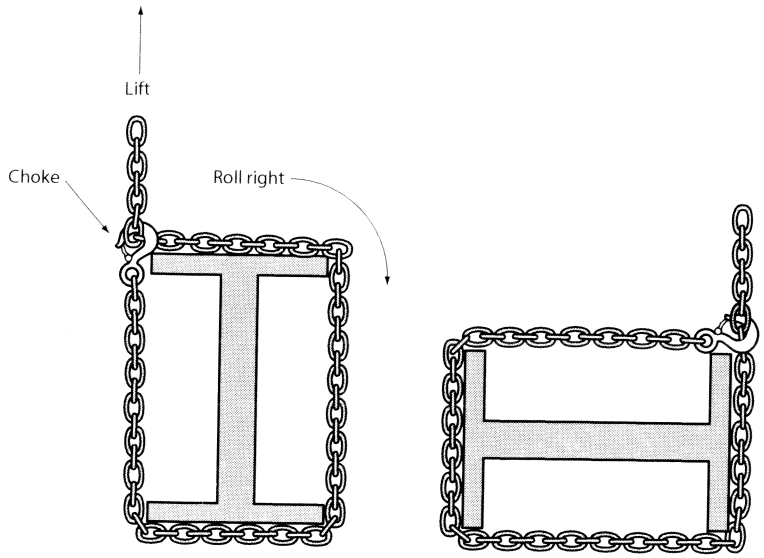

Figure 33. A Controlled Roll

Incorrectly loading the structural shape as in Figure 34 will cause the load to roll violently regardless of how slowly the lift is made. This violent rocking is a hazard that must be avoided.

NOTES

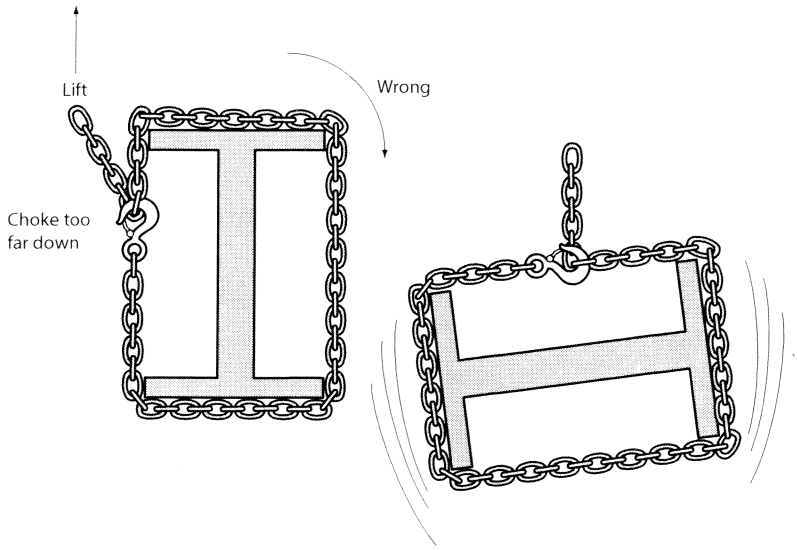

Figure 34. Unsafe Roll

Smaller sections can be turned by hand with the aid of a turning bar (Figure 35). A turning bar is designed to release and drop the steel once it is turned past the point of balance. You should make sure everyone's hands and feet are clear of the landing area.

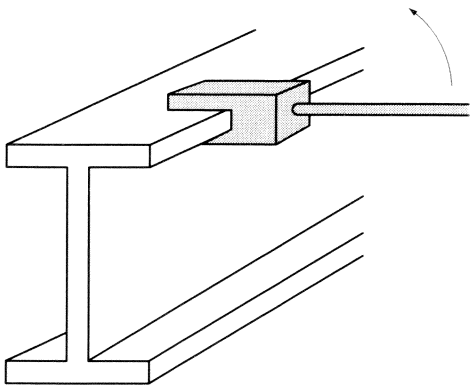

Figure 35. Turning Bar

Correct Storage Practices

NOTES

Materials should be stored so that they will be easily accessible, are protected from harm, and pose no threat to people in their vicinity. To allow cranes or forklifts access to materials, the materials should be stored on dunnage blocks or pallets.

Blocking and Stacking

Materials that can be damaged by bending or buckling should be stored on adequate supports to prevent such damage. If the materials will be exposed to rain, store them at a slight slope so water will run off (Figure 36).

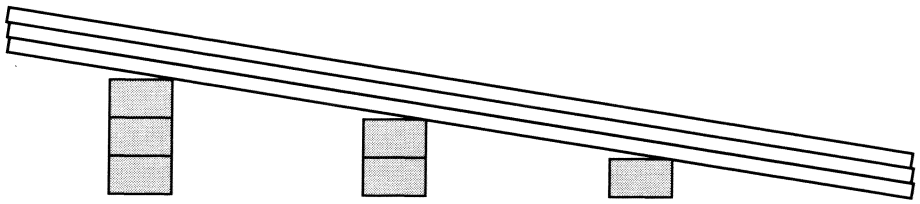

Figure 36. Slope for Water Run-off

When stacking round materials such as rods, cylinders, and pipes, block the bottom row of each stack (Figure 37). The blocking prevents the bottom row from being spread apart by the weight of the rows on top.

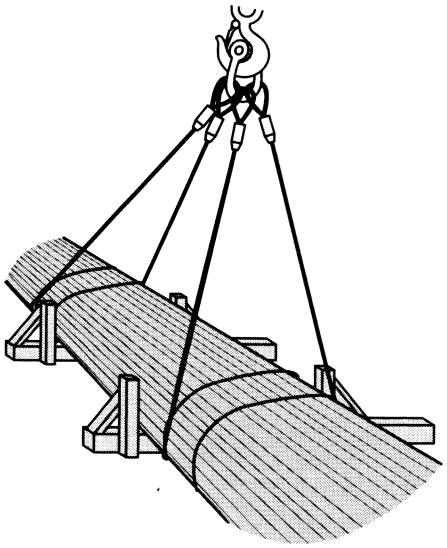

Figure 37. Block Round Stock

Loose materials should be stored in containers or bins. They can also be tied to prevent them from falling over.

NOTES

When stacking structural shapes, place blocking under the first row and cross-sticks between each new row. The cross-sticks must be positioned directly above those in the previous row to prevent the materials from buckling and kinking (Figure 38).

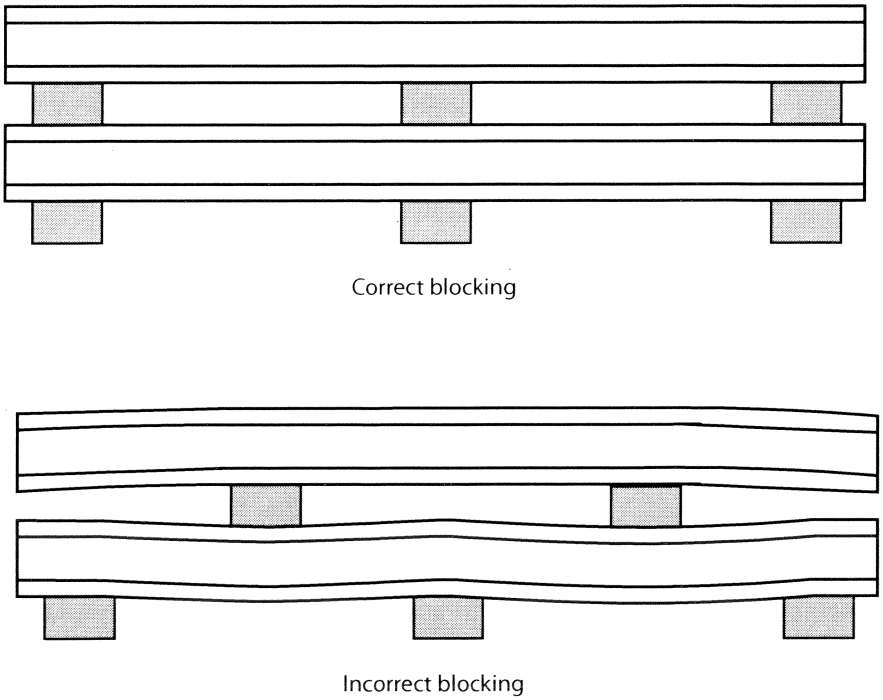

Figure 38. Blocking

Metal sections such as I-beams, wide flange, and channels should be stacked in interlocking and alternating order (Figure 39). Interlocking without alternating will create leaning stacks that can easily topple causing injury or damage.

NOTES

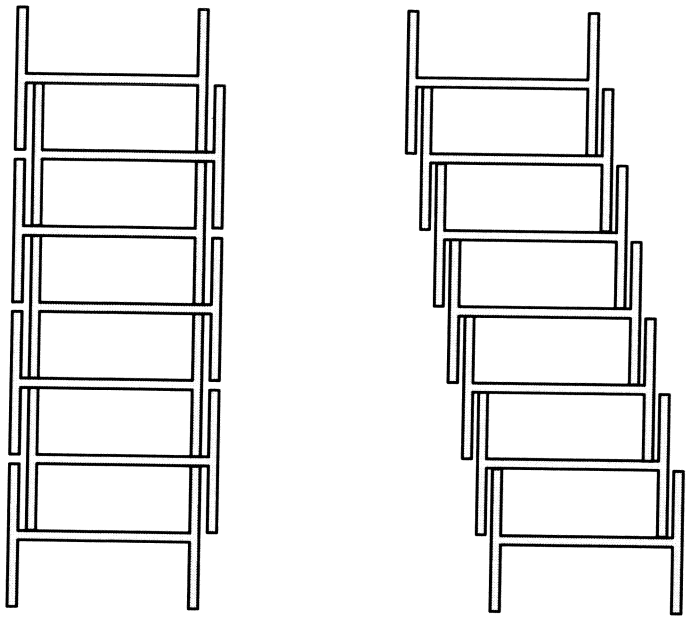

Figure 39. Stacking I-beams

Angled sections should be stacked in an interlocking pattern (Figure 40). High stacks of angles that are not interlocked are unstable and dangerous.

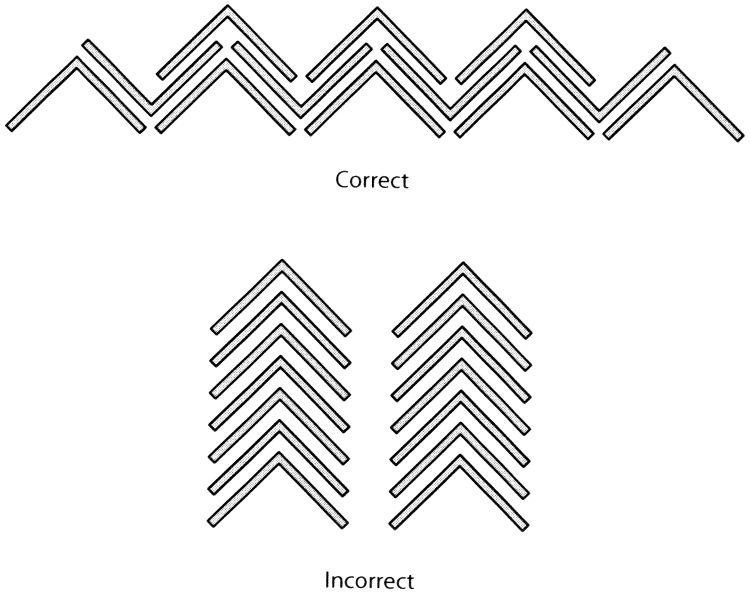

Figure 40. Interlock Angles

Stack materials that cannot be interlocked by cross-stacking or using cross-sticks at each level. Make sure the weight is directly over the supports to prevent the cross-sticks from breaking.

Quiz A-6

1. What is the first step before lifting any load?

   a. check lifting chain rating
   b. check lifting attachments rating
   c. determine weight of the load
   d. determine lifting capabilities of the crane

2. When lifting a load yourself, what are some good lifting practices?

   a. bend at your back and keep your knees straight
   b. bend at your knees and keep your back vertical
   c. bend over at your waist and keep your back straight
   d. spread your legs very wide and lift with your back

3. What must be done if you need to lift a load over a co-worker?

   a. have the co-worker wear a hard hat
   b. move the co-worker only if the load is over 100 kg (220lbs)
   c. install double the chains
   d. move the co-worker out of the way

4. What happens to the lifting capabilities of a floor hoist as the boom is extended?

   a. lift more weight but not as high
   b. lift more weight and lift it higher
   c. lift less weight but not as high
   d. lift less weight but higher

5. What must be done if your shop builds a custom support stand?

   a. it must be certified by a professional engineer
   b. tagged "custom built"
   c. weight rated at half of a comparable stand
   d. it must be painted red to indentify the custom stand

6. What are two methods of wrapping wire when manufacturing a wire rope?

   a. regular lay and lang lay
   b. cole lay and seale lay
   c. filler lay and sisal lay
   d. fibre lay and quad lay

7. What is the minimum grade of chain when hoisting overhead?

   a. 4A
   b. 6A
   c. 8A
   d. 10A

8. What is the minimum number of wire rope clips required for a 5/8" wire rope?

   a. 1
   b. 3
   c. 5
   d. 7

9. What is used to prevent the load from tipping or slipping and distributes the load evenly while lifting?

   a. turnbuckle
   b. eye bolt
   c. spreader bar
   d. shackle pin

10. What are two types of natural fibre rope?

    a. polyester and raw
    b. polypropylene and sinew
    c. manila and sisal
    d. gathered and bolt

11. What must be done to the ends of a newly cut nylon rope?

    a. melt and flatten out
    b. braid together
    c. apply epoxy
    d. apply plastic wrap

12. What type of knot does "left over right, then right over left" describe?

    a. bowline
    b. reef
    c. clove hitch
    d. timber hitch

13. When lifting with a crane, what does blowing the horn twice signal the hoist operator to do?

    a. stop
    b. raise
    c. lower
    d. all clear

14. When lifting a load what is the hand signal to hoist up?

    a. thumb up
    b. thumb up, rotating hand
    c. forefinger up
    d. forefinger up, rotating hand

15. What is the hand signal to the crane operator to "dog everything"?

    a. clasping your hands in front of your body
    b. extending both arms out horizontal
    c. extending both arms up vertically
    d. crossing both arms in front of your chest

16. What are two types of come alongs?

    a. synthetic line or sisal rope
    b. chain or cable
    c. wire rope or nylon
    d. steel rod or chain

17. What type of sling configuration will lift twice the sling's working load limit?

    a. choker hitch
    b. single basket hitch
    c. single vertical hitch
    d. single double wrap choker hitch

18. What happens to the working load limit of the slings as the lifting angle increases?

a. decreases
b. is not affected
c. doubles for every 5°
d. doubles for every 10°

Heavy Duty Mechanical Lines and Competencies

Line A Common Occupational Skills
- A-1 Use Safe Work Practices
- A-2 Apply Occupational Health and Safety
- A-3 Use Environmental Practices
- A-4 Use Hand Tools, Power Tools, and Shop Equipment
- A-5 Use Fasteners and Fittings
- A-6 Lift and Support Loads
- A-7 Operate Equipment
- A-8 Use Shop Resources and Record Keeping Practices
- A-9 Service Winch Wire Rope
- A-10 Identify Lubricants
- A-11 Service Bearings and Seals
- A-12 Apply Math and Science
- A-13 Use Electronic Media
- A-14 Use Cutting and Welding Equipment
- A-15 Prepare Job Action
- A-16 Describe Diagnostic Procedures
- A-17 Prepare for Employment

Line B Brakes
- B-1 Service and Repair Hydraulic Brakes
- B-2 Service and Repair Hydraulic Power Brakes
- B-3 Service and Repair Air Brakes
- B-4 Diagose and Repair Advanced Brake Systems

Line C Hydraulics
- C-1 Describe Hydraulic Systems
- C-2 Service Hydraulic Components
- C-3 Diagnose and Repair Advanced Hydraulic Systems

Line D Electrical
- D-1 Describe Electricity
- D-2 Use Electrical Testing Instruments
- D-3 Service and Diagnose Batteries
- D-4 Service Charging Systems
- D-5 Diagnose and Repair Charging Systems
- D-6 Service Starting Systems
- D-7 Diagnose and Repair Starting Systems
- D-8 Service Electrical and Electronic Circuits
- D-9 Diagnose and Repair Electrical Components and Systems
- D-10 Diagrnose and Repair Electronic Compoments and Systems
- D-11 Diagrnose and Repair Vehicle Management Systems
- D-12 Service, Diagnose, and Repair Hybrid Systems
- D-13 Service, Diagnose, and Repair Electric Drive Systems

Line E Suspension and Steering
- E-1 Service and Diagnose Tires, Wheels, and Hubs
- E-2 Service Steering Systems
- E-3 Diagnose and Repair Truck Hydraulic Assisted Steering Systems
- E-4 Service, Diagnose, and Repair Machine Suspension Systems
- E-5 Remove and Install Undercarriage
- E-6 Diagnose and Repair Frames
- E-7 Align Vehicle
- E-8 Diagnose and Repair Wheeled Equipment Steering
- E-9 Diagnose and Repair Track Machine Steering
- E-10 Diagnose and Repair Undercarriage

Line F Trailer
- F-1 Service Landing Gear and Trailer Accessories
- F-2 Service and Repair Coupling Systems
- F-3 Service, Diagnose, and Repair Trailer Body Components
- F-4 Service, Diagnose, and Repair Trailer Heating and Refrigeration Systems

Line G Heating, Ventilation and Air
- G-1 Describe Heating and Air Conditioning Fundamentals
- G-2 Diagnose and Repair Heating and Air Conditioning Systems

Line H Engines and Supporting Systems
- H-1 Describe Engine Fundamentals
- H-2 Service Engine Support Systems
- H-3 Diagnose and Repair Engine Support Systems
- H-4 Service Diesel Fuel Supply Systems
- H-5 Diagnose and Repair Diesel Supply Systems
- H-6 Service Gasoline Fuel Systems
- H-7 Describe Alternative Fuel Systems
- H-8 Diagnose Engines and Components
- H-9 Remove and Install Diesel Engines
- H-10 Repair Engines and Components
- H-11 Describe Diesel Fuel Injection Fundamentals
- H-12 Diagnose and Repair Mechanical Fuel Injection Systems
- H-13 Diagnose and Repair Electronic Diesel Fuel Systems
- H-14 Diagnose and Repair Diesel Emission Systems
- H-15 Diagnose and Repair Engine Brakes
- H-16 Service, Diagnose, and Repair Electronic Ignition Systems

Line I Powertrain
- I-1 Describe Power Transfer Systems
- I-2 Service Clutches
- I-3 Diagnose and Repair Clutches
- I-4 Service Manual Transmissions
- I-5 Diagnose and Repair Manual Transmissions
- I-6 Diagnose and Repair Automated Transmissions
- I-7 Service Torque Converters and Dividers
- I-8 Service Powershift and Automatic Transmission
- I-9 Diagnose and Repair Automatic Transmissions and Torque Converters
- I-10 Diagnose and Repair Powershift Transmissions
- I-11 Service Drivelines
- I-12 Diagnose and Repair Drivelines
- I-13 Service Drive Axles
- I-14 Diagnose and Repair Drive Axles
- I-15 Service Final Drives
- I-16 Diagnose and Repair Final Drives
- I-17 Diagnose and Repair Driveline Retarders
- I-18 Diagnose and Repair Winches
- I-19 Diagnose and Repair Power Takeoffs and Transfer Cases
- I-20 Remove and Install Transmissions
- I-21 Remove and Install Driveline and Differentials
- I-22 Remove and Install Final Drives

Line J Structural Components and Accessories
- J-1 Indentify Protective Structures
- J-2 Service Cab Structures
- J-3 Repair Advanced Cab and Body Structures
- J-4 Diagnose and Repair Working Attachments
- J-5 Diagnose and Repair Pnuematic System