PART

A

Rail Maintenance Study Guide

Basic Coach Maintenance Practices and Theory

Table of Contents

Introduction

The singular vision of this document, and those who support it, is to give you the necessary information in preparation for the *Coach Technician Qualifying Exam*. This study guide may be used to reference items during the course of your maintenance career. However, it is NOT intended to be the final answer to maintenance practices. Never substitute information in this study guide for information provided in specific equipment maintenance manuals. Always follow maintenance guidelines, manuals and the information provided by your supervisor.

The study guide is separated in to two parts, Part A and Part B, to cover basic areas of study to advanced wiring schematic diagnosis. Part A provides basic information regarding safety, tools, theory, and hardware. Part B will primarily cover advanced electronic theory and multiple circuit configurations. While this study guide attempts to cover most maintenance and informational topics, it is not all encompassing. Again, specific maintenance manuals should be used in all cases. However, if you find your self in a situation to where you find no written guidance, consult your supervision and the Utah Transit Authority training office.

This manual provides Chapter review questions. They are intended for you to gauge your understanding of the material. They are NOT intended to be solely studied in preparation for the exam. Failure to comprehend the information provided could result in poor exam results.

Chapter 1
Maintenance

Preventative Maintenance

DEFINITION AND CONCEPT

Preventative maintenance is seldom considered in daily life. We operate our cars day in and day out without thinking about the complex nature of what makes it go. Most people are good enough to change the oil on a regular basis and schedule a tune up when it starts running a little rough. Often though, a mechanical failure in a car is "unexpected". The driver simply does not see it coming. A catastrophic transmission failure can be costly and disrupt your personal and professional life. In this case a $100 transmission service and inspection and about an hour of your time surely out weighs a $2000 transmission repair or replacement and the potential for losing your vehicle for weeks. This is the concept of preventative maintenance. In the example above you can argue that the owner made his or her choice on maintenance and has to live with the results. You're right! However what if we thought the same about airline maintenance. That thought of catastrophic failure doesn't seem so trivial now. Preventative maintenance is obviously critical in preventing inconvenience, loss of time, unnecessary expense, and possibly lives. Preventative maintenance is simply preventing pre-mature or catastrophic failure of mechanical, hydraulic, and electrical systems, sub-systems, and components.

Unscheduled Maintenance

Preventative maintenance cannot protect a piece of equipment from all failures. Some are unpredictable due to outside factors. Examples of outside influence include but are not limited to:

- Part life or manufacturing defects
- New and untested part failure
- Unexpected operating conditions (Extreme temperatures, etc.)
- Foreign object interference (Sand in a hydraulic cylinder)

For example: Rotating the tires on your car at regular intervals is good preventative maintenance against pre-mature tire wear. But it does not stop a nail from puncturing the tire and causing a flat. That is when we experience unscheduled maintenance.

PART OR COMPONENT FAILURE

Nothing lasts forever. Even the most durable of components are subject to a life span. Some components such as large axles tend to wear slowly over time and are limited to internal failure because of a relatively few amount of parts. Other components are delicate and have many precision mechanical or electrical details. These parts generally have a shorter life span due to their fragility. Mechanical components, such as a gear box, can have long usage with care and preventative maintenance. Changing fluids and performing regular inspections can keep mechanical components in service for many years. Electrical components differ from mechanical in the fact their failures are not easily predictable. In most electronic theory, which you will see later in this manual, is typically in an "on or off" state in digital and some analog circuits. Simply put; it either works or it doesn't. There are no warning signs of impending failure. Preventative maintenance does tie in with these types of components. It is what is called care in handling.

Component Handling

CARE IN HANDLING

Today's electronic components are sophisticated and complex. In fact, many components today are designed to control, monitor, and apply adjustments to a large system, such as the flight controls on modern fighter aircraft to the entire fuel system on a car. With electronic components being so prevalent, handling of these items is critical. Many circuit cards require protective gloves to be worn and/or your hands to be properly grounded. Failure to adhere to this can negate the reliability of the component. Likewise in mechanical parts handling, items such as bearings can have their serviceability greatly affected. Dirt, and sometimes the very corrosive salt from your hands, can determine how long the part will last after installation. Many of the mechanical and electrical failures in equipment are caused by improper handling of components. Always follow specific instructions related to any component you work on. UTA has invested time and money in the maintenance department and YOU! The cost far outweighs the alternative. Costly repairs and commuter disruption can potentially cost UTA an abundance of money and resources. If you think you are just another "grease monkey", you are wrong. UTA is counting on you to perform the highest quality maintenance possible. Your actions secure the positive public image of UTA.

Review

1. What is preventative maintenance?

2. Give an example of preventative maintenance:

3. Improper handing of parts during installation or inspection can cause:
    A. Pre-mature wear of the component
    B. Increased life span
    C. Health problems
    D. Nothing, it does not effect part life

Chapter 2

Safety

INTRODUCTION

Safety in the work place takes precedence over everything else. For you to hurry through a job and avoid safety can take away a valuable asset, you. It is better to be a thousand times careful than once dead! Accidents in the work place affect all involved. Co-workers feel a loss and a sense of danger, supervisors and managers feel responsible and guilty, and the injured person has to live with the injury, most often, for life. Some say that there are *extreme* cases where one loses his or her life. This statement is not necessarily true, loss of life can occur from even the smallest of accidents such as slipping on an oily floor and suffering a traumatic head injury. Heavy equipment and high voltage aren't the only things that kill.

Personal Protective Equipment

HEAD COVER

When it comes to head cover, hard hats are the most common in industrial and construction trades. As stated above, it takes very little depending on distance to do severe damage to your head. When ever the OSHA symbol for hard hat requirement is displayed, make sure you have it on at all times.

GLOVES

A good portion of reported maintenance injuries are to the hands. While concentrating on your work and being aware of dangers can prevent most of these injuries, hand gloves can offer additional protection. Glove design and protection levels range from latex to heavy leather welders gloves. The glove you use should protect you from your jobs daily hazards and yet allow you to perform your duties uninhibited. For example: A welder should wear welders gloves while actually welding, but may wear simple latex gloves to prevent contact with hazardous fluids. The many styles of gloves can protect you from:

- Burns related to heat or sparks
- Cold
- Contamination from hazardous materials
- Lacerations and punctures
- Reducing electrical shock(in certain instances)

FOOTWEAR

Adequate footwear in industrial and maintenance fields is not only smart, it's required by OSHA. The standard requirement is the safety toed boot. Safety toed boots are generally constructed of steel or Kevlar. Both offer good protection the outer foot. Steel has a better resistance against flattening and Kevlar stays warmer in cold temperatures. Either is an acceptable safety boot. Steel shank boots and /or high tops may also be required. Consult your supervisor or safety representative for work area requirements.

EYE PROTECTION

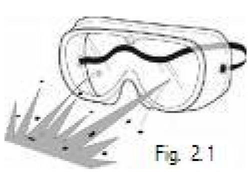


Fig. 2.1

Your eye sight is valuable to you. It is irreplaceable. Protecting your eyes is one of the easiest things you can do in your job. There are three types of eye protection available. Safety goggles come in two variations, vented and sealed sides. The sealed sided goggles (Fig 2.1) protect against flying debris and splashing chemicals and liquids. The other type is the ventilated side (Fig 2.2) which is very effective in protecting your eyes from flying debris. However, when working with or around splashing liquids, the sealed side style should be worn.

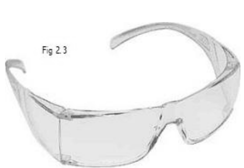


Fig 2.3

The third style of eye protection is the safety glasses (Fig 2.3). This style is the most comfortable to wear during long periods of work. They offer adequate protection against flying debris and general wear around the shop. Their distinct disadvantage is that they do not provide good side entrance protection from debris or liquids. The advantages are comfort and they can be made with prescription lenses for those who require it.

HEARING CONSERVATION

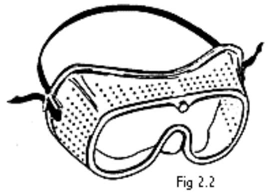


Fig 2.2

Fig 2.4

Like protecting your eyes, there is no cure for hearing loss. The most common mistake that maintainers make is that they do not notice any hearing degradation from activities at work. Unlike eye sight loss, hearing loss can worsen slowly over time and once the damage is done, there is no recovery. Your work area should be posted with standard OSHA warning signs that identify hearing conservation areas. There are two basic protective devices used to conserve hearing. The first is the hearing defender, or head set. This item is effective in protecting against sharp loud noises in high ranges. The second is the ear plug. The ear plug can be in a rubber format that comes in several sizes to match your ear opening. This type should be sized by a hearing specialist. The other is a simple squeeze foam style that you role in to a small shape and allow to expand to seal your ear opening. Figure 2.4 shows some examples of the styles of hearing protection available.

RESPIRATORY PROTECTION

Respiration protection can prevent lifelong conditions that can be fatal. Respirators are worn to protect against hazardous chemical fumes, pain fumes, material and metal sanding or grinding, and welding. Respirators offer different levels of protection based on design (Fig 2.5).

Fig 2.5

The level of respiration protection is dependant on factors such as work being performed and building ventilation characteristics. Contact your supervisor or safety representative with questions.

The Work Area

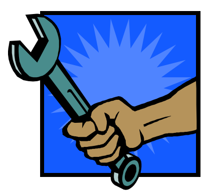
THE SHOP

Clean work areas look good. Looking good is just a side benefit of a safe work area. If a shop is kept clean and organized, accidents tend to be fewer. It's dependent on all individuals in a work area to keep the area safe and organized.

Before starting a job, look around to make sure that the work area is safe. Check the condition of power cords. Ensure there is enough lighting to do the job safely. If ventilation is required, make sure it is operating properly. When you are finished working, pick up any debris left after the job is complete. Wipe up all fluids to protect against slipping and falls. Identify and report any equipment or shop safety issues observed to your supervisor. Inspect emergency eye wash stations to make sure they are functional and know where your first aid kits are located.

PROPER TOOL USAGE

Always use tools for what they are designed for. Using a Metric wrench on an SAE bolt, not only damages the tool, it poses a risk to the user by slippage. A circular saw made for cutting wood is a dangerous item if someone tries to cut a lead pipe with it. Using the right size tool is just as important. To remove a stuck 1 inch head bolt, you would not want to use a ¼ inch drive ratchet and socket set up. Again, not only are you looking at damaging the tool, but flying material when it breaks can cause serious injury. Selecting a ¾ inch drive socket and ratchet set up; along with some break free solvent will more than likely save the tools and prevent a mishap. When using power or air driven tools always wear eye and ear protection. If you are not qualified to use an advanced or complex piece of equipment, do not use it. Without training you are a danger to yourself and others. Adhere to these general guidelines:



1. Always wear safety goggles or glasses when using punches, chisels, hammers, power tools, and cutting tools. When grinding or cutting at high speeds, a full face shield should be worn.

2. Wear hearing protection when working in an area with excessive noise such as power tool usage or hammering.

WARNING

Engine exhaust fumes can cause sickness or death!

3. Wear a dust mask or respirator when grinding, welding, or working in an area with high fumes. If you must run an engine in an enclosed area, install a tail pipe extension to the outside of the enclosure.

4. Wear appropriate clothing. Never wear loose clothing around moving machinery or parts.

5. Use the right tool for the job and keep them clean and serviceable.

6. Never use a tool as a hammer, unless it's a hammer!

7. Screwdriver handles usually incorporate an insulated (plastic) handle. NEVER ASSUME THIS WILL PROTECT YOU FROM ELECTRICAL SHOCK! Do NOT use on live electrical circuits.

8. Never use a pipe extension, “cheater bar”, to increase the leverage of any wrench. Shattering tools can cause severe injury or loss of sight.

9. Keep all guards in place on power and grinding tools.

10. When moving a tool cabinet, never pull it towards you. Push in the direction desired. Lock all drawers and doors before attempting to move the cabinet or box.

11. Set the brakes on tool boxes with casters. Do not open more than one loaded drawer at a time. Too many open drawers will cause the tool box to tip over.

12. When breaking hardware loose with a wrench or breaker bar, always pull toward you. Pushing on the handle can cause severe hand injury if tool loses grip.

13. Finally, store your tools properly. A messy shop is a dangerous shop.

FIRE EXTINGUISHERS, FIRST AID KITS AND EXITS

As part of general shop safety knowledge, you should first know where to locate fire extinguishers, first aid kits, and exits. Familiarize yourself with their locations. They are easy to find in normal daily operations but what if there is no light or the area is thick with smoke.

Fire

If there is a fire in your facility, follow the guidelines provided by UTA. As a general rule, you should make an effort to put out small fires with a fire extinguisher. Before attempting to put out a fire, evacuate other personnel and pull the fire alarm. Putting out a small fire can save many dollars in resources and maybe prevent injuries, but remember that nothing is worth your life. If you are not confident or the fire is overwhelming, leave the facility via the quickest and safest route possible. Don't attempt more than you can handle. The most common fire extinguisher is the ABC dry chemical. This extinguisher is effective in putting out class A (combustible), class B (liquid), and class C (electrical) fires. To use this extinguisher, pull the safety key, point the nozzle at the base of the fire and discharge the agent while sweeping back and forth. Again, if the fire becomes too big, evacuate immediately. NOTE: Always call the fire department no matter how small the fire is.

First Aid Kits

First aid kits are supplied in your work area. They contain items as small as band aids and up to large absorption pads for severe bleeding. If you can treat your own injury, such as a minor cut, clean your wound and apply a bandage. No matter how insignificant the injury may seem, it *MUST* be reported to your supervisor or safety representative. If you are applying first aid for a co-worker, call 911 immediately if alone or appoint someone to call emergency response immediately. There are many procedures to treat injuries that will not be covered in this manual. Learn first aid through the proper training programs at UTA.

Emergency Exits

Emergency exits are located throughout your work area. They are lighted at all times and should be equipped with battery back up lighting in case of power failure. Even with these security measures in place, it is critical that you are familiar with all possible points of evacuation in times of emergency.

If you identify fire extinguishers that are unserviceable, first aid kits without supplies, or emergency exits without working lights, it is your responsibility to get these resolved. If out of your control, notify your supervisor.

Electrical Safety

IT'S NOT THE VOLTS – IT'S THE AMPS

You may have heard this from people who work around electricity, and it is true! We often look for high voltage signs and stay clear from them. Typically we don't see the sign that reads: DANGER – High Amperes. Voltage most often relates to how many amperes can flow through a circuit. But as you will find out in a later chapter, volts aren't the killer. It's the amperes, or amount of current that causes electrocution. A typical car battery carries enough amps to kill a healthy human depending on outside conditions and body chemistry. Electricity, like a bolt of lightning, will take the path of least resistance. Sometimes the human body is that path and that is when electrocution happens. When working with electricity, use caution and safety devices to prevent such accidents.

BATTERIES

Any vehicle battery is a dangerous component. As discussed above, it has the potential to kill. It poses many other dangers.

- Fires
- Explosions
- Acid Burns

Fire

Shorted wire connections on a battery or improper handling will allow the current to flow. If the current flows fast enough, it causes friction, which causes heat, which can start fires. If you are working in a fuel fumed area, the spark alone can start a large fire. Always check for proper ventilation.

Explosions

Charging a lead cell battery naturally produces hydrogen and oxygen. Normally this condition is relatively safe until the cell becomes over charged. If over charging increases levels of hydrogen to 4%, the mixture of gases becomes very volatile. The sparks from a "jumped" battery or from charging alone is more than enough to set off the mixture of gases. When charging a battery, follow the instructions of the charger to ensure it is not being over charged. Never leave a charging battery to sit overnight. If jump starting a battery is necessary, make your terminal connections quick and do not move it around on the post. This will reduce the spark potential. Batteries that have low electrolyte levels leave excessive room at the top of the battery. This excessive room allows for a pocket of hydrogen to form. Always ensure electrolyte levels are serviced to the proper level. Follow these steps for battery charging and boosting:

Warning

1. Check the electrolyte level for proper service
2. Use a flashlight to check levels. Never use flame or smoke around an open cell battery.
3. Wear eye protection
4. DO NOT charge a battery that is frozen. A battery should be warmed to 60 degrees before charging or boosting.
5. DO NOT short across the terminals of the battery. This causes the battery to rapidly overheat and can lead to an explosion.
6. Always remove the ground (-) terminal of the battery first and replace it last.
7. If equipped, always remove all battery caps before charging or jumping.
8. NEVER touch booster or jumper cables together. The spark is enough to set off an explosion.
9. If connecting a charger or booster, ensure the voltage is set to the voltage of the battery.
10. Keep your face as far away from open cells as possible during connection. The battery contains anywhere from 30 – 40 percent pure sulfuric acid. This can cause severe burns and blindness.
11. Always used distilled water to service electrolyte levels. Ensure that you service the battery in a well ventilated area to disperse the gases.

Review

1. List personal protective equipment you may be required to wear during the course of your job.

2. What are the two common types of safety-toed boots?

3. This type of fire extinguisher is recommended for combustible, liquid, and electrical fires.
    A. Water fire extinguisher
    B. Type B Fire Extinguisher
    C. A,B,C Dry Chemical Extinguisher
    D. All of the above

4. Know where these items are in your work area!
    A. Fire Extinguishers
    B. Emergency Exits
    C. First Aid Kits
    D. All of the above

5. The active solution in battery electrolyte that can cause burns to the skin is:
    A. Baking Soda
    B. Lime
    C. Distilled Water
    D. Sulfuric Acid

6. What may cause a battery to explode?
    A. Shorting Negative to Positive
    B. Servicing Electrolyte Level
    C. Cleaning Terminal Posts
    D. Charging a Frozen Battery
    E. Both A & D
    F. Both D & C
    G. None of the above

7. Voltage is normally directly proportional to how much of this may flow through a circuit.
    A. Resistance
    B. Capacitance
    C. Current (amperes)
    D. None of the above

Chapter 3
Shop Tools

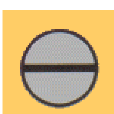
INTRODUCTION

A technician may be intelligent, skilled, and experienced well above peers, but without tools, the technician is extremely limited. Technology has evolved rapidly in the last 50 years and the tools to service that technology has also evolved. Tools today are not limited to a screwdriver, hammer, and a wrench. A Coach Technician is required to use delicate measurement instruments and special tools specific to the equipment being worked on. With these higher tech tools, care in handling and proper usage is required. To start, follow these three simple guidelines regarding tools.

- Purchase or use only quality tools
- Keep tools in a safe and serviceable condition
- Always use the right tool for the job

Screwdrivers

COMMON SCREWDRIVER



The common screwdriver, also known as the flat screwdriver, has three simple parts (Figure 3.1). The handle is usually made of plastic substance. Even though it is a non-conductive material, it is not intended to be used on live circuits. The shank will come in various lengths depending on design and purpose. Most common screwdriver shanks are round, but some are square or hex shaped. This may look "wrench friendly", but are not intended for wrenching. Use a larger screwdriver if necessary or one with a square opening on the end of the handle for ratchet attachment.

WARNING: Excessive force while wrenching can cause injury to you and damage to the equipment. The bit (or blade) of the screwdriver is where the work is done. Make sure your hands are not on the screw while driving. The driver may slip and cut you. It should be smooth and have a gripping surface suitable for the job. If the bit becomes damaged, grinding of the tip is permissible. Keep in mind that the original shape and contour must be maintained. A bit that is too sharp will slip back out of the screw. When grinding, do not let the tip get too hot. Occasionally dip it in water to keep its hardness.

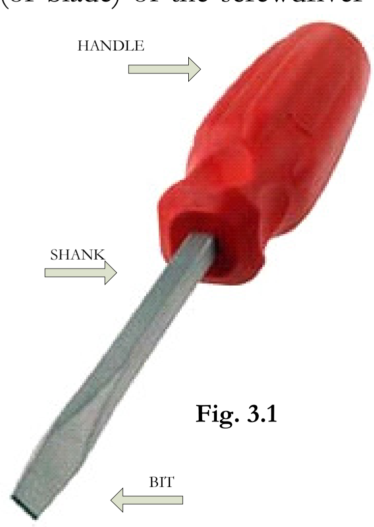


Fig. 3.1

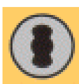
PHILLIPS SCREWDRIVER

Sometimes called the "cross tip", this screw driver does not have the side slip that a common screwdriver has. It needs to be the correct size to fit in to the cross of the screw with no slop. While side slip is prevented, it takes a little more force to keep the bit inside the screw. If the blade on a Phillips screw driver becomes damaged or broken, replace the screwdriver.

STARTING SCREWDRIVER

Starting screwdrivers are usually common or Phillips with a spring loaded clip on the lower part of the shank that will hold a screw at the end of the driver for ease in starting in a difficult location. Designs differ for the clip style. The most simplistic is the magnetized screwdriver.

CLUTCH-HEAD SCREWDRIVER



Also know as the Figure eight or butterfly screwdriver, this driver is used with screws on sheet metal products that require a neat finish. The tip stays in place easily which prevents disfiguration of the screw head, maintaining good appearance.

POZIDRIVE

The pozidrive, or supadrive, screw driver is similar in design to the Phillips screwdriver. However, they are not the same and should not be interchanged for one another. Doing so can damage the hardware as well as the tool. A Phillips tip is angled while the pozidrive fastener is flat, providing a tighter fit between tool and screw.

TORX SCREWDRIVER

Torx screws are becoming more popular because of the success gained with them. It is a six point, star shaped, flat tip that has a large amount of surface contact. With such a large amount of contact, it is easier to apply higher toques to fasteners. The torx screwdriver comes in a wide variety of sizes. They are always preceded with the letter "T". For example: T25, T40, T60, etc.

SCRULOX OR SQUARE TIP SCREWDRIVER

This screwdriver is used to remove scrulox fasteners commonly found on recreational vehicles and automobiles panels.

OFFSET SCREWDRIVER

Fig. 3.2

The offset screwdriver is designed for hard to reach fasteners. They come in a wide variety of lengths. Typically the offset is at a 90 degree angle. Some offset screwdrivers have a Phillips on one end and a common bit on the other.

Hammers

BALL PEEN HAMMER

The ball peen hammer is a metal hammer with different sides to the head of the hammer. One side is flat and is used to move material or to drive a drift or punch. The opposite side is the peen end. This is used to shape metals with light accurate blows. Never use this end for driving a punch or drift; this could lead to hand injury. Ball peen hammers come in different head weights.

Fig. 3.3

CAUTION

- Always wear proper eye protection when hammering hardened surfaces. It is still recommended for less hardened surfaces.
- Check the hammer head for looseness. A loose hammer head could easily fly off injuring you or a co-worker. If the hammer has a wooden head, it may be tightened with a wedge.
- When striking an object with the hammer, ensure the surface mates evenly. If you use only the edge of the flat face, it can cause debris to break off.
- Never use the hammer handle for prying or pounding. The handle could break during the next normal use causing the head to fly off.

MALLETS

A mallet is a soft hammer relative to the hardened steel on a ball peen hammer. At times, a technician needs to move machined surfaces and delicate parts into position with a soft hammer. Mallets vary in weights and materials used to construct them. The technician should choose the appropriate soft hammer for the job being performed. As a general rule, if a light mallet will work, there is no need to use a heavy lead mallet. The typical designs are as follows:

- Rawhide mallets are made of wrapped animal hide. They are the lightest group of mallets and should be used for small jobs.
- Rubber mallets are slightly heavier and are good for most surfaces.

- Plastic mallets use screw-on replaceable heads. These mallets are in the middle weight range and can be used on most surfaces.
- Lead & Brass mallets are considered soft hammers even though they are metallic. The difference is the weakness of the metal. When used on hard surfaces, such as steel, the lead or brass will give way before the steel. With that said, it is not always best to use a lead or brass mallet even on a hardened surface if a softer lighter mallet will do the job.
- Urethane composite mallets are far superior to the other mallets listed above. This mallet is generally constructed of polyurethane with a hollow head that is partially filled with small lead balls to give it weight. This mallet has particular advantages in that it carries the weight of a heavy mallet, the surface of a light mallet and the construction prevents bounce back. As the hammer strikes the surface, the weight of the beads shifts forward and stops the mallet dead. The mallet is sometimes called a "dead blow hammer" (Fig. 3.4).

Fig. 3.4

Pliers

COMMON OR COMBINATION PLIERS

Fig. 3.5

Inexperienced technicians will sometimes use the common pliers (Fig. 3.5) for removing and sometimes installing hardware. This is NOT what any style of pliers is designed for. Almost all piers, with the exception of special purpose pliers, are designed to *hold* material that is being worked on. The combination pliers have a slip joint and small outer teeth and larger inner teeth. The outer teeth are to hold flat objects and the inner teeth are to hold round objects. Never put too much pressure on hardened materials. This will dull the teeth and make the pliers ineffective. Table 3.1 shows pictures of the different pliers described in the paragraphs below.

DIAGONAL CUTTING PLIERS

As the name suggests, diagonal cutting pliers (Fig 3.6) are used for cutting. Wire is the primary object for cutting, although they may also be used to remove cotter keys from castellated nuts, spreading, and trimming cotter keys. Never try to cut a large diameter wire or cotter key with these pliers. They are intended for small gauges. General rule; if it cuts easily with normal hand pressure, the diameter is acceptable.

SIDE CUTTING PLIERS

For larger diameter wire, the side cutting pliers (Fig 3.7) are ideal. Unlike the diagonal cutting pliers, they have a straight cutting edge with a larger handle for heavy cutting. Further more, they have a flat gripping surface, like combination pliers, for straightening large gauge wire.

NEEDLE NOSE PLIERS

Needle nose pliers (Fig. 3.8) are for handling small objects, reaching in to difficult areas, and bending small wire. They are not designed for heavy gripping. Too much pressure will ruin the tip of the pliers.

SNAP RING PLIERS

Snap ring pliers (Fig. 3.9) come in a variety of styles used to remove and install snap rings. Some open the snap ring when squeezed (external pliers) while others close when squeezed (internal pliers). The best snap ring pliers can open and close around snap rings by using the handle direction (convertible pliers). Snap ring pliers tips can be found in straight, 45 degree angle, and 90 degree angle.

LOCK GRIP PLIERS (VISE GRIPS)

One of the technicians favorite set of pliers are the lock grip style pliers (Fig. 3.10). These pliers have an adjustable jaw to allow for locking grips on round materials. The locking mechanism on these pliers is strong and should never be used on surfaces that cannot be marred. There are many different jaw constructions for the lock grip pliers not illustrated here.

SPECIALTY PLIERS

There are several specialty pliers designed for specific jobs. Some examples are: Battery terminal nut pliers, water pump nut pliers, ignition pliers; hose clamp pliers, and slip-joint (channel) pliers (Fig. 3.11).

CARE FOR PLIER

Keep pliers clean and dry. Occasionally put a drop of oil on the joint pin to prevent rusting

Fig 3.4

Table 3.1

Diagonal Cutting Pliers Fig. 3.6	
Side Cutting Pliers Fig. 3.7	
Needle Nose Pliers Fig. 3.8	
Snap Ring Pliers Fig. 3.9	
Lock Grip Pliers (Vise Grips) Fig. 3.10	
Specialty Pliers Fig. 3.11	

Wrenches

OPEN-END WRENCHES

Open end wrenches are designed to fit over or around a nut or bolt. On a standard open end wrench, the head is usually tilted slightly at a 15 to 22 ½ degrees to the body to get more swing from the wrench by "flopping", or alternating sides.. These wrenches are often configured with open ends on opposite sides of the wrench (Fig 3.12). The openings come in a combination of sizes in inches or metric (5/16 by 3/8 or 15mm by 17 mm).

Fig. 3.12

ADJUSTABLE OPEN-END WRENCHES

The adjustable open-end wrench, most commonly referred to as the Crescent® wrench, is simply an open-ended wrench with an adjustable jaw (Fig 3.13). This wrench is not intended to replace the open-end wrench. In fact, the adjustable open-end wrench should only be used when an odd sized fastener is encountered. NOTE: Always tighten or loosen hardware so that the force is applied to the fixed jaw. The fixed jaw can withstand much more force and prevent wrench damage and injury. Adjust the wrench jaw to the fastener size after you place it over the fastener. This prevents slippage and rounding of the hardware. Keep the wrench clean and occasionally put a drop of oil on the adjuster.

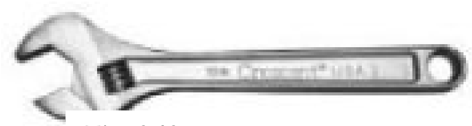


Fig. 3.13

BOX WRENCHES

Box wrenches are a configuration that grabs the fastener on all sides possible. This style greatly reduces slippage and is the preferred wrench for breaking torque (Fig 3.14)

The box wrench will either have a 6 point opening or a 12 point opening. The 12 point opening (Fig 3.14) allows for tightening or loosening of hardware with a minimum swing. A 12 point can work in tight areas with about 15 degrees of swing clearance compared to a six point which requires 30 to 60 degrees of swing. The 6 point box wrench (Fig 3.15) also has advantages. Since it has fewer contact points, more of the actual wrench surface is in contact with the fastener. This makes for a better choice on hard to break and larger fasteners. Trying to apply to much torque with a 12 point box wrench will damage the gripping edges of the wrench. The box wrench is often seen in a variety of offset configurations. These configurations are sometimes common offsets (Fig. 3.16) or special offsets designed for a particular job. Often, you will find the box wrench configured as a combination wrench, (Fig. 3.17) with one end box and the other open-ended.

Fig. 3.15

Fig. 3.14

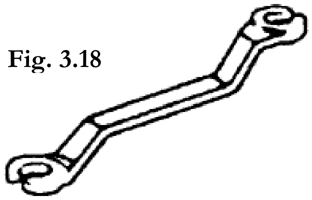
Fig. 3.16

Fig. 3.17

TUBING WRENCHES

The tubing wrench (Fig. 3.18) is very similar to the box wrench. It is usually found in a 12 point configuration. The difference is the box has an opening large enough to fit around a tube and can be placed on the tubing nut. Some tubing wrenches are offset and marked with an arrow for direction of swing. Always follow the correct direction to avoid damage to the wrench.

Fig. 3.18



SOCKET WRENCHES

Fig. 3.19

Socket wrenches and their attachments (Fig. 3.19) make short work of maintenance jobs. The socket wrenches is designed for speed. The start of all this utility begins with the socket. Sockets, like wrenches, are found in 6 and 12 point design. They can be standard or metric. Some are deep well sockets for reaching the wrenching point over other hardware, like on a spark plug. From the socket, the mechanic can choose a variety of attachments to access and remove or install hardware quickly. The ratchet handle can be placed directly on to a socket, or a combination of extensions and universal joints can be used. In either situation, the ratchet is not designed for heavy loads, such as breaking torque. The gears inside the head of the ratchet are for convenience and ease of use. Torque should always be broken with a breaker bar or sliding T-handle. Once torque is broken, the ratchet or speed handle attachment can make work quick.

TABLE 3.2

Standard Socket	Used for removal or installation of bolts or nuts.	
Deep Well Socket	Used for removal and installation of hardware in deep areas for extra extension or over hardware parts to reach the wrenching surface	
Ratchets ¼" drive 3/8" drive ½" drive ¾" drive	The ratchet handle comes in various handle lengths and drive sizes. The ratchet has a lever or dial to change direction of the ratchet.	
Universal Joints	Like the ratchet, the universal comes in all drive sizes. It enables the reach of hardware at odd angles. It is NOT intended for heavy work	

	like breaking torque.	
Speed Handle	The speed handle is to rapidly remove and install hardware. It can be used with extensions or universals. It is NOT for breaking or final torque.	
Breaker Bar	Used to *break torque* on hardware. It comes in all drive sizes with handles manufactured for maximum leverage. NEVER use a cheater bar! The breaker bar also comes in a sliding t-handle design. The T-handle design works well in tight spaces, but does not have the force of a straight breaker bar.	

SET SCREW WRENCHES

This wrench is used to remove and install hardware with internal wrenching features. The most common is the hex head style. The tool can be found as a bound set or individual "L" shapes.

Fig. 3.20

SPANNER WRENCHES

Spanner wrenches are typically classified as special tools for a certain piece of equipment. The different styles are: Hook type, U-shaped hook type, End spanner, Pin spanner, and Face pin spanner.

Fig. 3.21
Pin Spanner Wrench

PROPER USE OF WRENCHES

Stuck nuts and bolts are a fact of life for maintenance technicians. Often, a good spray of WD-40® or Break Free® will loosen oxidation and facilitate removal of the hardware. However, most of the time we need to throw a little elbow grease behind it to break the torque.

TORQUE WRENCHES

Torque wrenches measure resistance to turning. It is not a measurement of force. If you were to pull on a length of flat bar to get it to bow, that would be classified as resistance. Torque, on the other hand, is the resistance encountered during twisting. Think of it this way, the torque wrench is not determining how hard you can pull. Instead, it reads how much force is being counter acted by the nut or bolt being twisted. There are three styles of torque wrenches:

- The flex type
- The dial indicator type
- The breakaway or click type

Fig. 3.22
Flex wrench

The *flex type wrench* is the most cost efficient and maintenance free style. However, it comes with a lack of accuracy. It is a simple design that measures the flex of the handle as pressure is applied.

The *dial indicator type* is more accurate in that it uses a calibrated dial indicator that is mechanically attached to the square drive. The limitation of accuracy on this wrench is human error reading the dial.

Fig. 3.23 Dial indicator

The *breakaway or "click" type* torque wrench is by far the most accurate torque wrench available. It is used in the highest technical fields of today. The breakaway torque wrench is designed to "break" or "click" at the head of the wrench when the desired torque is met. It does this with internal springs from the handle to the square drive. By twisting the handle to the desired torque value (imprinted on the wrench near the handle) the head will break at the exact torque specified as long as the wrench is used properly.

Fig. 3.24
Breakaway "click" wrenches

No matter how good a torque wrench is, it is only as accurate as its user. By far the biggest mistake technician's encounter while using a torque wrench is in the grip. ALL TORQUE WRENCHES measure torque from the center of the square drive to the handle. If torque is being applied with the hand short of the handle, or an extension of the handle, the torque will be inaccurate.

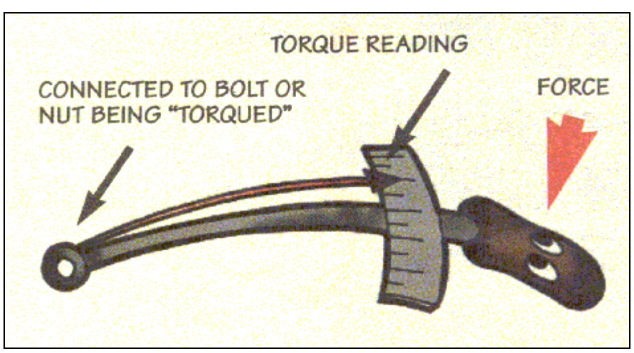


Fig. 3.25

In ALL wrench styles, NEVER change the length of the handle.

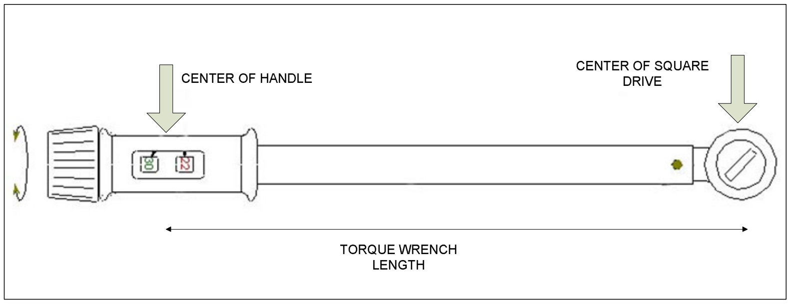


Fig. 3.26

As you can see from the (Fig. 3.26), the length of the torque wrench is constant. We can change that length by increasing the length of the handle, for example, placing an extension on the square drive. Once that is done, you have changed the length of the handle to the item being tightened and thus changed the accuracy of the wrench. A simple way to avoid this is by placing an extension to the wrench at a 90 degree angle. As shown in the Figure. Below, it does not change the length of the handle, thereby maintaining torque wrench integrity.

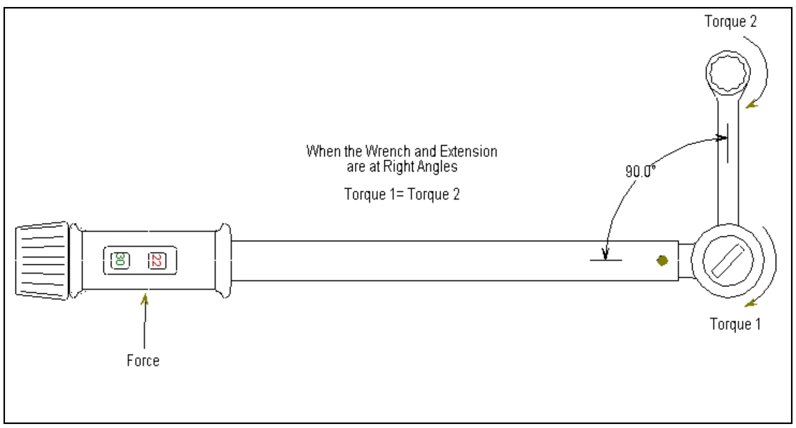


Fig. 3.27

When it is necessary to use an extension that cannot be placed at 90 degrees, torque formulas must be used to ensure accurate tightening of hardware.

Ta=torque at the end of the adapter
Tw=torque wrench reading
L=lever length of torque wrench
A=length of adapter

The formula is:

$$Ta = Tw \times \frac{L+A}{L}$$

If the length of the torque wrench is 24"
L=24
If the length of the adapter is 3"
A=3
If the torque wrench's setting is 525 pound-inches
Tw=525

Ta=525x $\underline{24+3}$ Ta=590.625

24

By setting the torque wrench to 525 and adding the three inch extension, the nut would be over torqued 66.625 pound-inches.

Torque wrenches are designated by the range of torque they can accurately apply. On larger applications the wrench is measured in pounds-foot (Newton-meters). For smaller jobs, the torque wrench will usually be in pound-inches (Newton-millimeters). To convert between the two, use this formula:

Pound-foot multiplied by 12 = pound-inches

Pound-inches divided by 12 = pound-foot

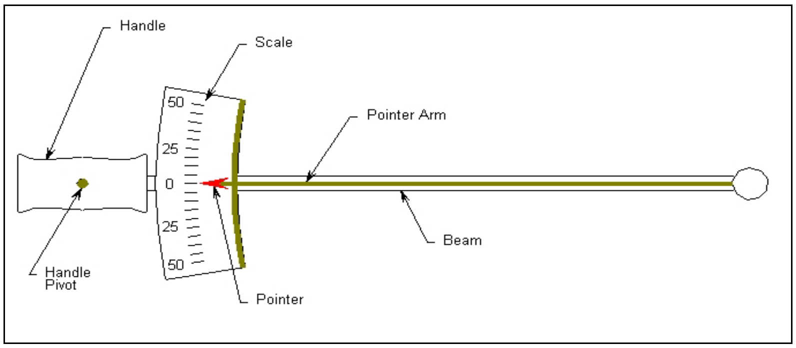


Fig. 3.28

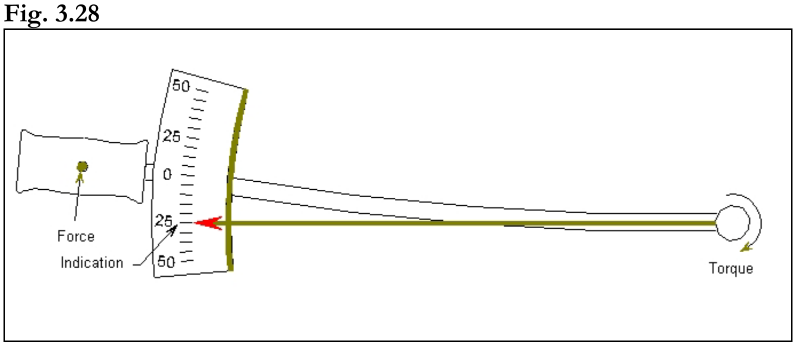


Fig. 3.29

Above is the deflection style torque wrench in rest and force (Fig. 3.29).

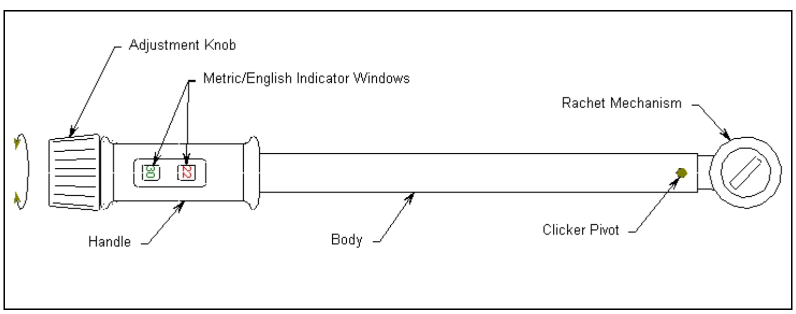


Fig. 3.30

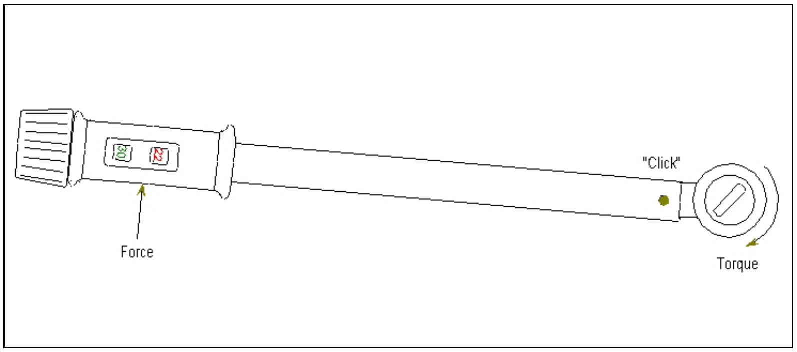


Fig. 3.31

The breakaway or click type at rest and with force applied.

SELECTING A TORQUE WRENCH

To get the most accurate torque, use a wrench that will allow you to operate in the middle two quarters of the scale. For example:
If you choose a 600 pound-foot torque wrench, any job within 150 to 450 pound-feet is the best working range. Check specifications of the torque wrench, many newer models are very accurate at higher ranges.

HANDLING TORQUE WRENCHES

Torque wrenches, especially the breakaway type, are very delicate instruments. Generally these require periodic calibration. If calibration or torque wrench checking equipment is not available, you can test the torque wrench by placing the drive on an immovable square opening and test by hanging weight from the handle or using a tension gage to pull on the handle. If a torque wrench is dropped, it should be inspected by an appropriate authority before using it on equipment. The internal springs are delicate and can cause inaccurate readings. When storing a torque wrench always return it to the lowest setting or zero.

USING THE TORQUE WRENCH

Considering all matters discussed previously, the use of a torque wrench is really quite simple. Remember to always pull or push the torque wrench from the center of the handle in a smooth steady movement. If you encounter resistance from a self locking nut or damaged threads, read the amount of force it takes to go thru these threads. This is called running torque. If you have running torque, add it to the torque value for the final torque. For example:
If your desired torque is 500 pound-inches and your resistance (or running torque) is 60 pound-inches, the total final torque should be set at 560 pound-inches.

THE IMPORTANCE OF PROPER TORQUE

For a bolt to stay tightened, it must have a load greater than the load it will absorb during operation. Hardware is selected by engineers to withstand the forces of the machines operation. When selecting these particular bolts, the final torque is an important factor. An over tightened bolt will stretch the threads to the point that threads are completely damaged and mating surfaces become unusable. An under tightened bolt allows a small freedom of movement that under certain circumstances, will cause the bolt to shear. Always follow torque specific guidelines provided in maintenance manuals.

Chisels

CAUTION: Always wear eye protection when using a chisel.

Chisels come in a small set of styles. The most common being the flat cold chisel. This chisel is capable of cutting thru course metal bolts and other materials. For heavy work, use a heavy chisel and a heavy hammer to match (the bigger the chisel, the bigger the hammer). When using a chisel, hold between the thumb and forefinger loosely. This will minimize injury in case of a miss from the hammer. In many cases, it is wise to use a set of pliers or vise grips to hold the chisel to prevent injury to the hand.

Fig. 3.32

Fig. 3.33

CAPE CHISEL

Cape chisels have a narrow cutting edge in various sizes that is designed for cutting keyways, narrow grooves and square corners.

DIAMOND POINT CHISEL

The diamond point is used for cutting v-grooves and squares.

ROUND NOSE CHISEL

Round nose chisels are designed to cut semi-circular grooves and chipping inside corners which have a fillet or radius.

Punches

Punches have a different purpose than chisels, but two things remain the same:

- Always wear eye protection
- Hold the punch with loose grip to lesson the impact from the hammer if you miss

STARTING PUNCH

A starter punch has a long gentle taper which extends from the tip to the body of the punch. This punch is designed for knocking out rivets and to start driving out tapered pins.

Fig. 3.34

Fig. 3.35

PIN PUNCH

The pin punch is used to drive pout pins *after* you have started the removal with a starter punch. The pin punch is *not* designed for starting pin removals. Striking this punch too hard may cause it to break.

CENTER PUNCH

A center punch is used to mark an area for further work, most typically drilling. This punch puts an indent in to hardened materials like steel. Once the indent is marked, a drill bit will hold its position with out wandering. The center punch should not be used on materials too hard for the punch to be efficient. If the punch should need re-shaping, it should be ground to the original specification of a 60 degree point.

Fig. 3.36

ALIGNING PUNCH

An aligning punch does exactly that, aligns two or more parts with holes. When mating pieces together with holes it is sometimes necessary to get them exactly aligned to put hardware through. The aligning punch is delicate and should *never* be used as a center punch.

Fig. 3.37

BRASS DRIFT

A brass drift is used as a pin punch. It is designed to knock things out or in to place. Since it is made of brass, it reduces the possibility of damage to surfaces that you are working on. It is the drift (punch) of choice when working on machined parts.

Fig. 3.38

Files

Files are made in numerous sizes and shapes. They also are designed in different cutting formats for specific needs. Some are course while others are fine. Below is a breakdown of the file parts:

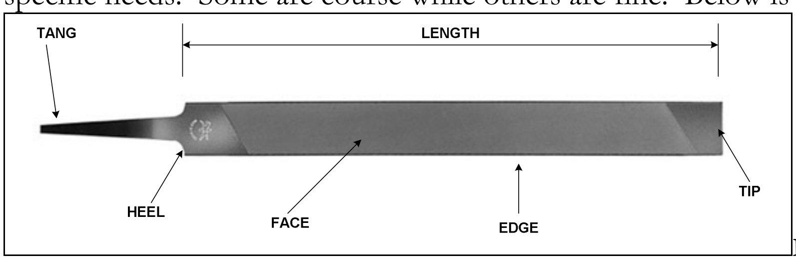


Fig. 3.39

When using a hand file, you should fit a handle over the tang of the file. This provides for a good working grip as well as preventing hand injury.

Fig. 3.40

CORRECT USE OF FILES

When using a file to mill off excess material, always push the file over the surface. This is how the teeth are designed to cut. After pushing the file forward, raise it and bring it back to the starting position. Dragging the file back across the material with the teeth dragging will ruin the file. Like screwdrivers, files are not meant to be hammered on or to be used as prying devices.

FILE STYLES AND USAGE

These are the file styles with tooth patterns. This will give you an idea of the different uses.

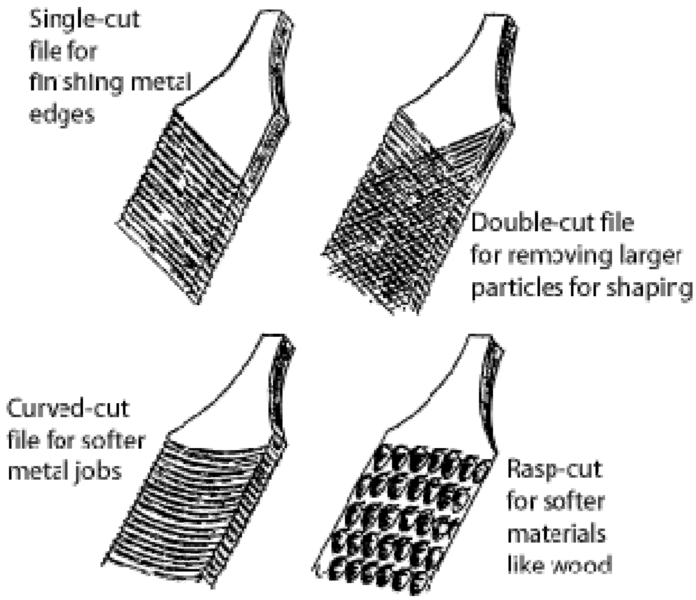


Fig. 3.41

CLEANING FILES

To keep a file in good working condition, they must be cleaned periodically. To clean file teeth, use a file card. This is a brush with short, stiff wire bristles. When chips are still stuck in the file's teeth after using the file card, use a scribe or "scorer" to pick out the remaining material. Keep the blades sharp by protecting the file while not in use. Never throw the file around or into your tool box.

Hacksaws

Hacksaws are unique to saws in that the frame can support multiple sizes of blades. Furthermore, the blade can be positioned at multiple axis for accurate abnormal cuts. When placing a blade in the frame, you need to make sure you have ample room to stretch the blade tightly. When the blade is tightly secured, it will vibrate when plucked. Another key factor in setting up the hacksaw is to ensure that the teeth are pointing forward, away from the handle. Like a file, the hacksaw cuts on the forward stroke.

Fig. 3.42

HACKSAW USE

By far the most common mistake technicians make when using a hacksaw is improper blade selection. Generally speaking, the smaller the teeth, the better the saw will cut. There are however large teeth available. These are use for large cutting surfaces. As a general rule, lay the hacksaw on to the material being cut. You should have a minimum of two teeth contacting the material when sawing. When cutting thin material, holding the hacksaw at about a 45 degree angle will give you more teeth in contact with the material.

MAKING A CUT WITH A HACKSAW

Start the cut by using a small length of the blade slowly. This will get the initial groove in place. Once you have the initial groove, put pressure on the saw on the forward stroke. Relieve pressure on the back stroke. It is not necessary to remove the blade from the cut on the back stroke, just relieve the pressure to prevent tooth damage. For cutting average metal, 40 to 50 strokes of the saw is preferred. When working with hardened metal, reduce the amount of the strokes for temperature control

CARE FOR HACKSAWS

Store the blades away from other tools so that teeth are not damaged. Wipe the blades with a light coat of oil to prevent rusting. When hacksaw blades become worn, do not attempt to sharpen them. It is more cost and time effective to simply replace them.

Vises

Vises are built for holding objects in place. It can be used for a variety of reasons. The two common vises are the bench vise and the drill press vise.

BENCH VISE

The bench vise is used to hold almost any object that needs to be cut, filed, milled, bent or otherwise worked. The vise can come in many sizes, but large vises are most commonly seen in maintenance shops. The vise has one fixed jaw and one adjustable jaw. The adjustable jaw is positioned by the vise handle. Since it uses a screw method of adjustment, squeezing pressure from the handle produces high pressure at the jaw. Caution must be used not to crush more delicate material. No matter how hard the material is, never use a hammer to tighten or loosen the handle. When working with machined surfaces or delicate material, it is a good idea to place soft jaw covers on the vise to prevent damage to the surface.

Fig. 3.43

DRILL PRESS VISE

The drill

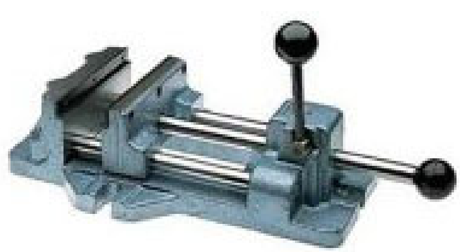


Fig. 3.44

press vise is used on a drill press to drill small parts and to hold large parts in place for accuracy. Never try to use pliers or even a bench vise for drilling. Precision is about craftsmanship and using the right tools. The right tool to hold items when drilling is the drill press vise

C-Clamps

C-Clamps are a versatile holding device. Their advantage is that they are more mobile. The disadvantage is that they do not provide the strength of a bench vise or the accuracy of a drill press vise. However, they are very handy for holding material together to let glue dry or to perform welds.

Twist Drills

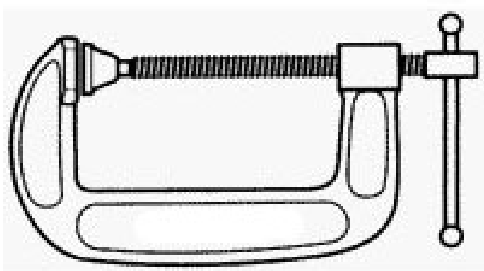


Fig. 3.45

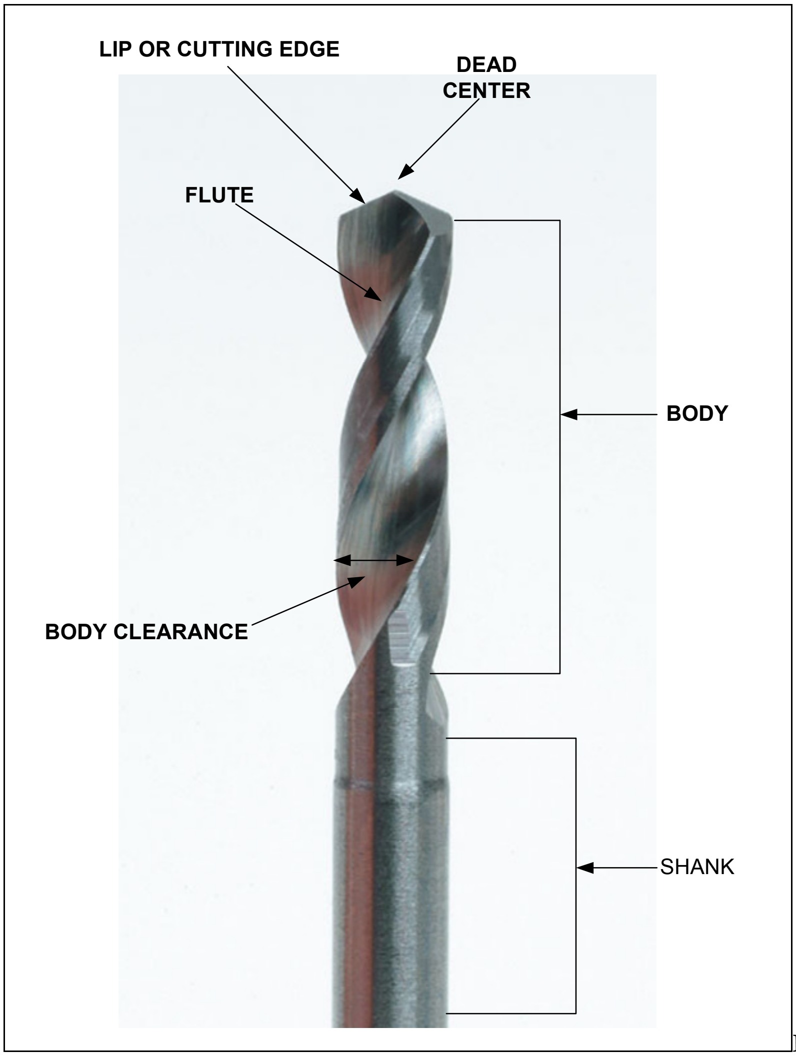


Fig. 3.46

TWIST DRILL PARTS

Twist drills are made of different materials for different applications. A standard carbon tool grade steel will lose its hardness when overheated. Typically this type of drill is used on softer materials, operating at lower speeds. Drills made for high speed and hot operating temperatures are made from high speed tool grade or have additional metal properties added, such as cobalt. This style can literally get red hot and not lose its temper.

GRINDING OR SHARPENING DRILLS

Most often drill bits are relatively inexpensive and can be replaced when worn or chipped. There are instances when you may need to sharpen a twist drill that is unique or expensive to replace. The only portion of a drill that needs to be worked is the lip (the cutting edge). Use a grinder or file and take off just enough material to get the sharpness back while maintaining the same angle of the cutting edge. Keep the tip cool while grinding as not to affect the bits original hardness.

Taps and Dies

TAPS

Taps are the cutting tool used for repairing or making *internal* threads. Taps come in all sizes.

- Course standard thread (N.C.)
- Fine standard thread (N.F.)
- Special thread (N.S.)

Along with these American standard measurements, taps can also be found in all metric sizes and are measured in millimeters.

There are plenty of specialty taps on the market; however, there are four styles that are most commonly used.

Fig. 3.47

TAPER TAP

The taper tap is used to tap completely through the hole. Note the gradual taper that allows the tap to start easily.

PLUG TAP

The plug tap is used to tap holes partway through.

Fig. 3.48

BOTTOMING TAP

The bottoming tap is used to cut threads all the way to the bottom of a blind hole. Use the plug tap first on a blind hole. This will allow for the bottoming tap to get a start.

Fig. 3.49

Fig. 3.50

MACHINE SCREW TAP

The machine screw tap is generally found in the fine category of threads. It has a steeper taper than the other taps because of the sensitivity of a smaller opening and thread pitch size.

DETERMINING THE THREAD PITCH AND DIAMETER TAP TO USE

Before you can start repairing threads, you need to know the thread size. The first part will be to get the pitch of the thread you are working with. The simplest tool to use for this is a thread gage. This works by simply matching teeth to the hardware you are using. To measure the diameter of the hardware, the most accurate method is to use an outside micrometer (covered later in this chapter).

Fig. 3.51

USING THE TAP

Taps have a square wrenching feature on the end. This feature is used to attach various styles of handles to the tap. Once the handle is installed you can start to tap the hole with either a taper tap or a plug tap depending on the application. Taps are actually quite brittle and should never be forced. Rotate the tap in the clockwise direction while keeping the handle straight. When roughness or binding is felt, back the tap out to remove debris and continue with the process until the tap moves easily throughout the length of the hole.

Fig. 3.52

DIES

Dies work in the exact same fashion as a tap except that they cut *external* threads. The methods for selecting size and thread pitch are the same. Some dies have adjustments to decrease thread diameter, but only very slightly. While there are a multitude of special die tools for specific applications, the typical die is generally round with indentions along the outside perimeter to allow for a die wrench to be attached.

Fig. 3.53

TAP AND DIE SET (TYPICAL)

Fig. 3.54

Screw Extractors

Screw extractors look like a reverse drill bit. They are tapered to grab broken screws or bolts. When a broken screw or stud cannot be removed externally, drill a hole in to the direct center of the broken stud. Insert the extractor in to the hole while using a small wrench to turn it counter clockwise.

Pullers

There are many pullers made specifically for equipment. Consult your technical manual for specific pullers that may be required. Aside from specific pullers, there are three basic styles:

- The external puller
- The press puller
- The inside puller

EXTERNAL PULLER

The external puller is used to pull items such as gears or pulleys. The puller has jaws that hook to the outside diameter of the object. The threaded shaft on the puller is then rotated, moving the item off of the shaft.

Fig. 3.55

THE PRESS PULLER

The press puller is used to push objects through a stationary piece. The press puller will have legs that are anchored to the stationary piece, usually by threading in to or bolting on. The threaded shaft then becomes a puller, since the legs cannot move. This puller is typical for pressing a shaft from a bore.

Fig. 3.56

THE INTERNAL PULLER


Fig. 3.57

The internal puller is like a combination of the press and external puller. It has legs that are stationary like the press puller and jaws to hook on to the object being pulled. This type of puller is often used to remove bearings from inside a bore

PULLER USE

When using pullers, there are few things to keep in mind. Never try to wrench too hard on the puller to remove stuck objects. If necessary, obtain a hydraulic puller for large or stuck parts. The puller is not designed to hammered on nor to have a cheater bar used on the wrenching device. Reasonable force is the rule when pulling. If you think you are going to damage the threads of the pulling shaft, then something is wrong. Make sure your threads are clean and not burred. Also check that the puller is installed correctly and evenly.

Pick Up Tools

MAGNETIC PICK UP TOOL

The magnetic pick up tool is useful for retrieving hardware that is dropped or difficult to get to. It has a telescoping handle and a swivel head for getting in to difficult areas.

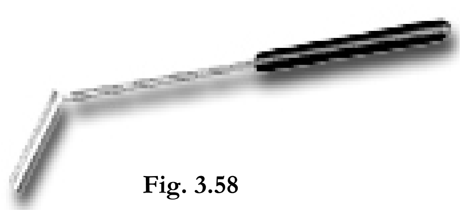


Fig. 3.58

MECHANICAL PICK UP TOOL

The mechanical pick up tool can be used to retrieve objects whether they are magnetic or not. It has a plunger on the handle for opening and closing metal jaws at the opposite end. These pick up tools normally have a flexible shaft to get in to difficult areas.

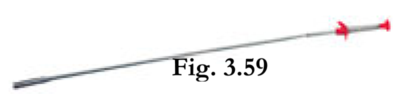


Fig. 3.59

Inspection Mirrors

Inspection mirrors are used to look at objects in blind spots. Like the name suggests, they are often used to inspect parts or hardware. They can also be handy to locate dropped hardware. The mirrors come in all sizes and shapes and generally have telescoping shaft for extension.


Fig. 3.60

Tubing Cutters

Fig. 3.61 These tools are used to cut tubing made of copper, aluminum, or steel. The tool is mounted on to the tubing with one side holding it in place and the other with a cutting wheel. As the tool is turned it cuts in to the tubing. Pressure is slowly increased until the tube is cut off smoothly.

Soldering

Soldering is the process of joining two pieces of metal by using a third metal as an adhesive. Unlike welding, soldering does not involve melting the two metals being joined. The solder is the only item melted. Standard solder melts at 800°F, which is way below the melting point of most metals. Most metals can be soldered with the exceptions of: chromium, beryllium, magnese-bronze, and titanium.

SOLDERING METHODS

There are three methods of soldering:

- Soldering iron
- Torch
- Resistance

The soldering iron is a tool that is heated either electrically or in a flame. The iron is placed on the metal that is to be adhered which will get hot enough for the solder to melt and fill the joint. If the iron is the type that is to be heated with flame, it will have to be periodically re-heated.

Soldering with a torch is much faster because of the amount of heat it produces. Torches are generally used to heat sheet metal and heavy pipes. Torches are not practical for small wiring soldering because it could melt and damage surrounding parts.

Resistance soldering is similar to "spot" welding in that the adjoining metals are heated with electrical current to a point where the solder can melt, then heat is removed.

SOLDERING MATERIAL

Solder quite simply is a mixture of tin and lead. It comes in ranges of "soft" to "hard" solder. Soft solder has less tin and melts faster. Hard solder has more tin and tends to bond better. When soldering items, refer to technical manuals to ensure you are using the right type. Solder can be found in wire or stick form. Some solder contain their own flux, while others have to be dipped or applied to the solder area. Flux is a chemical substance that aids in fusing the two metals.

SOLDERING PROCEDURES

1. Clean the joint thoroughly
2. Tin the soldering iron by placing it on a sal ammoniac block, then touching solder to it. Or, simply heat the soldering iron and place solder to it.
3. Heat both pieces to be soldered and apply flux, if not included in the solder.
4. Apply the solder to the joints, not the iron.
5. Lap the two pieces and hold the heated iron over the seam to fuse the solder. Remove the heat after the solder has thoroughly penetrated the joint.
6. Hold the two lapped pieces until the solder cools and sets.

Feeler Gauges

Fig. 3.62

STANDARD FEELER GAUGE

A standard feeler gauge is made up of multiple "leafs" or "blades". The blades range in size from .001 (one thousandth of an inch) to .025 (twenty-five thousandths of an inch). Feeler gauges are primarily used for measuring the gap in between surfaces.

OTHER FEELER GAUGES

As seen in the previous picture, feeler gauge come in different configurations. A stepped feeler gauge has blades with two thicknesses. The tip has a designated thickness and the rest of the blade is two thousandths larger. These feeler gauges are handy for quick, approximate measurements.

For thicknesses of more than .025", a wire feeler gauge can be used. Spark plug gap gauges are this type of gauge.

USING THE FEELER GAUGE

When measuring the gap between two surfaces, ensure the gauge blade is clean and straight. Insert several blades in to the gap until a snug fit is found. Never try to force a blade in. If it is too tight, go to the next smaller blade and try it.

Keep the feeler gauge blades covered with a light film of oil to prevent corrosion. Never bend or twist the blades.

Micrometers

Micrometers are precision measuring tools that measure in thousandths of an inch. Some micrometers are capable of measuring up to ten thousandths of an inch. There are four types of micrometers:

- Outside micrometer
- Inside micrometer
- Depth micrometer
- Telescope gauges

OUTSIDE MICROMETER

The outside micrometer measures, in fine detail, the outside diameter of an object. It is a precision device capable of accurately measuring to thousandths of an inch. Let's look at the components that make up an outside micrometer.

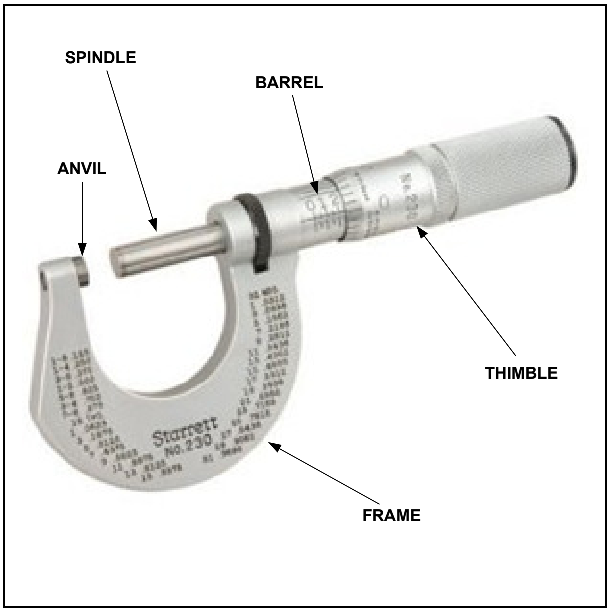


Fig. 3.63

Some micrometers come with a ratchet feature on the thimble to help get an accurate measurement without over tightening the thimble. The ratchet is not shown in the example above.

HOW TO USE A MICROMETER

The first step in using an outside micrometer is to determine how large the item is. Any micrometer has an effective measuring range of one inch. So, in the case of an outside micrometer, some measurement range examples are:

0" – 1"
1" – 2"
2" – 3"
3" – 4"

Fig. 3.64

For example: If you need to measure the outside diameter or thickness of an object, you first need to know an approximate size. If you use a common ruler and see that it is roughly 3-1/2", then the micrometer you would select would be a 3-4 inch outside micrometer. If you are measuring an item known to be under an inch, you would select a 0-1 inch micrometer.

When measuring the thickness of a flat bar, place the micrometer anvil on to the surface. Turn the thimble gently until the spindle makes solid, but gentle contact.

When measuring a cylindrical shaped item, such as a car piston, position the anvil on one side. Adjust the thimble so that the spindle makes slight contact with the *furthest* diameter of the part. To get to the most outside diameter, furthest point, move the micrometer spindle around the outside until you get the closest contact and take your measurement.

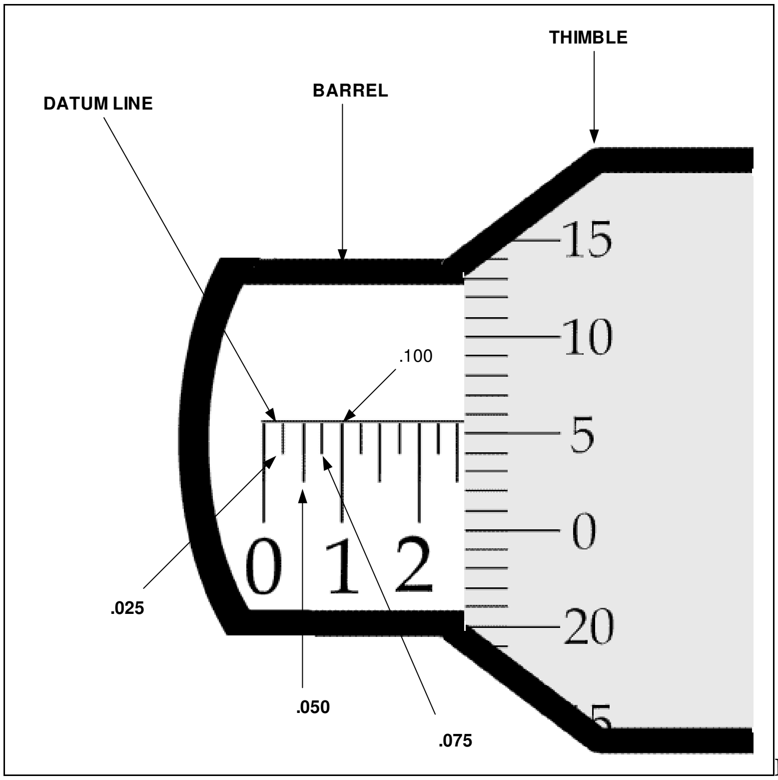


Fig. 3.65

When taking measurements, don't be afraid to take a couple more to make sure you are accurate. Even the most skilled technicians check their work. If possible, take you reading before moving the micrometer away from the work. This will help prevent accidental rotation of the thimble.

HOW TO READ A MICROMETER

We now know that each micrometer can only read a total length of one inch. However, the micrometer was designed to read much more critical and minute sizes. We will break down the micrometer over the following pages. When it comes time for the real thing, practice does make perfect.

If our thimble started at the zero line and we turned it one full revolution, it would read .025". No matter what the size of the micrometer, one revolution of the thimble equals .025". As you can see by reading the scale off of the datum line, the scale reads in .025" increments. There fore two revolutions would equal .50", three revolutions would be .075", and four .100". Let's break down this measurement:

The thimble is past the 2, so our first number is .200
The .050 line is visible behind the 2, so we are adding that .050.

.200 + .050 = .250

So far we have read down to one hundredths of an inch, but we want to get down to thousandths of an inch.

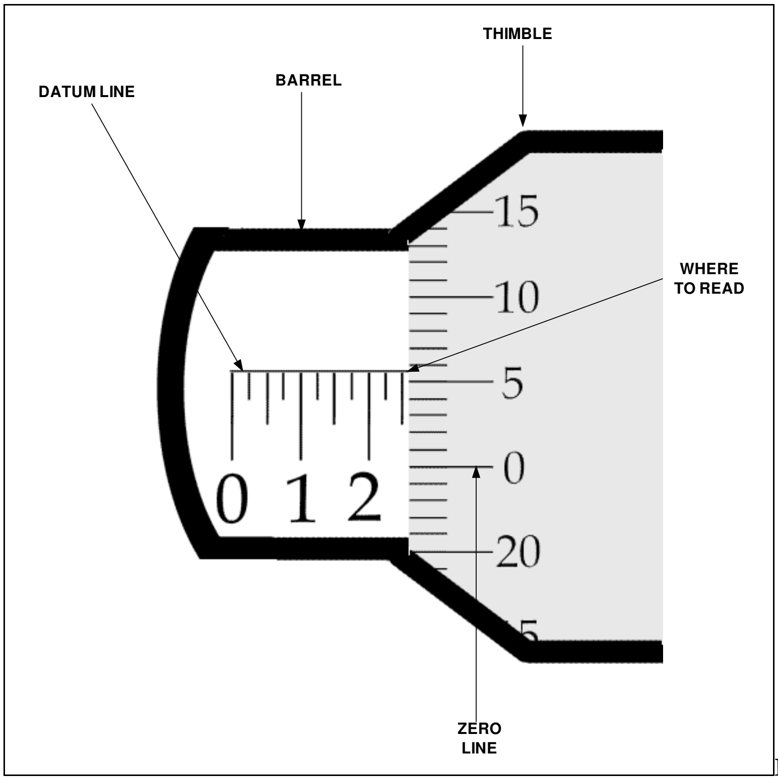


Figure 3.66

We know we have .250 already. To get the rest of the measurement we will read from the thimble. As you can see on the reading, we are closer to the six, so we will add .006 to our Figures.
.250 + .006 = .256
From the examples above, if we were using a 1-2" micrometer, our measurement would break down as follows"
1" + .200 + .050 + .006 = 1.256. Stated, it would be one and two hundred fifty-six thousandths of an inch. Notice that we had to guess on the .006 by seeing which number was closer to the datum line. There is another scale on some micrometers that measures down to ten thousandths of an inch. With this, we would not have to round the number, we could get it precise.

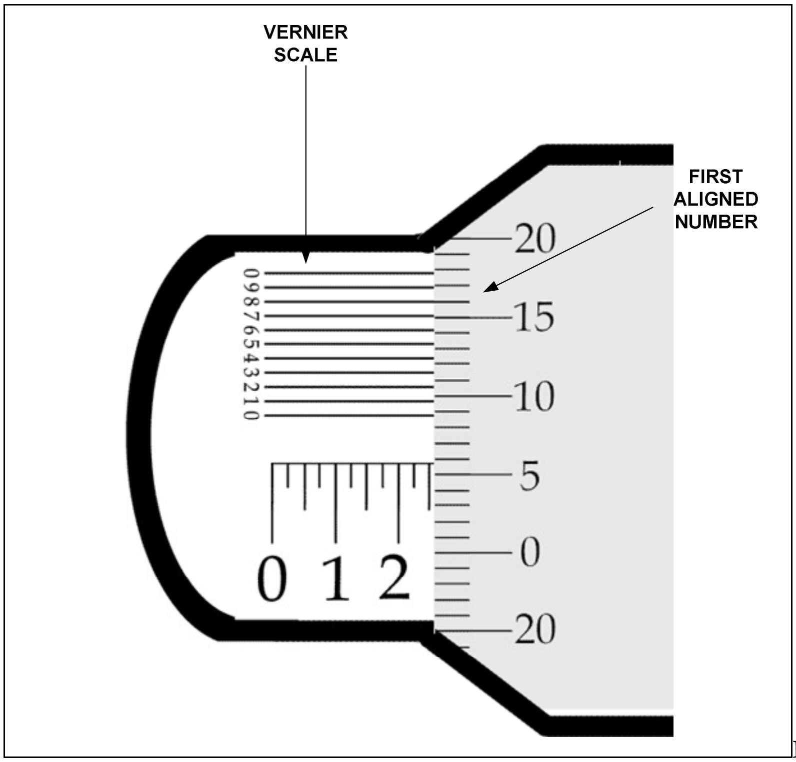


Figure 3.67

This micrometer has an additional scale. The Vernier scale is used to measure accurately down to ten thousandths of an inch. To read the scale, go up the numbers until you find the first line from the scale and the thimble to match. That number is.0008. So instead of our previous measurement of .256 of an inch, we have narrowed it down to .2558 ten thousandths of an inch.

METRIC MICROMETERS

Metric micrometers read exactly the same as inch micrometers. A few differences are that one revolution equals .05mm instead of .025". The metric micrometer has a full travel range of 25mm compared to 1 inch.

INSIDE MICROMETERS

Inside micrometers have all the same measuring parts of an outside micrometer; it simply looks different because it is made for measuring inside dimensions. Some inside micrometers are caliper type, while others use various rod lengths to measure large inside diameters.

Fig. 3.68

DEPTH MICROMETERS

Fig. 3.69

Reading a depth micrometer is exactly the same except that you are reading the numbers you can't see. Its scale reads backward from 10 instead of starting at 0. When using a depth micrometer, ensure the anvil is firmly on the surface.

TELESCOPE GAUGE

The telescope gauge is used to measure bore openings. This is a good option for measuring where there is no room to work an inside micrometer. The telescope gauge is placed in to the bore in a squeezed position. Once it is inside and level, release the locking mechanism and the telescope will open. Find the largest diameter, hold the gauge steady and lock it in to place. Pull the gauge from the bore and delicately measure it with an outside micrometer.

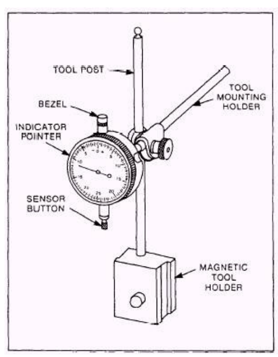
Fig. 3.70

CARING FOR MICROMETERS

Keep micrometers clean. Dirt or abrasions on the anvil and spindle faces will cause inaccurate readings. Store in a box and keep clean with a light coat of oil. NOTE: If a micrometer is dropped, have it checked for calibration before using it again.

Dial Indicators

Fig. 3.71



Dial indicators are used to measure movement of parts such as shafts or gears. Dial indicators have a variety of mounting systems. Two popular ones are the C-Clamp type and the magnetic type. Dial indicators have a face with various increments depending on its function. You should start all measurements from the zero position. From there the indicator can swing from positive to negative numbers. It is important to take the full movement of the gauge. For example: if an indicator starts at zero while you are checking movement and the gauge reads positive 15 and then to negative 23, the total measurement would be 38.

Spring Testers

Spring testers check springs for resiliency to see if they match the specifications. To use the tester, insert the spring, pull on the lever to compress the spring to the specified compressed length, and read on the indicator pounds of pressure exerted. Always zero the indicator prior to each test.

Speed Measuring Tools

Shop tools used for measuring speed are available in many shapes and forms. The following types are discussed further.

- Revolution counters
- Tachometers
- Vibration tachometers
- Stoboscopes (timing lights)
- Photo tachometers

- Oscilloscopes
- Electronic tachometers

REVOLUTION COUNTER

The simplest tool for measuring speed is the mechanical revolution counter. When taking a reading, the rubber tipped shaft is pressed against the end of a rotating shaft. The number of revolutions is indicated on a dial and Figures as revolutions per minute (RPM).

TACHOMETERS

These do the same thing as a revolution counter in that it measures RPM. A tachometer in a car is doing just that. It measures the speed of your engine and transfers that to some type of indicator in revolutions per minute.

VIBRATION TACHOMETER

The vibration tachometer (sirometer) will indicate the revolutions per minute (RPM) by matching RPM to vibration frequency. Place the vibration tachometer on a level surface of the operating equipment. When the adjustable length of wire resonates consistently with the equipment, the RPM is read on the tachometer scale.

Fig. 3.72

STROBOSCOPE

The stroboscope gives speed of rotation or vibration. The light matches a point on a rotating shaft or gear. When the light flashes are adjusted so that the shaft appears to be still, the speed of the scope is read in RPM.

PHOTO TACHOMETER

A photo tachometer is a highly accurate instrument used to check RPM and stopping time. The equipment uses a photo (light) probe and reflective tape. The meter measures the time between each pass of the tape.

OSCILLOSCOPE

An oscilloscope can measure speeds as slow as a heart beat to very high ratio frequencies. It is widely used in testing the vibration in various parts of a test engine or other components. It uses a common time signal, such as 60 cycle current for comparison against the unknown cycle.

ELECTRONIC TACHOMETERS

These measure speed in a few different ways. One example is of an inductive pick up sensor clamped to a fuel injection pump line. The sensor will read the fuel pulsation in the line and send a signal to a digital meter. Other meters can pick up electricity from a spark plug cable and time the pulses.

SPECIAL TOOLS

Special tools are the tools that are made specifically for a piece of equipment and are used for limited or one task. These tools are sometimes complex. Instructions and care for the tools will be found in the equipment technical manual.

Review

1. The tip, or working end of a screw driver is know as
   A. The bit
   B. The shank
   C. The cross
   D. The handle

2. When a fastener is difficult to break loose, you should
   A. Use a cheater bar
   B. Use a small drive ratchet
   C. Use a breaker bar
   D. Use a adjustable jaw wrench

3. When installing a hacksaw blade
   A. Ensure the teeth are pointing toward the handle
   B. Leave the blade loose in the frame for more control
   C. Install tight and so the teeth are pointing forward
   D. None of the above

4. When you store a click type torque wrench
   A. Leave it at its last setting
   B. Place with hammers and chisels
   C. Set it to the highest torque setting
   D. Set it at the lowest indicated torque setting

5. What are the two common styles of vises and how are they used?

6. Box end wrench's come in this form?
    A. Combination open end
    B. Offset box
    C. 12 point box
    D. All of the above

7. A puller that has both legs and jaws is usually this type of puller
    A. An arbor press
    B. An external puller
    C. A press puller
    D. An internal puller

8. One revolution of a micrometer will measure this amount of inches
    A. 1.25
    B. 1.00
    C. .001
    D. .025

9. The Vernier scale on a micrometer can measure down to
    A. One thousandth of an inch
    B. One ten thousandth of an inch
    C. One tenth of an inch
    D. One hundredth of an inch

Chapter 4

Fasteners

Introduction

Virtually everything made, or that has been made, by man is fastened in some way. In the maintenance world we think of fasteners as nuts and bolts. However, fasteners can be found in a variety of designs. A button on a shirt, safety pin, paper clip, and a nail are all fasteners. One of the leading fasteners today is VELCRO®. It has even found its way in to maintenance. A fastener can be anything that is designed to hold two or more items together.

In coach maintenance, the primary fasteners we will discuss are more typical of the maintenance industry. But even in heavy mechanics, we find fasteners as simple as locking pins. All fasteners have to be right for the job. A bolt may have to meet certain strength levels as well as be sized correctly. Some hardware installations may require washers, locking nuts, or special securing devices to be properly installed.

CAUTION: It is extremely important to use hardware listed in specific maintenance manuals. When using an alternative is the only option, it MUST match or exceed the requirements of the item being replaced.

WHY FASTENERS

Fasteners of all types are used in just about everything we operate. Their design has been modified to fit needs for a specific piece of equipment for safety or operating requirements. Fasteners hold our transmissions in our car to our engine. They hold a door on its hinges. When we use fasteners like this, it gives us the opportunity to remove them for maintenance, replacement, or inspection. If everything were welded or forged in to one piece, it would restrict access as well as limit the internal operation of complex components.

QUALITY FASTENERS

Fasteners have to be able to hold up to the job. You wouldn't want your steering system on your car to have weak, unreliable fasteners installed. Some of the factors in considering fasteners are:

- Made of good materials, capable of long life and non-interference with parent metals.
- Strength to be able to handle stresses of the equipment
- Easy to remove and install. Re-usable.
- Corrosion resistant relative to life span and safety concerns.
- Ability to withstand extreme temperatures.
- How well it holds up to vibration

Bolts and Cap Screws

A bolt (or a cap screw) is a length of metal rod with a head and a body. The head is usually hexagonal but can be found in various forms discussed later in this chapter. The shank of a bolt has external ribs called threads. The top of the rib is called the crest and the groove is called the root.

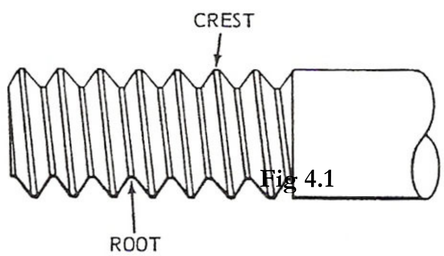
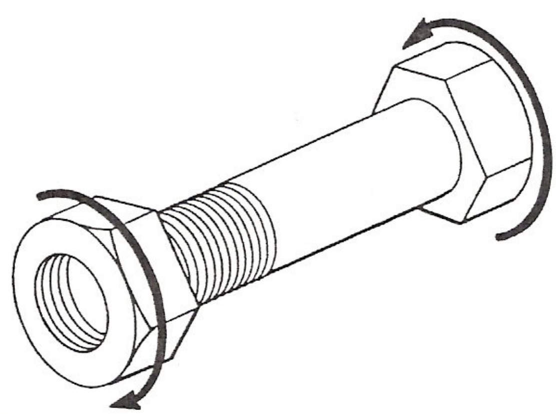


Fig 4.1

The threads are to mate with internal threads of a component, most commonly a nut. Threads are normally manufactured to tighten in the clockwise direction. However some special applications tighten in the counter-clockwise direction. This is known as reverse threads.

Fig 4.2



MEASURING BOLTS

The sizes of standard bolts are measured this way:

- Length = the distance from the bottom of the head to the end of the threads.
- Size (thread diameter) = the outside diameter of the crest of the threads.

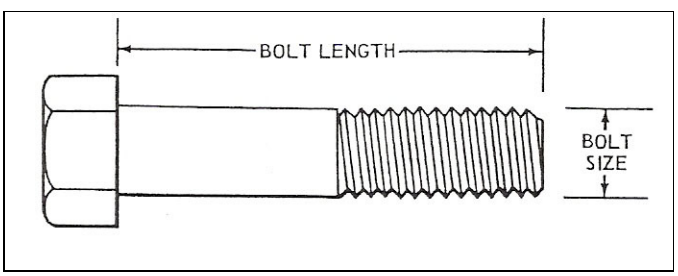


Fig. 4.3

The unthreaded part of the bolt shank is called the body. Some bolts have long bodies and others have none at all. The threads are designed to hold the items tightly; the body is for aligning parts and keeping them in place. The bolt head is measured across flats. This measurement determines what size tool to be used on the head.

THREADS

Threads are measured by counting the number of threads per inch on standard bolts. Metric threads are

measured by the distance in the thread. This is done by measuring from crest to crest. Like most tasks, tools were made to make our jobs a little easier. The thread pitch gauge is handy for quick reference of thread count.

Some threads are coarse while others are fine. Coarse threads are standard in most machinery and automotive industries. However, fine threads are more common in delicate areas and in instances of high strength requirements, such as aircraft parts. Usually one thinks of a coarse threaded bolt as being stronger. It is not necessarily true. The threads are what lock the two parts together, the more threads, the more locking. Coarse threads hold up better in dirty, rusty conditions because the threads are simply more beefy.

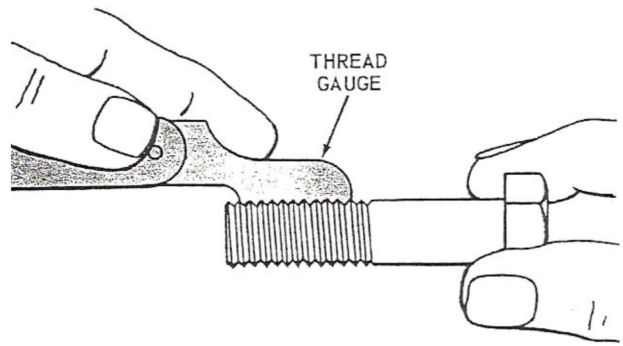


Fig 4.4

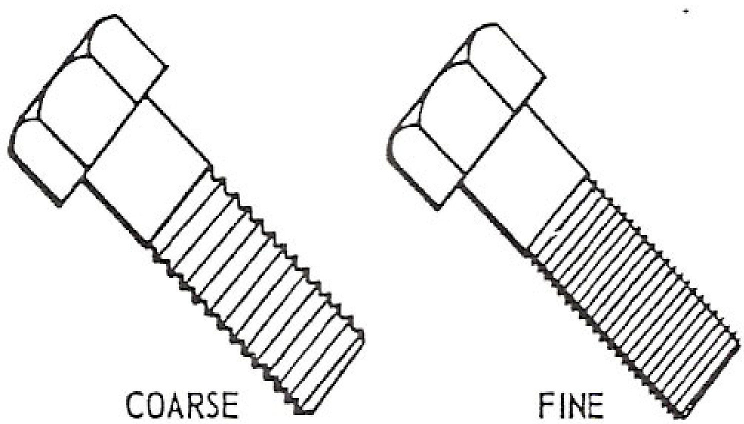


Fig. 4.5

There are carefully controlled standards for threading nuts and bolts. These are approved by the American National Standards Institute (ANSI). They establish such things as the pitch of threads, the depth of the root, and manufacturing tolerances (fit) designated by a thread class symbol, such as 1A or 2A. The ANSI specifications are referred to as "Unified Screw Thread Standards".

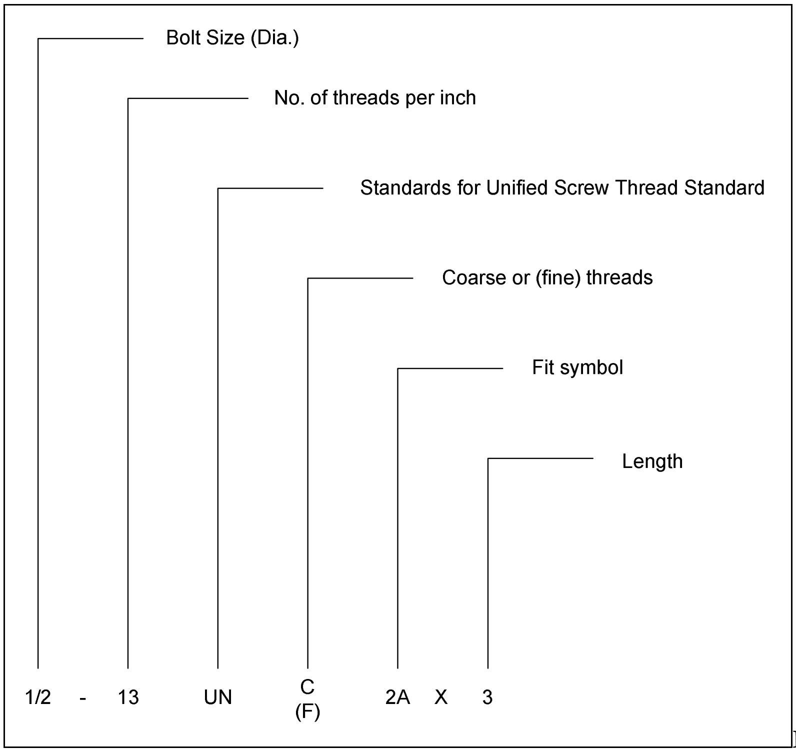


Fig. 4.6

The diagram above describes a bolt identified as:
1/2-13UNC-2AX3
NOTE: If this was a fine thread bolt it would read:
1/2-13UNF-2AX3

The following breaks down metric bolt measurements:

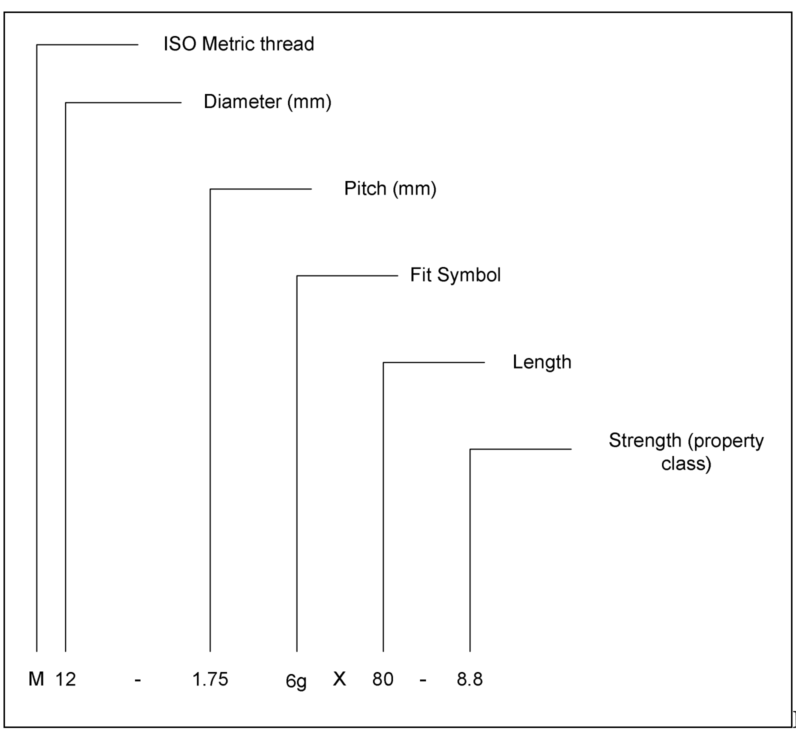


Fig. 4.7

BOLT CORROSION CONTROL

Many modern high quality bolts and other fasteners are coated with zinc or cadmium for resistance to corrosion. Sometimes they are dipped in chromate as further resistance to rust.

GRADES (OR PROPERTY CLASSES) AND HEAD MARKINGS

The type of steel used and how that steel is treated in the manufacturing process determines what grade the bolt is. The grade is determined by the strength of the bolt.

The Society of Automotive Engineers (SAE) has established certain standards for classifying unified (inch series) bolts and screws into grades. They do this based on the material and treatment used in manufacture. They also consider the tensile strength and yield strength (how much pull they can stand without breaking).

The SAE has also designated markings to be put on bolt and screw heads to indicate the grade. The markings consist of radial slashes.

GRADE (OR PROPERTY CLASS) MARKINGS FOR STEEL BOLTS & SCREWS

UNIFIED (INCH) STEEL BOLTS & SCREWS					METRIC STEEL BOLTS & SCREWS			
HEAD MARKING	SAE GRADE	DIAMETER inches	TENSILE STRENGTH psi (MPa)		TENSILE STRENGTH (MPa)	DIAMETER mm	SAE PROPERTY CLASS	HEAD MARKING
no mark	Grade 1	1/4 to 1-1/2	60,000 (414)	Approx. Equiv.	400	5 to 36	Class 4.6	4.6
					420	up to 16	Class 4.8	4.8
no mark	Grade 2	1/4 to 3/4 (Length up to 6 in)	74,000 (510)	Approx. Equiv.	520	5 to 24	Class 5.8	5.8
	Grade 5.1	(.138) No. 6 to 5/8	120,000 (827)	Approx. Equiv.	800	up to 16	Class 8.8	8.8
	Grade 5.2	1/4 to 1						
	Grade 5	1/4 to 1			830	over 16 to 36		
		over 1 to 1-1/2	105,000 (724)					
	Grade 7	1/4 to 1-1/2	133,000 (917)	Approx. Equiv.	900	up to 16	Class 9.8	9.8
	Grade 8.2	1/4 to 1	150,000 (1034)	Approx. Equiv.	1040	up to 36	Class 10.9	10.9
	Grade 8	1/4 to 1-1/2						
Socket Head	(none)	up to 1/2	180,000 (1241)	Approx. Equiv.	1220	up to 36	Class 12.9	12.9
		5/8 and larger	170,000 (1172)					

— SAE Grade Markings and Strength Specifications — Metric Steel Bolts and Screws

The following chart gives even more designations of special manufactured bolts:

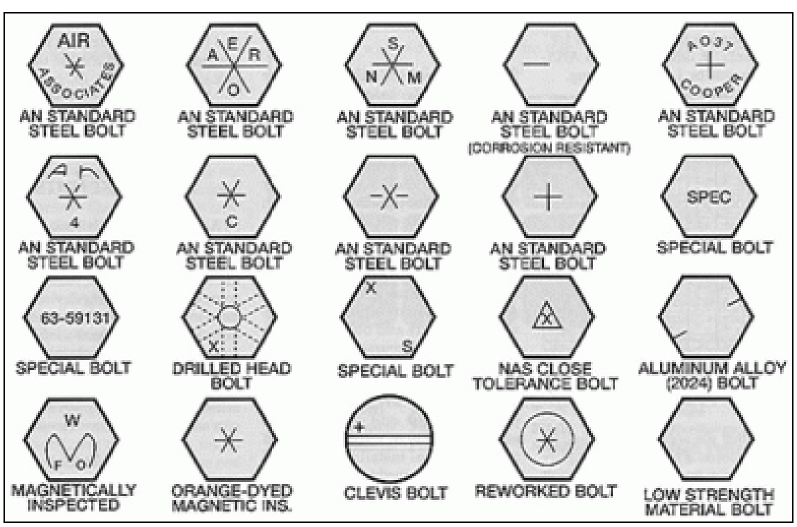


Fig. 4.8

Screws

Screws differ from bolts in the head. Screws are typically driven internally or manually, as in a thumb screw. Furthermore, they are typically driven in to a threaded surface rather than a nut, although they can be used with nuts. There is an enormous amount in screw variety. We will discuss the more typical ones here.

MACHINE SCREWS

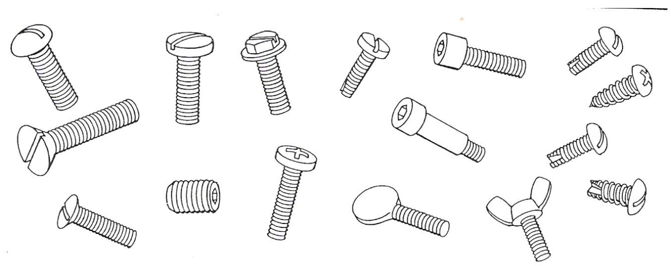


Fig. 4.9

Machine screws are very common in industry as well as your local hardware store. Screws are usually smaller in diameter. You may have noticed that when dealing with screw diameters of less than a 1/4 inch, they are referred to with numbers.

MACHINE SCREW SIZES

Screw Number*	Size in Decimals	Approximate Size in Fractions
No. 2	0.086″	a little over 5/64″
No. 3	0.099″	a little over 3/32″
No. 4	0.112″	a little over 7/64″
No. 5	0.125″	exactly 1/8″
No. 6	0.138″	a little under 9/64″
No. 8	0.164″	a little over 5/32″
No. 10	0.190″	a little over 3/16″
No. 12	0.216″	a little under 7/32″

But the markings go even further. A typical screw size annotation is this:

No. 4 X 1-1/2

This represents a number 4 screw size (.112") by the screw length in inches (1-1/2"). Screws that are over 1/4" in diameter are designated by fractions of an inch. These screws are generally the equivalent of SAE grade 1 material.

Metric screws are measured by the outside diameter of the screw in millimeters. For example: A 4 millimeter diameter screw would be labeled M4. A screw labeled M4X0.8 would be the screw diameter plus the pitch distance. *Remember when dealing with metric fasteners, it is not the overall length of the screw or bolt, rather the distance between crests in millimeters (as discussed in the section under bolts).* Unlike bolts, screw length is measure in inches from the very end of the screw head to the end of the threaded shank.

Machine crews are straight shank screws that have various head designs.

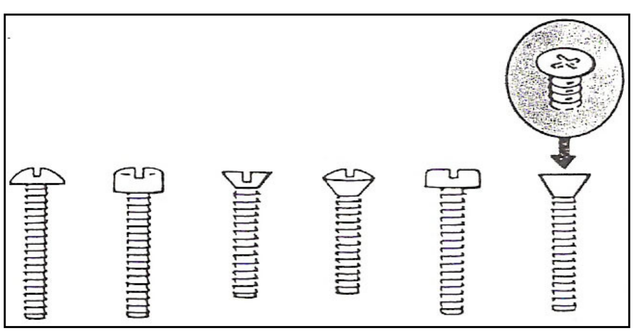


Fig. 4.10

Most machine screws are removed or installed with the various types of screwdrivers. Some machine screws have square openings or TORX® openings and the appropriate driver would be needed.

HEX SOCKET CAP SCREWS

The hex head screw is used in recessed or small opening areas. It has an internal wrenching feature (hexagonal) that is removed or installed with a hex key wrench as discussed in Chapter 3.

12 POINT FLANGE HEAD SCREW

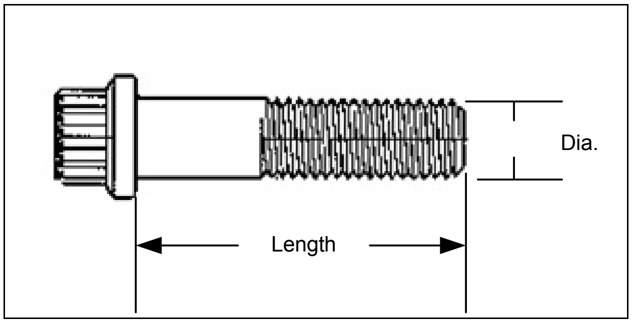


Fig. 4.11

These are high strength screws that are wrenched externally. If you remember from Chapter 3, sockets and box wrenches come in 12 point configurations for ease of use AND 12 point flange screws. This type of head allows it to fit in tight places, yet has the strength and external wrenching to withstand higher torques. These screw sizes are identified by the same criteria as a standard bolt.

TAPPING SCREWS

These screws are widely used to attach panels, covers, and other relatively light parts. The material most commonly used is sheet metal, but it could be fiberglass, plastic, brass, or wood. They are some times referred to as sheet metal screws or thread forming screws.

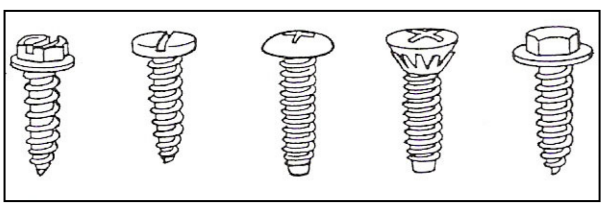


Fig. 4.12

Tapping screws usually require a small hole to get started in the material. The threads act as cutting surface into the material, creating its own mating threads. This provides for a very tight fit that can withstand high vibration. These screw diameters are measured in number size similar to the machine screw diameters. A true self-tapping screw is also available. Rather than a pointed tip, it uses a small auger to start the hole and finishes with threads.

DRIVE SCREWS

Drive screws are ideal for one time installations. There is no driving feature for a screwdriver. These screws have a gradual twist and cut their own mating threads via installation with a hammer.

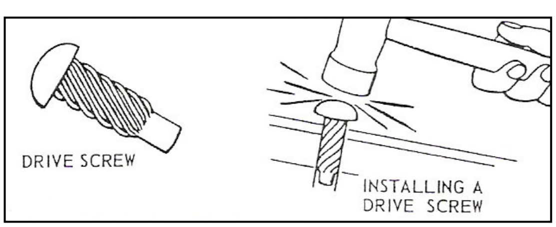


Fig. 4.13

SET SCREWS

Set screws are used in pulleys, gears, and shafts to prevent relative movement between the parts. Some do this by pressing into a flat, others by inserting into a designated hole. Set screws are found with external wrenching heads, but most often with internal wrenching, such as a hex Allen wrench.

The cup and the dog styles are the most commonly used. The cup style presses against a surface using friction to hold the two parts in place. The dog style enters a pre-placed indention or hole, using less overall force to hold it in place. The cone type works well to grab the other part without exerting too much pressure, but it usually creates a burr on the shaft.

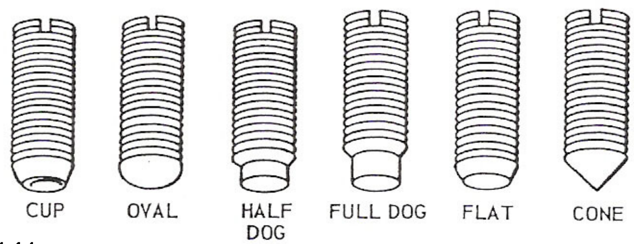


Fig. 4.14

Nuts

HEX NUTS AND SQUARE NUTS

The most common nuts are hexagonal. Occasionally you will see square nuts on older, simpler equipment. The nuts are generally made of steel and often coated for corrosion control as bolts are. The nut size is measured across the flats, the same way as bolts. They are found in inch sizes as well as metric. The internal threads are measured in the same way as discussed earlier. If the nut is large enough, you can use a thread pitch gauge. The corners of most machinery nuts are chamfered (beveled). If the nut only has one chamfered edge, that is the edge that should be installed against the mating surface to prevent galling. SAE and ASTM are the responsible authority for nut strength standards for unified (inch) nuts. For metric, it is ASTM and ISO.

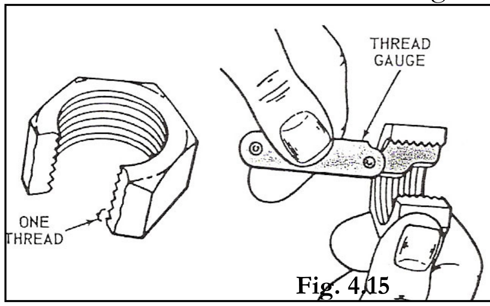
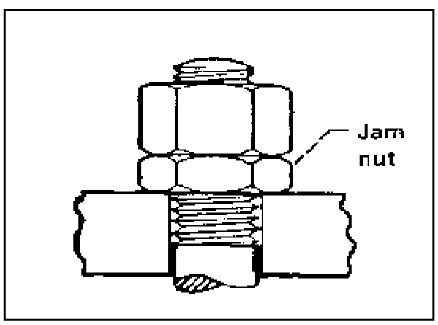


Fig. 4.15

JAM NUTS



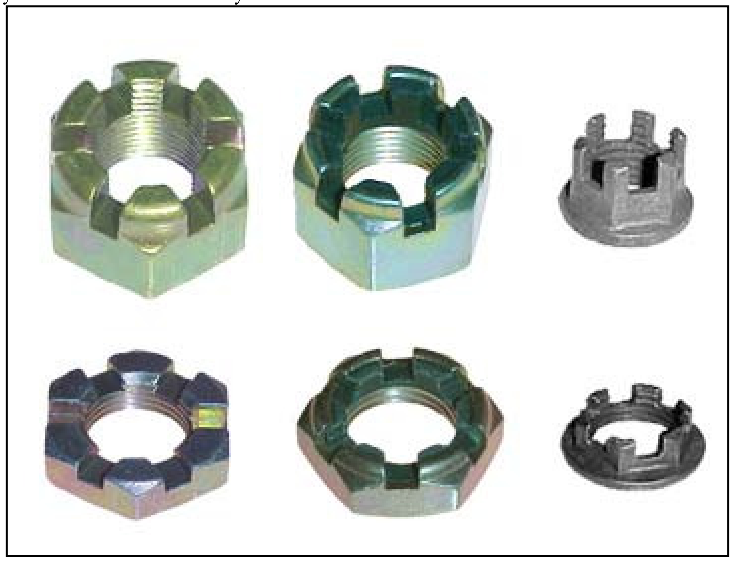
Jam nuts are used on tie rods and turnbuckles to lock the respective parts in to place. If it is a metric part, the jam nut is called a "thin" nut.

Fig. 4.16

CASTELLATED AND SLOTTED NUTS

There are times when a nut is installed and needs to be locked in to place. There are a few nuts on the market that accomplish this. The castellated nut gets its name from the resemblance to an old castle top. It is installed against a surface and held in place with a cotter pin, locking wire, or spring pin. The advantage of a castellated nut is that it does not need a high level of torque to remain in place, and can be used or adjusted as many times as necessary.

Fig. 4.17



As seen above, castellated nuts come in various sizes and materials. Slotted nuts are the same as castellated nuts with the exception that they are used to adjust the position or tension on a machined part. They are not tightened to a solid joint. They also use a pin to hold them in place.

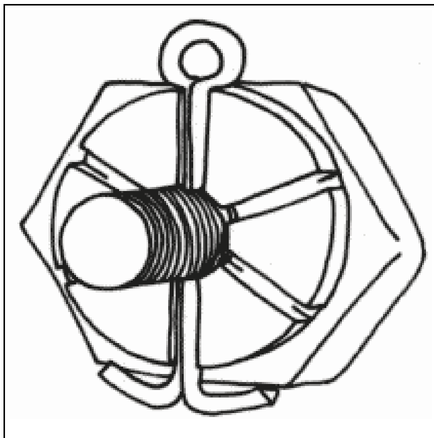


Fig. 4.18

SELF-LOCKING NUTS

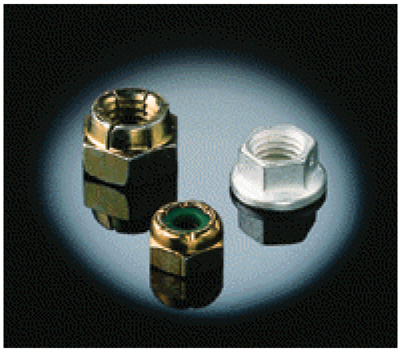


Fig. 4.19

Self locking nuts are one of the best solutions for keeping a nut in place. There are three methods of making a nut self locking. The first two fall under the category of *prevailing* nuts. The prevailing nuts work by either a crimp at the end of the nut or with thin slots cut into the end and crimped inward. The other is the *elastic* nuts. These are lined with a plastic insert that molds to the thread, preventing it from backing off. The newer styles of these nuts are lined with Teflon or nylon, which is longer lasting than plastic.

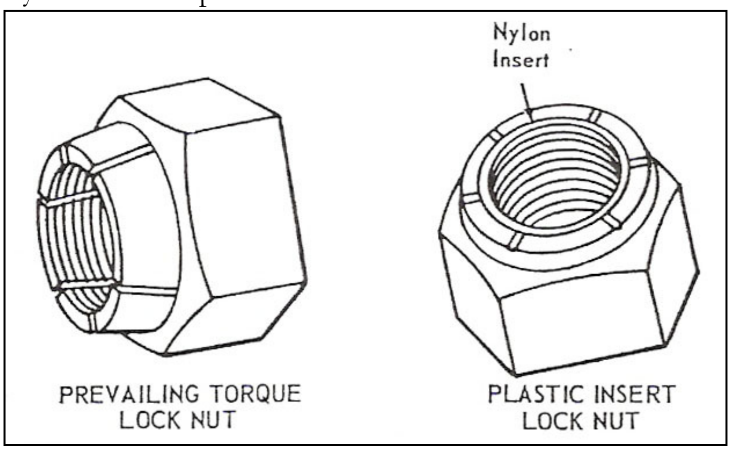


Fig. 4.20

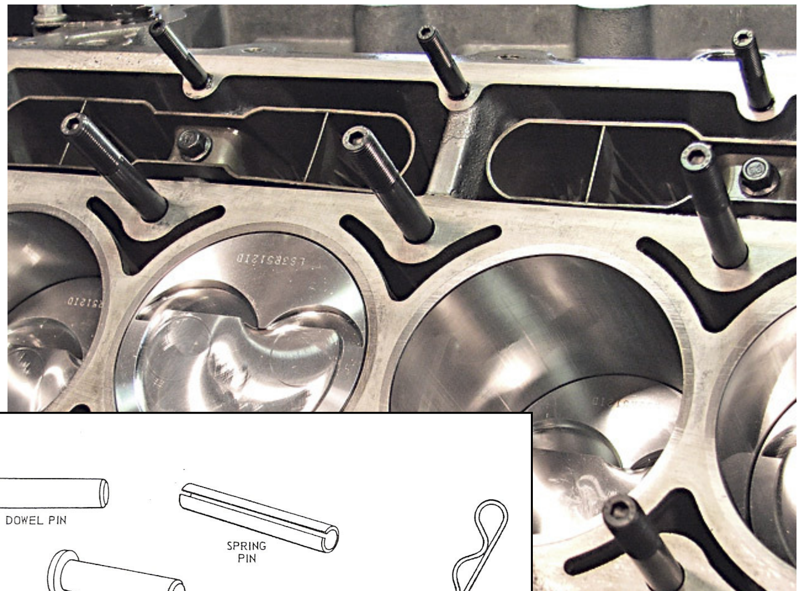
A distinct disadvantage to a self locking nut verses the castellated nut is that whether it is prevailing or elastic, these nuts have a limited life span. The nut looses its crimp after a handful of uses or from temperature. The nylon strip also has limited use. Temperature would be an obvious factor along with the wearing of the plastic, nylon, or Teflon. They are generally good for 2 to 3 uses.

CHEMICAL NUT LOCKS

The most common chemical locking product is LOCTITE®.
It is a liquid that when applied to a surface, will harden into a plastic. This reduces the possibility of the nut breaking loose on its own. While it does a good job of holding the nut in place, the nut can be removed and re-used.

Studs

Studs are simply a straight rod with threads on both ends. Studs work well in machine assembly. They can act as a guide as well as the fastener. A part will be put over the studs and then secured with a nut. Studs are threaded on both ends. The end going in to the solid machined part will not have a wrenching feature. The opposite will have an internal wrenching feature, such as an Allen hex opening. The threads are often different pitches on the opposite ends. The portion going in to the solid piece can be either straight or tapered. On straight studs, a locking adhesive is normally used. Tapered studs lock in to place from the increase in thread diameter as it is being inserted. When installing studs, it is critical to follow torque values specified in the maintenance manual. Under tightening will cause the stud to come loose when you try to remove the nut. Over tightening can snap the stud inside the machined part. NOTE: If studs break off, remove them with a screw extractor as discussed in Chapter 3.



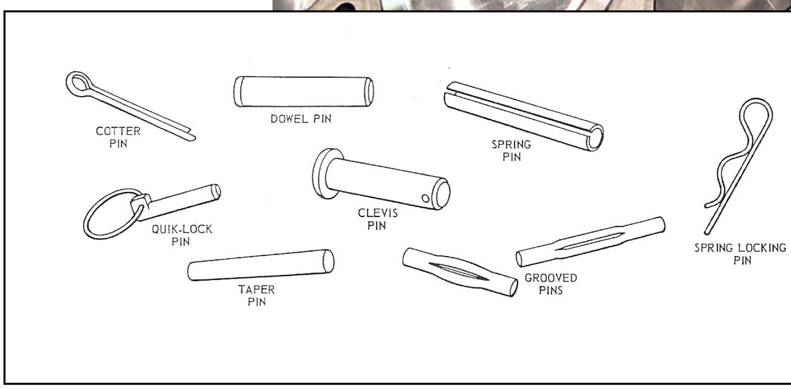


Fig. 4.21

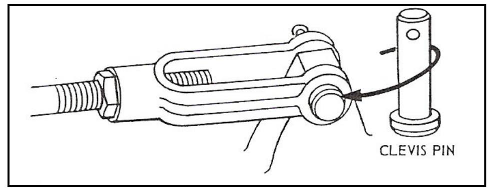
Pins

Above are some of the more common pins found in equipment maintenance. There are a few specialized pins for specific equipment that will not be discussed here. Most pins are to connect two components or lock two components in place much like a set screw. The dowel, spring, taper, and grooved pins fall in to this category. At times pins are used together, as in a clevis pin.

CLEVIS PINS

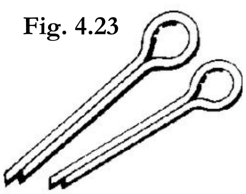
The name comes from what it typically does. The pin is installed in to a "U" shaped yoke, known as a clevis. However, the pin does have a few other applications. These pins have a head on one end and are drilled on the other for installing a cotter or spring locking pin.

Fig. 4.22



COTTER PINS

Fig. 4.23



Cotter pins were discussed briefly in this chapter under castellated and slotted nuts. Typically this is where we use cotter pins the most. They are, however, used on other items such as the clevis pin. Cotter pins are made of various materials and should be matched with the hardware you are using. Furthermore, the diameter should allow for a non-forced, tight fit when installed.

Washers

Washers have three basic purposes:

- Providing a barrier between the bolt or nut and the machined surface to prevent scratching and galling.
- As a shim for alignment of parts or cotter key holes.
- Locking nuts or bolts in to place

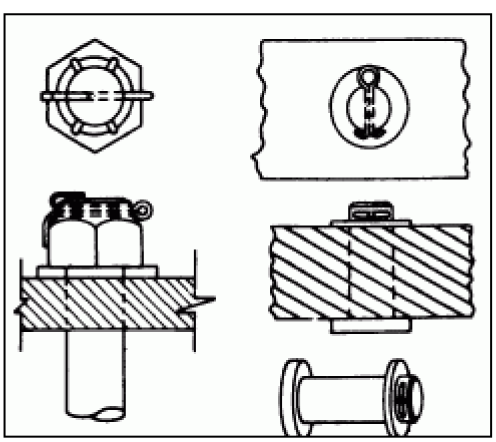


Fig. 4.24

PLAIN WASHERS

This washer is simply a plain disk with a hole in the middle. Along with providing anti-galling, this washer spans across larger openings and distributes some of the force exerted by the bolt or nut. The plain washer is also used as a shim for aligning holes. For example: a washer may be added to get the right cotter key alignment on a castellated nut.

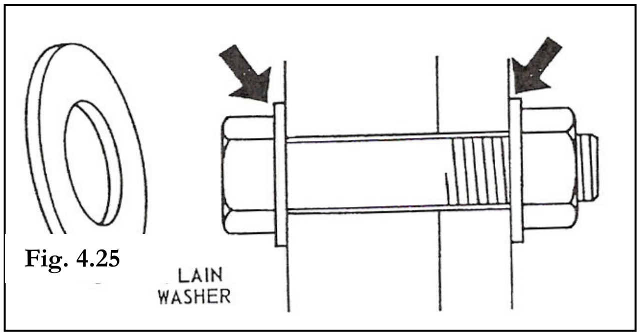


Fig. 4.25

LOCK WASHERS

Fig. 4.26

Lock washers do exactly what they say. They lock. There are various designs that allow washers to hold a nut or a bolt in place. To the left you see the very common helical spring lock washer. This washer acts as a plain washer in that it protects surfaces and distributes loads. Its locking feature is the helical shape. As the nut or bolt is tightened, the spring pressure puts a strong pressure on the surface as well as the nut. This action greatly increases friction, holding the nut in place.

OTHER LOCKING WASHERS

There are a variety of other lock-washers used. The internal and external tooth washers work like the helical spring washer by using tangs to create more friction between the parts. The locking tab washer has tabs that can be bent over the machined surface and the nut, holding it secure.

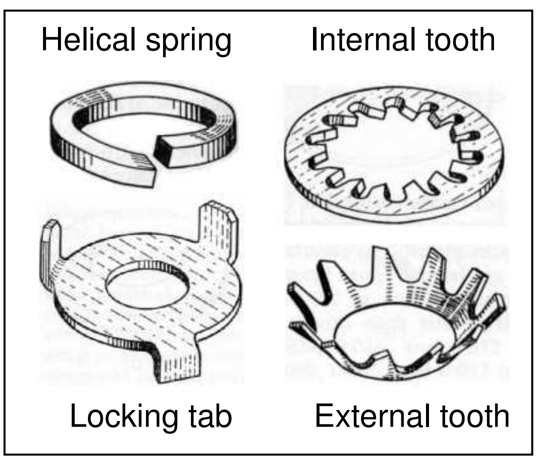


Fig. 4.27

Snap Rings

Fig. 4.28

Snap rings come in a few different forms. The most common are the external hole (shown at the left), the internal hole, the internal prong, and the external "E" style. Snap ring pliers are used to remove and install external and internal hole rings. The "E" type (right) are pressed in to place and can be removed with a small scribe pick.

The internal snap ring (left) is used to hold items in place in an internal bore. Some of these rings have prongs instead of holes for normal snap ring pliers. In this case you would use needle nose pliers.

Fig. 4.30

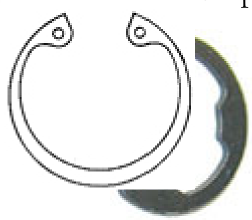
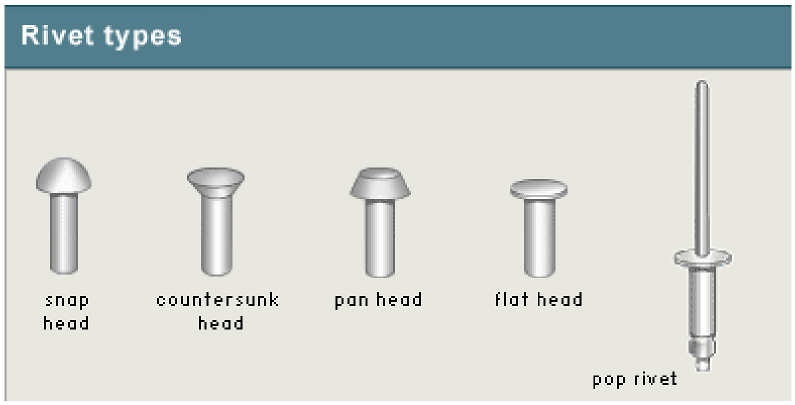


Fig. 4.29

Rivets

Rivets are a very quick and easy form of fastening parts. Most often, when riveting tools can be used, they can be installed faster than any other fastener. They are also very low cost fasteners. The down side of low cost is that you sacrifice quality and strength. However, with that said, rivets are still a popular source of attachment.

Fig. 4.31



The above rivets, with the exception of the pop rivet, are installed with a hammer. The rivet is driven in to place and the shank is formed with a hammer or hammer and punch. The pop rivet is used with an installation tool, referred to as a rivet gun.

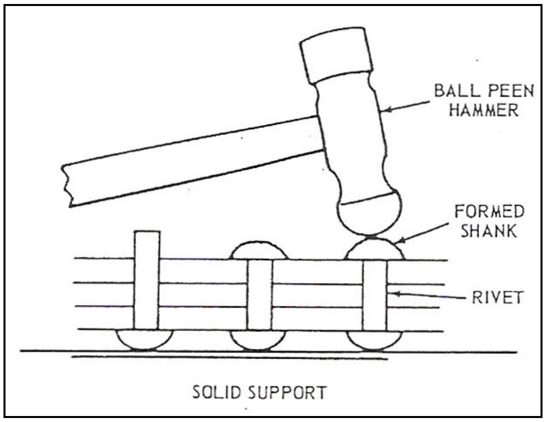


Fig. 4.32

The pop rivet is also known as a *Blind Rivet.* This type of rivet is intended for light duty work.

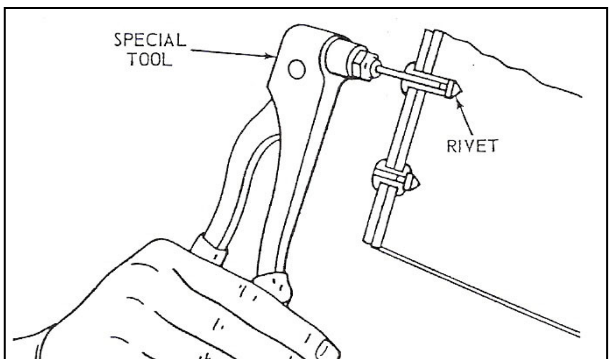


Fig. 4.33

Review

1. To measure the diameter of a common unified bolt, you would measure
    A. The diameter of the root
    B. The amount of threads per inch
    C. The outside diameter from crest to crest
    D. The head span

2. A high strength screw that can be used in tight places is
    A. A machine screw
    B. A wood Screw
    C. A set screw
    D. A 12 point flange screw

3. Thread pitch for a unified bolt or screw can be measured with a thread gauge or by
    A. Counting the threads per inch
    B. Measuring the length of the root
    C. Using an outside micrometer
    D. None of the above

4. A nut with a Teflon insert inside is this type of nut
    A. A wing nut
    B. A self locking nut
    C. A slotted nut
    D. A castellated nut

5. Castellated nuts lock onto a bolt without any other parts needed
    A. True
    B. False

6. Plain washers are used for
   A. Disbursing the load of the bolt head or nut
   B. Filling areas where large openings are present
   C. Shims
   D. All of the above

7. A pin with a head on one end and a drilled hole on the other is known as a
   A. Cotter pin
   B. Clevis pin
   C. Roll pin
   D. Quick release pin

Chapter 5
Hydraulics

Basic Principles of Hydraulics

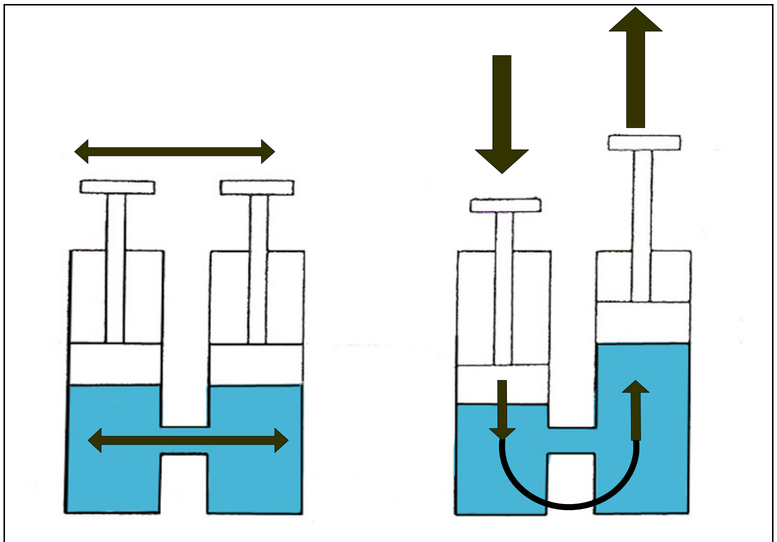
The basic principles of hydraulics are few and simple:

- Liquids have no shape of their own.
- Liquids are practically incompressible.
- Liquids transmit applied pressure in all directions, and act with equal force on all equal areas and at right angles to them.
- Liquids provide great increases in work force.

LIQUIDS HAVE NO SHAPE OF THEIR OWN. They
Acquire the shape of any container they are in. Because of this, Oil in a hydraulic system will flow in any direction and into a passage of any size or shape.

LIQUIDS ARE PRACTICALLY INCOMPRESSABLE
For safety reasons, we obviously wouldn't perform the experiment shown. However, if we were to push down on the cork of the tightly sealed jar, the liquid in the jar would not compress. The jar would shatter first. NOTE: Liquids will compress slightly under pressure, but for our purposes they are incompressible.

LIQUIDS TRANSMIT APPLIED PRESSURE IN ALL DIRECTIONS. The experiment of shattering the glass jar also showed how liquids transmit pressure----in all directions when they are put under compression. This is very important in a hydraulics system. Take two cylinders of the same size (one square inch) and connect them by a tube. Fill the cylinders with oil to the level shown. Place in each cylinder a piston which rests on the columns of oil. Now press down on one cylinder with a force of one pound. This pressure is created throughout the system, and an equal force of one pound is applied to the other piston, raising it as shown below in Fig. 5.1.



Liquids Transmit Applied Pressure in All Directions

Fig. 5.1

LIQUIDS PROVIDE GREAT INCREASES IN WORK FORCE. Now let's take two more cylinders of different sizes and connect them. The first cylinder has an area of one square inch, but the second has an area of ten square inches. Again, use a force of one pound on the piston in the smaller cylinder. Once again, the pressure is created throughout the system. So, a pressure of one pound per square inch is exerted on the larger cylinder. Since, that cylinder has a piston area of ten square inches; the total force exerted on it is *ten* pounds. In other words, we have a great increase in work force.

The principle helps you to stop a large machine by pressing a brake pedal. The force (F) exerted by a piston can be determined by multiplying the piston area (A) by the pressure (P) applied.

CAUTION: The forces in a hydraulic system can be very high. Use extreme caution.

How a Hydraulic System Works

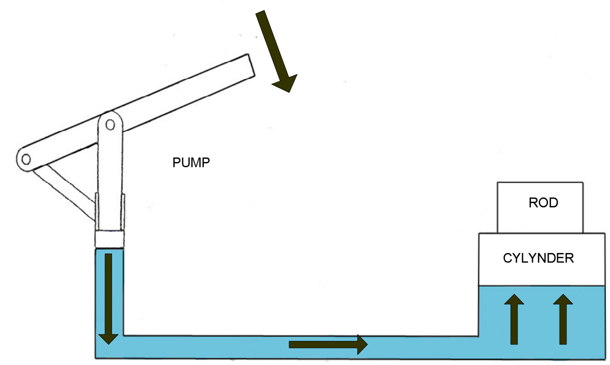
Let's build up a hydraulic system, piece by piece. The basic hydraulic system has two parts:

1. The PUMP which moves the oil.

2. The CYLINDER which uses the moving oil to do work.

When you apply force to the lever, the hand pump forces oil into the cylinder. The pressure of this oil pushes up on the piston and lifts the weight.

In effect, the pump converts a mechanical force to hydraulic power, while the cylinder converts the hydraulic power back to mechanical force to do work. But for continued operation of the system, we must add some new features.



A Basic Hydraulic System

Fig. 5.2

3. CHECK VALVES hold the oil in the cylinders between strokes and to prevent oil from returning to the reservoir during the pressure stroke. The ball-type valves open when oil is flowing but closes when the flow stops.

4. RESERVIOR to store the oil. If you keep on pumping to raise the weight, a supply of extra oil is needed. The reservoir has an air vent which allows oil to be forced into the pump by gravity and atmospheric pressure when the pump piston is retracted.

Notice that the pump is smaller than the cylinder. This means that each stroke of the pump would only move enough oil to move the piston a small amount. However, the load lifted by the cylinder is much greater than the force applied to the pump piston. If you want to lift the weight faster, then you must work the pump faster, increasing the column of oil to the cylinder.

The system we have just described is a system which might be found on a hydraulic jack or a hydraulic press; however, to meet the hydraulic requirements in most other applications, we must provide a greater quantity of oil at a more consistent rate and also have better control of the oil movement.

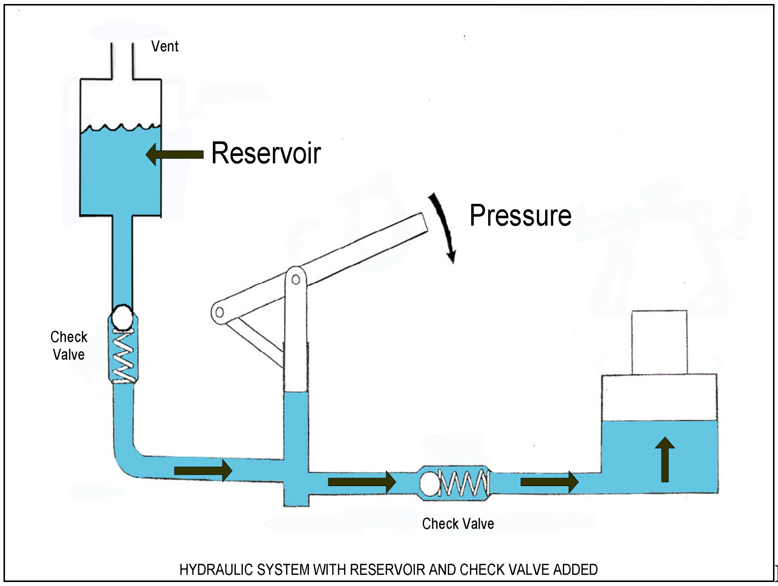


Fig. 5.3

Let's complete the process and add some new features as shown. We have now added a *gear-type pump*. This is one of many types of pumps which transform the rotary force of a motor or engine to hydraulic energy.

5. The CONTROL VAVLE directs the oil. This allows the operator to control the constant supply of oil available from the pump to and from the hydraulic cylinder.

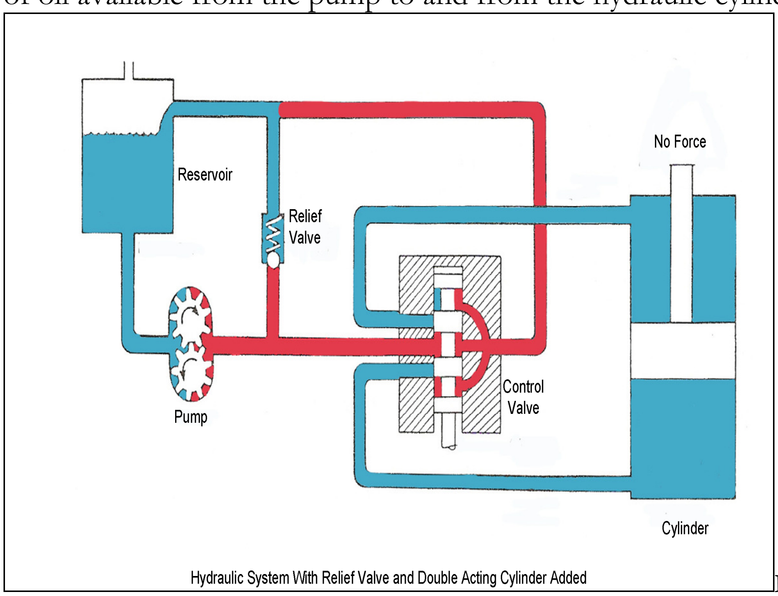


Fig. 5.4

When the control valve is in the neutral position, the flow of oil from the pump goes directly through the valve to a line which carries the oil back to the reservoir. At the same time, the valve has trapped oil on both sides of the hydraulic cylinder, thus preventing its movement in either direction.

When the control valve is moved down, the pumped oil is directed to the cavity on the bottom of the cylinder piston, pushing up on the piston and raising the weight. At the same time, the line at the top of the cylinder is connected to the return passage, thus allowing the oil forced from the top side of the piston to be returned to reservoir.

When the control valve is moved up, oil is directed to the top of the cylinder, lowering the piston and the weight. Oil from the bottom of the cylinder is returned to the reservoir.

6. The RELIEF VALVE protects the system from high pressures. If the pressure required to lift the load is too high, this valve opens and relieves the pressure by dumping the oil back to the reservoir. The relief valve is also required when the piston reaches the end of the stroke. At this point, there is no other path for the oil, and it must be returned to the reservoir through the relief valve.

This completes our basic hydraulic system.

- **The pump = generating force**
- **The cylinder = working force**
- **The valve = oil flow and direction control**
- **The reservoir = oil storage**

The Pros and Cons of Hydraulics

As you have seen in the simple hydraulic system, we have just described, its purpose is to transmit power from a source (engine or motor) to the location where this power is needed to perform work.

To look at the advantages and disadvantages of the hydraulic system, let's compare it to the other common methods of transferring this power. These would be mechanical (shafts, gears, belts, chains, or cables) or electrical.

ADVANTAGES

1. FLEXABILITY-----Unlike the mechanical method of power transmission, where the relative positions of the engine and work site must remain relatively constant, hydraulic lines allow power to be moved to almost any location.

2. MULTILPICATION OF FORCE----In the hydraulic system, very small forces can be used to move very large loads by simply changing cylinder sizes.

3. SIMPLICITY---- The hydraulic system has fewer moving parts, fewer points of wear. And it lubricates itself.

4. COMPACTNESS---- Compare the size of a small hydraulic motor with an electric motor of equal horsepower. Then imagine the size of the gears and shafts that would be required to create the forces which can be attained in a small hydraulic press. The hydraulic system creates more horsepower for its size, than either of the other systems.

5. ECONOMY----This is the natural result of the simplicity and compactness which require relatively low cost for the power transmitted. Also, power and frictional losses are comparatively small.

6. SAFETY---There are fewer moving parts such as gears, chains, belt and electrical contacts than in other systems. Overloads are more easily controlled using relief valves. This is much more difficult with the overload devices required in the mechanical and electrical systems.

DISADVANTAGES

1. EFFICIENCY----While the efficiency of the hydraulic system is much better than the electrical system, it is lower than the mechanical system when it comes to the transmission of power.

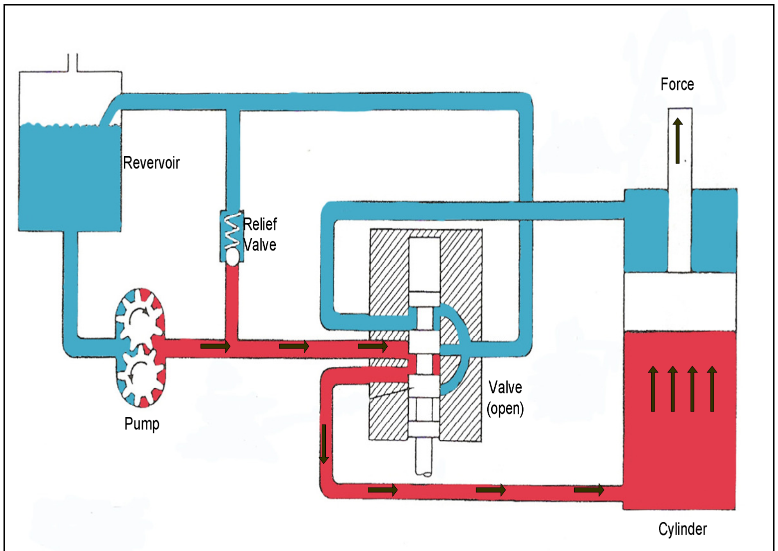
2. NEED FOR CLEANLINESS---Hydraulic systems can be damaged by rust, corrosion, dirt, heat and breakdown of fluids. Cleanliness and proper maintenance are more critical in the hydraulic system, than in the other methods of transmission.

Compare Hydraulic Systems

Two major types of hydraulic systems are used today:

- **Open-Center Systems**
- **Closed-Center Systems**

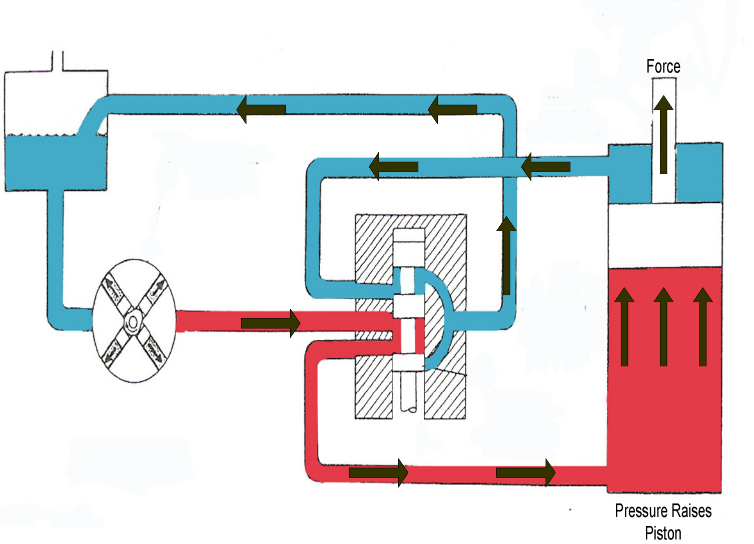
The simple hydraulic system which we developed earlier in this chapter is what we call an OPEN-CENTER SYSTEM. This system requires that the control valve spool be open in the center to allow pump flow to pass through the valve and return to the reservoir. The pump supplies a constant flow of oil and the oil must have a path for return when it is not required to operate a function.



Hydraulic System in Operation – Raising a Load (Open-Center Type)

Fig. 5.5

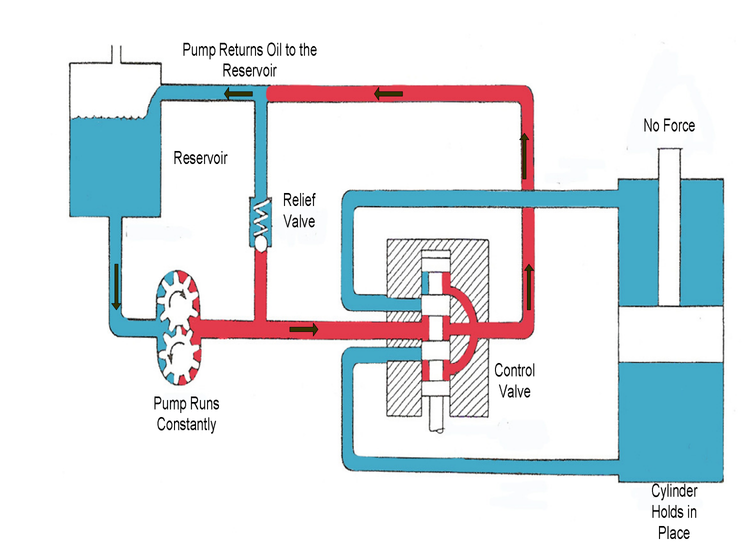
In the CLOSED-SYSTEM, the pump is capable of "taking a break" when oil is not required to operate a function. Therefore, the control valve is closed in the center, which stops (dead ends) the flow of oil from the pump—the "closed center" feature.



Closed Center System in Operation – Raising a Load

Fig. 5.6

The open-center system is shown in neutral position in the next figure. The closed-center in a neutral system is shown below that.



Open Center System In Neutral

Fig. 5.7

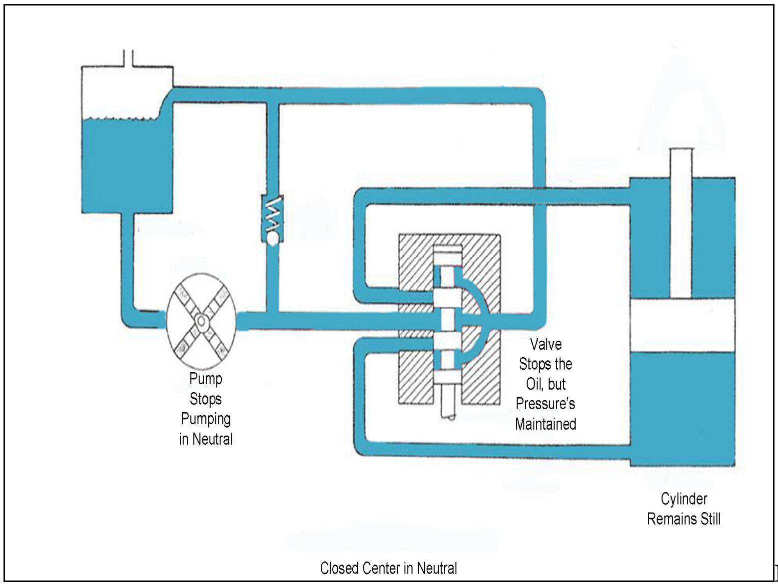


Fig. 5.8

To summarize:

- Open-Center System----oil is pumped constantly, with valve open in center to allow oil to return to reservoir.
- Closed-Center System---valve spool closed in center to dead end pump oil in neutral.

CLOSED CENTER SYSTEM

Let's look at a closed-center system with a variable displacement pump.

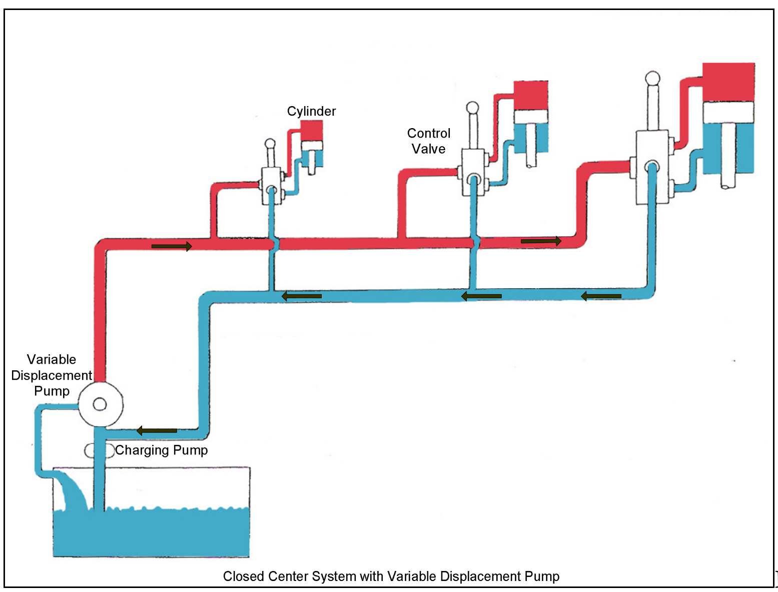


Fig. 5.9

In neutral, the pump pumps oil until pressure rises to a predetermined level. Then a pressure regulating valve allows the pump to shut itself off and to maintain the pressure to the valve.

When the control valve is operated as shown, oil is diverted from the pump to the bottom of the cylinder. The drop in pressure caused by connecting the pump pressure line to the bottom of the cylinder causes the pump to go back to work, pumping oil to the bottom of the piston and raising the load.

When the valve moves, the top of the piston is connected to a return line, thus allowing return oil, forced from the piston, to be returned to the reservoir or pump.

When the valve is returned to neutral, oil is again trapped on both sides of the cylinder and the pressure passage from the pump is dead ended. At this time, the pump again takes a break.

Moving the spool in the downward position (not shown), directs oil to the top of the piston, moving the load downward. Then oil from the bottom of the position is sent into the return line.

With the closed center system, if the load exceeds the predetermined standby pressure or if the piston reaches the end of its stroke, the pressure build-up simply tells the pump to take a break, thus eliminating the need for relief valves to protect the system.

We have now described the simplest of open- and closed-center systems. However, most hydraulic systems require their pump to operate more than one function. Let's look at how this is done and compare the advantages and disadvantages of each system.

Variations on Open-Center and Closed-Center Systems

To operate several functions at once, hydraulic systems have the following connections:

OPEN-CENTER SYSTEMS

- Open- Center with Series Connection
- Open-Center with Series Parallel Connection
- Open-Center with Flow Divider

CLOSED-CENTER SYSTEMS

- Closed Center with Fixed Displacement Pump and Accumulator
- Closed-Center with Variable Displacement Pump

Let's discuss each of these systems.

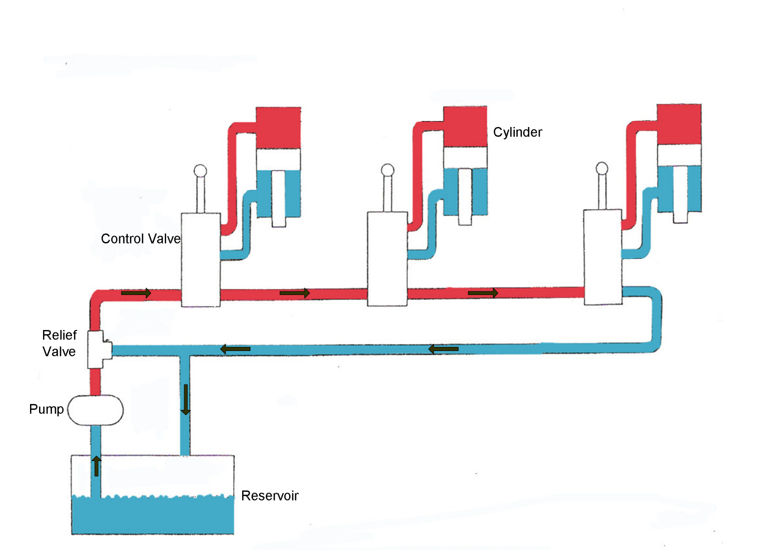
OPEN-CENTER SYSTEMS

Open- Center System with Series Connection

In a series connection of the open-center system, oil from the pump is routed to the tree control valves in series. The return from the first valve is routed to the inlet of the second, etc.

In neutral, the oil passes through the valves in series and returns to the reservoir as shown by the arrows. When a control valve is operated, incoming oil is diverted to the cylinder which that valve serves. Return oil from the cylinder is directed through the return line and on to the next valve.

This system is satisfactory as long as only one valve is operated at a time. In this case, the full output of the pump at full system pressure is available to that function. However, if more than one valve is operated, the total of the pressures required for each individual function cannot exceed the system relief setting.



Open Center System with Series Connection

Figure 5.10

Open-Center System with Series Parallel Connection

This system is a variation on the series connected type. Oil from the pump is routed through the control valves in series---but also in parallel. The valves are sometimes “stacked” to allow for the extra passages.

In neutral, the oil passes through the valves in series as shown by the arrows. But when any valve is operated, the return is closed and oil is available to all valves through the parallel connection.

When two or more valves are operated at once, the cylinder which needs the least amount of pressure will operate first, then the next least, etc. This ability to satisfy two or more functions at once is an advantage over the series connection type.

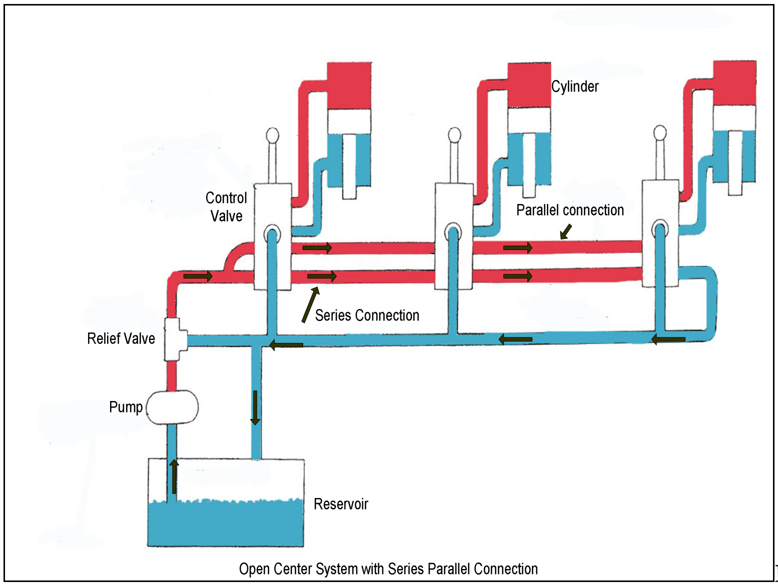
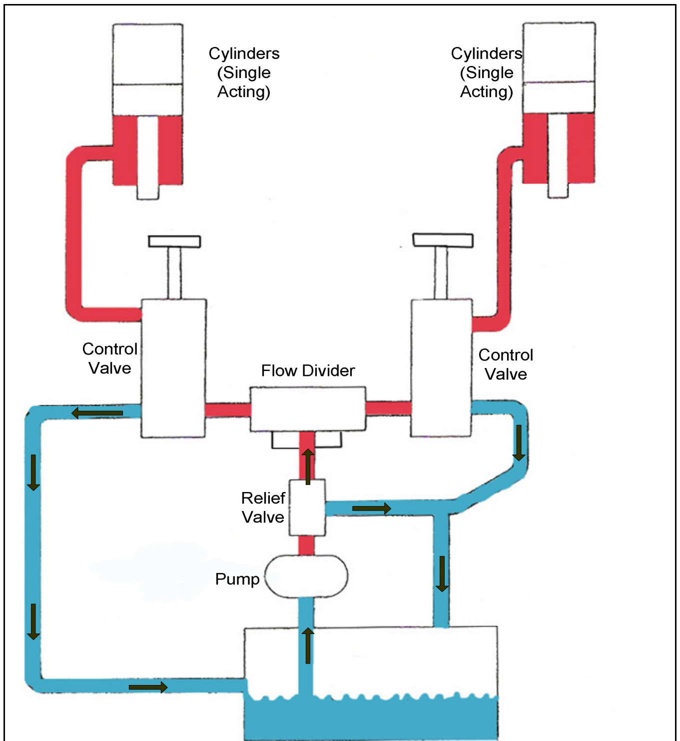


Fig. 5.11

Open-Center System with Flow Divider

A flow divider used with an open-center system. The flow divider takes the volume of oil from the pump and divides it between two functions. For example, the flow divider might be designed to open the left side first, in case both control valves were actuated at the same time, or it might divide oil to both sides—either equally or by percentage. With this system, the pump must be large enough to operate all the functions at once. The pump must also supply all this oil at the maximum pressure of the highest function. This means that a lot of horsepower is wasted when operating only one control valve.

We can see now that while the open-center system is efficient on single functions, it has a limited value for use with multiple functions.



Open Center System With Flow Divider

Fig. 5.12

CLOSED-CENTER SYSTEMS

Closed-Center System with Fixed Displacement Pump and Accumulator

This pump is small, but has constant volume and is able to charge an accumulator. When the accumulator is charged to full pressure, the unloading valve diverts the pump flow back to the reservoir. The check valve traps pressure oil in the circuit.

When a control valve is operated, the accumulator discharges its oil and actuates the cylinder. As pressure begins to drop, pump flow is again directed by the unloading valve to the accumulator to recharge it.

This system, using a small capacity pump, is effective when operating oil is needed only for a short time. However, when the functions need a lot of oil for longer periods, the accumulator system cannot handle it, unless the accumulator is very large.

Closed-Center System with Variable Displacement Pump

We have already shown much of this system in Figure 5.7, but we are now adding a charging pump. This pumps oil from the reservoir to the variable displacement pump. The charging pump supplies only the make-up oil required in the system and provides some inlet pressure to make the variable displacement pump more efficient. Return oil from the system functions is sent directly to the inlet of the variable displacement pump.

We saw earlier that the open-center system was the simplest and least expensive of the hydraulic systems that only have a few functions. But as more functions are added with varying demands for each function, the open-center system requires the use of flow dividers to proportion the oil flow to these functions. The use of these flow dividers in an open-center system reduces efficiency with resulting heat build-up. Today's machines need more hydraulic power, and the trend has been to the closed-center system. On a modern tractor, for example, oil may be required for power steering, power brakes, remote cylinders, three point hitches, loaders, and other mounted equipment.

In most cases, each of these functions has a requirement for different quantities of oil. With the closed-center system, the quantity of oil to each function can be controlled by line size, valve size, or by orificing with less heat build-up when compared to the flow dividers necessary in a comparable open-center system.

Other Advantages of Closed-Center Systems

1. There is no requirement for relief valves in a basic closed-center system because the pump simply shuts itself off when standby pressure is reached. This prevents heat build-up in systems where relief pressure is frequently reached.

2. The size of lines, valves, and cylinders can be tailored to the flow requirements of each function.

3. By using a larger pump, reserve flow is available to ensure full hydraulic speed at low engine rpm, and more functions can be served.

4. On functions such as brakes which require force but very little movement on a piston, the closed-center system is very efficient. By holding the valve open, standby pressure is constantly applied to the brake piston with no loss of efficiency, because the pump has to standby.

In a similar open-center system, the pump would operate in relief to maintain this pressure.

Hydraulic Facts

1. Hydraulic power is nearly always generated from mechanical power. Example: A hydraulic pump driven by an engine.

2. Hydraulic power output is nearly always achieved by converting back to mechanical energy. Example: A cylinder which raises a heavy plow.

3. There are three types of hydraulic energy:
   a. Potential or pressure energy
   b. Kinetic energy, the energy of moving liquids
   c. Heat energy, the energy of resistance to flow, or friction.

4. Hydraulic energy is neither created nor destroyed; only converted to another form.

5. All energy put into a hydraulic system must come out either as work (gain) or as heat (loss).

6. When a moving liquid is restricted, heat is created and there is a loss of potential energy (pressure) for doing work. Example: A tube or hose that is too small or is restricted. Orifices and relief valves are also restrictions but they are purposely designed into systems.

7. Flow through an orifice or restriction causes a pressure drop

8. Oil must be confined to create pressure for work. A tightly sealed system is a must in hydraulics.

9. Oil takes the course of least resistance.

10. Oil is normally pushed in a pump, not drawn into it. Atmospheric pressure supplies this push. For this reason, an air vent is needed in the top of the reservoir.

11. A pump does not pump pressure: it creates flow. Pressure is caused by resistance to flow.

12. Two hydraulic systems may produce the same power output-one at high pressure and low flow, the other at low pressure and high flow.

13. A basic hydraulic system must include four components:
    a. A reservoir to store the oil
    b. A pump to push the oil through the system
    c. Valves to control oil pressure and flow
    d. A cylinder (or motor) to convert the fluid movement into work.

14. Compare the two major hydraulic systems:
    a. Open- Center System = pressure is varied but flow is constant.
    b. Closed-Center Systems = flow is varied but pressure is constant.

15. There are two basic types of hydraulics:
    a. Hydrodynamics is the use of fluids at high speeds “on impact” to supply power. Example: a torque converter.
    b. Hydrostatics is the use of fluids at relatively low speeds but at high pressures to supply power. Example: most hydraulic systems, and all those covered in this manual.

The Fundamental of Brakes

All types of automotive brakes are mechanical devices for retarding the motion of a vehicle by means of friction.

COEFFCIENT OF FRICTION

Friction is the resistance to relative motion between any two bodies in contact, and it varies not only with different materials but also with the condition of the materials. The amount of friction developed by any two bodies in contact is said to be their coefficient of friction, and this is expressed by stating the amount of force required to move the one body while it remains in contact with the other; the amount of force being expressed in relation to the weight of the moving body.

Thus, if the moving body weighs 100 pounds, and a force of 60 pounds is required to keep it moving while it remains in contact with another body, the coefficient of friction between the two bodies is said to be 60% or .6. If 50 pounds force is necessary to keep it moving, the coefficient of friction is said to be 50% or .5. If only 35 pounds force is required, the coefficient of friction is 35% or .35.

The coefficient of friction between any two surfaces changes with any variation in the condition of one or both surfaces. As an example, the introduction of oil or grease between two flat, dry, and metal surfaces will greatly reduce the friction between them, which proves that the condition of these surfaces plays a great part in the actual friction they develop. This possible variation in the coefficient of friction is always present when any factor contributing to the frictional value of any material is subject to change either permanently or temporarily.

Heat is always present where friction is being developed. For example, when a bearing is not properly lubricated, the lack of lubrication causes a rise in the coefficient of friction with a resultant rise in the heat that causes the bearing to fail.

ENERGY OF MOTION TO HEAT ENERGY

Since friction is the resistance to relative motion between two bodies in contact and since friction results in heat, a more complete definition of a brake would be that it is mechanical device for retarding the motion of a vehicle by means of friction, thereby changing the energy of motion into heat energy.

Thus, when the speed of a vehicle is reduced by applying the brakes, the energy of motion is actually changed into heat energy, thus the brakes must dissipate or absorb the heat developed.

FORCES INVOLVED IN BRAKING

It is difficult to appreciate the tremendous forces involved in stopping a modern commercial vehicle, particularly from higher speeds. A simple method of explaining this is to make a comparison between the horsepower required to accelerate a vehicle, and the horsepower required to stop it. A vehicle with an engine capable of developing 100 horsepower will require about one minute to accelerate to 60 miles per hour. The same vehicle should be capable of easily stopping from 60 miles per hour in less than six seconds. Ignoring the unknown quantities, such as rolling friction and wind resistance which plays a part in all stops, the brakes must develop the same energy in six seconds as the engine develops in 60 seconds.

In other words, the brakes do the same amount of work as the engine in one-tenth the time and must develop approximately 1,000 horsepower during the stop.

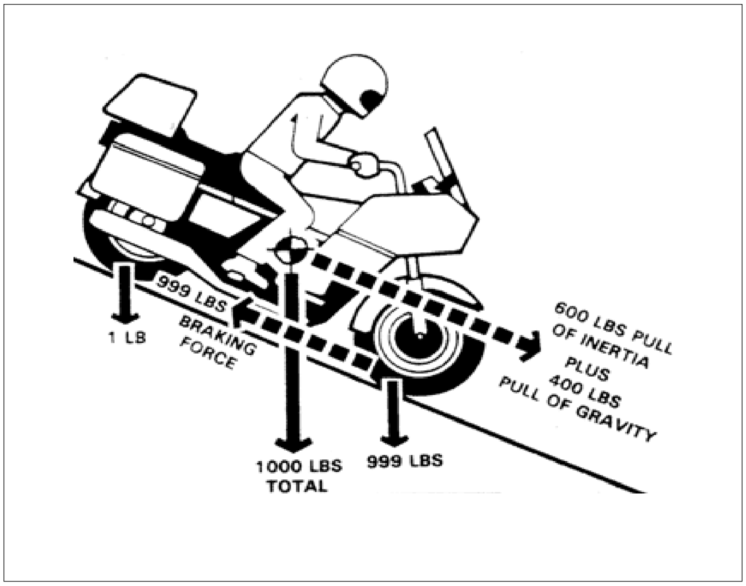


Fig. 5.13

EFFECT OF WEIGHT

Another factor to be considered is the effect weight and speeds have on a braking vehicle when they are increased. Brake systems are designed to properly control a vehicle loaded to its gross vehicle weight (GVW). If the GVW is exceeded, braking performance is affected; if the weight of the vehicle is doubled, the energy of motion changing into heat energy is also doubled. The brake cannot properly dissipate and absorb the increased heat and braking performance of the vehicle is lessened.

EFFECTS OF SPEED

The effect of higher speeds on braking is very serious. Not so many years ago the average speed of a commercial vehicle was only 20 miles per hour. Today, even conservative estimates place the average speed of commercial vehicles at 40 miles per hour. When stops from a speed of 20 miles per hour are compared with stops from a speed of 40 miles per hour, engineering calculations show there is actually four times as much energy of motion being changed to heat energy. Thus, if the speed is doubled, four times as much stopping power must be developed, and the brakes must absorb or dissipate four times as much heat.

It naturally follows that if both the weight and speed of a vehicle are doubled, the stopping power must be increased eight times and the brakes must absorb or dissipate eight times as much heat. Another way of illustrating the effect of speed on stopping ability is to compare the stopping distance if the speed is increased without the stopping power also being increased.

As shown, a car going 40 miles per hour will require 120 feet to stop and 206 feet to stop from 55 miles per hour. Introducing both weight and speed into the comparison again, a 10,000 pound vehicle traveling 60 miles per hour has 18 times as much motion energy as a 5,000 pound vehicle traveling at 20, miles per hour. If a stopping power is used on both vehicles, which will only stop the 5,000 pound vehicle from 20 miles per hour in about 40 feet, the 10,000 pound vehicle from 65 miles per hour will require 18 times as much distance or 540 feet to stop.

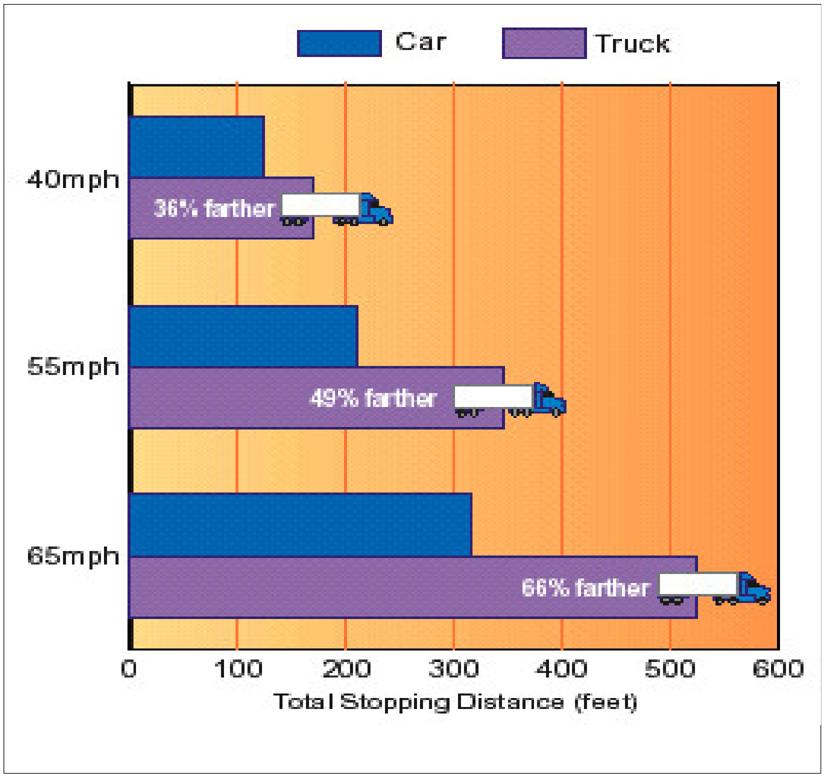
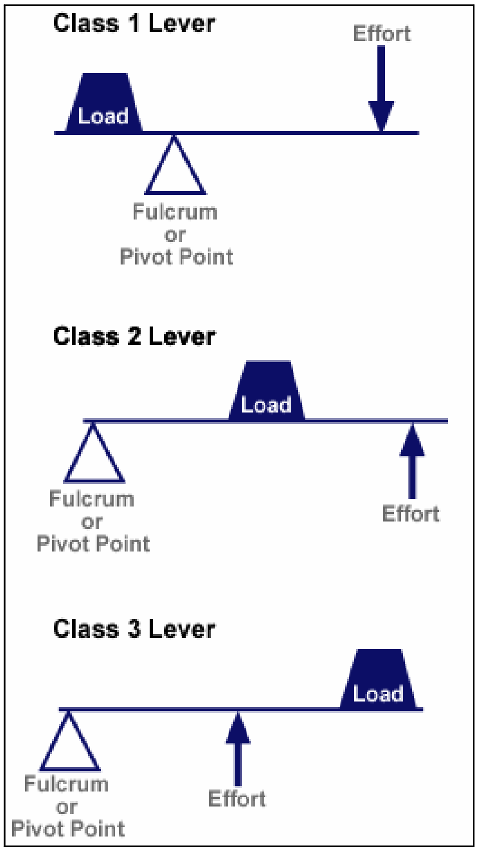


Fig. 5.14

LEVERAGE

Having reviewed the forces involved in braking a vehicle, consideration must also be given to how these forces are developed and directed to do the braking work. It is difficult even to imagine a braking system which does not, in some way, make use of one of the oldest mechanical devices governing the transmission and modification of force and motion, the lever. A lever is defined as an inflexible rod or beam capable of motion about a fixed point called a *fulcrum,* and it is used to transmit and modify force and motion.

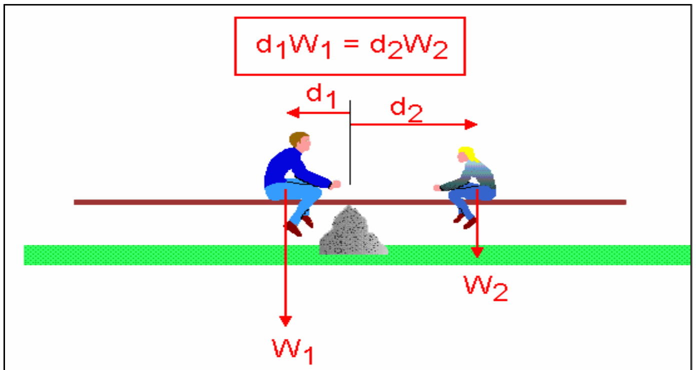
There are three simple types of levers. The only difference between them is the location of the fulcrum in relation to the applied force and the delivered force. All shapes and sizes of levers used in a brake system are one of these three types.



Three Simple Types of Levers

Figure 5.15

The simple law of levers is that the applied force multiplied by the perpendicular distance between the line of force and the fulcrum always equals the delivered force multiplied by the perpendicular distance between the fulcrum and the line of force. Thus, an applied force of 140 pounds, two feet from the fulcrum will give a delivered force of 200 pounds at a point one foot from the fulcrum. With a leverage arrangement as shown in Figure 5.16, an applied force of 140 pounds, 2 feet from the fulcrum will lift 300 pounds at a point one foot from the fulcrum, or in the example below, balance his 70 pound sister 4 feet from the fulcrum.



The 140 lb boy 2 feet from the fulcrum (center of gravity) balances his 70 pound sister 4 feet from the fulcrum
2 x 140 = 4 x 70

Fig. 5.16

The delivered force can exceed the applied force, because the applied force is farther from the fulcrum than the delivered force. With leverage arrangements where the delivered force is the farthest from the fulcrum; it will be less than the applied force. If the applied force in this case is 300 pounds at a point two feet from the fulcrum, the delivered force at a point three feet from the fulcrum will be 200 pounds.

The delivered force of any lever is determined by multiplying the applied force by the distance it is from the fulcrum, and then dividing this answer, by the distance the delivered force is from the fulcrum.

In determining the distance at which any force is acting on a lever, the true length of the lever's arm is the perpendicular distance from the force to the fulcrum, regardless of the shape of the lever. The lever arm is always measured at right angles to the direction of the force.

The product of the force acting on a lever, multiplied by how far the force is from the fulcrum, is called the *turning moment*. When this relates to a shaft it is called *torque*. The turning moment or torque is usually expressed in inch pounds, foot pounds, foot tons, etc., depending upon whether the force is measured in pounds or tons and whether the distance is measured in inches or feet. As an example—a force of 100 pounds acting on a lever arm five inches long would result in a turning moment or torque of 500 inch pounds.

The most easily recognized lever in an air system is the *slack adjuster*. The length of the lever arm of a slack adjuster is always the perpendicular distance between the center line of the brake camshaft opening and the center line of the clevis pin opening in the arm.

Another form of lever---not always recognized—is the *brake cam*. All brake cams are levers and are used to transmit and modify the torque and turning motion of the brake camshaft in such a way that the brake shoes are spread and forced against the brake drum, not only in the proper location but also with the proper force. Spreading the shoes in the proper direction, of course, depends on the proper location of the cam in respect to the location of the brake shoes. The transmission of the proper force is partially determined by the effective lever length of the cam. If the effective lever length of the cam is not considered, and is too long or too short, the brake shoe's force will be correspondingly too little or too much. Full consideration must therefore be given to the effective lever length of any brake cam, if the final shoe pressure is to be correct. It is also important that the effective lever length of the cam remains constant as the lining wears and the shoes have to be spread further; otherwise, the brake performance will vary as the lining wears.

Another form of lever found in all forms of braking systems is the *brake shoe*. This is one of the simpler forms, because it is easily recognized as a beam, fulcrum at one end on the hinge pin, which forces the brake lining against the drum when the brake cam force is applied to the other end.

Perhaps, the least easily recognized lever in a brake system is the relation of the *brake drum diameter* to the *tire diameter*. In order to understand this fully, remember that although brakes stop the brake drums and wheels, it is always the tires and road surface that stop the vehicle. This is clearly demonstrated when quick stops are attempted on wet or icy roads. Under these conditions, the brake equipment may still be as efficient as ever in stopping the wheels, but its ability to stop the vehicle quickly disappears because there is not sufficient friction between the tires and road to develop the necessary retarding force.

Returning to the principles of leverage involved in the relation of the tire and brake drum size, the retarding force developed by the brake shoes acting against the drum is working on an effective lever length of the brake drum radius. Counteracting this is the retarding force developed between the tire and the road, working on effective lever length of the rolling radius of the tire. Since, it is not practical to have brake drums as large as the tires; the principles of leverage require development of a greater retarding force between the brake shoes and the drums than between the tire and the road. Also, since a rubber tire on good road surface has a higher coefficient of friction than brake lining against a brake drum, it is necessary to develop additional retarding force between the brake shoes and brake drum in order to overcome the difference in friction.

DECELERATION

Deceleration means the actual rate at which a vehicle is losing speed and usually denotes the speed being lost each second, in terms of miles per hour or feet per second. As and example as shown above, if a vehicle is moving at the rate of 20 miles per hour, and one second later its speed is only 18 miles per hour, the vehicle has lost a speed of two miles per hour during one second. Its speed has dropped two miles per hour in one second; therefore, its deceleration rate is two miles per hour per second.

In the same way, if a vehicle is moving at a rate of 30 feet per second, and one second later its speed is only 20 feet per second, thus it is decelerating at the rate of ten feet per second. Therefore, the change in the rate of speed of a vehicle during a slow-down or stop is expressed by first stating the rate of speed being lost, such as miles per hour or feet per second, and then by stating the time required for this rate of speed to be lost.

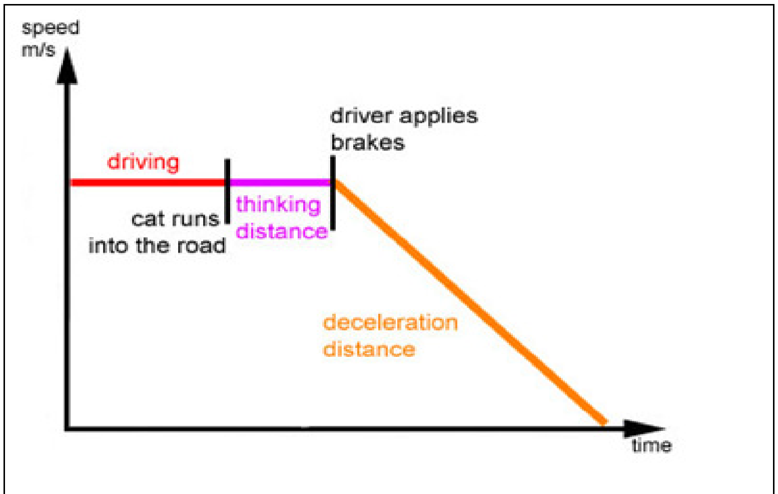
Thus, in examining the expression covering a deceleration rate of say “ten feet per second per second,” the first part—“ten feet per second”—is the rate of speed being lost, and the second part---“per second”—is the time in which the loss of ten feet per second takes place.

If a vehicle is moving at a known rate, and is decelerating at a known rate, the stopping time will be the initial speed divided by the deceleration rate, provided both the rate of speed and the deceleration rate are expressed on the same basis. As an example, if a vehicle is moving at the rate of 30 feet per second and is decelerating at the rate of ten feet per second, the stopping time will be the initial speed of 30 feet per second divided by the deceleration rate of ten feet per second per second, or a stopping time of three seconds.

This perhaps can be more easily understood if explain in the following manner. If a vehicle is moving at the rate of 30 feet per second and begins to decelerate at the rate of ten feet per second per second, at the end of the first second it will be traveling 20 feet per second; at the end of the second second, it will be traveling at ten feet per second, and at the end of the third second, it will be stopped. Thus, by losing speed at the rate of ten feet per second per second, it would lose its initial speed of 30 feet per second in three seconds.

Similarly, if the initial speed is 20 miles per hour and the deceleration rate is two miles per hour per second, the stopping time will be ten seconds.

One important thing to remember in respect to stopping vehicles is that while the deceleration rate may be constant for each second during the stop, the distance the vehicle travels each second during the stop varies greatly as the speed decreases.



Deceleration

Fig. 5.17

A vehicle decelerating at the rate of 10 feet per second per second from an initial speed of 30 feet per second, although its rate of deceleration remains constant throughout the stop, the vehicle actually travels 25 feet during the first second after the brakes are applied, 15 feet during the next second, and only five feet during the third second.

The distance being traveled each second during the stop is always greater at the beginning of the stop. To keep stopping distance as short as possible, it is important that the brakes become fully effective when the pedal is depressed by the driver. Any time lost between the instant the brake pedal is depressed and the instant actual deceleration begins is important, because the vehicle continues to travel at close to its initial speed. In this case, the loss of only one second between the instant the driver depresses the brake pedal and the point where the brakes are really applied will result in lengthening the actual stopping distance by 30 feet. Thus, if four seconds elapse, instead of three, between the time the driver depresses the brake pedal and the time actually stops, the actual stopping distance will be increased from 45 feet to 75 feet. So, by increasing the time of hitting the brakes by one second or 25%, in the example above, the actual stopping distance is increased by 30 feet or 40%.

It is this part of brake fundamentals which is often not considered when judging brake performance, particularly when different forms of brakes are involved. A common method of testing brakes is through the use of a *decelerometer*—a device that determines the maximum rate of deceleration developed during a stop and shows a calculated stopping distance from a speed of 20 miles per hour based on the maximum rate of deceleration developed during a stop. Such instruments do not, however, make allowances for lost time before the braking system develops full power and therefore are not suitable for analyzing time lag factors in brake performance.

The true performance of any type of brake system in terms of stopping time or stopping distance can only be determined by actually measuring the time and distance the vehicle travels from the instant the driver depresses the brake pedal to the point where the vehicle actually stops. Such tests can, of course, be made comparative only by using instruments to determine accurately the speed of the vehicle at the instant the brake pedal is depressed.

As far as brakes are concerned, a driver is mainly interested in the amount of time and the distance required to bring his vehicle safely to a stop under emergency conditions. Any lag in the time between the instant he does his part and the instant the brakes become effective affects stopping distance.

THE FUNDAMENTALS OF COMPRESSED AIR

Compressed air is air which has been forced into a smaller space than that which it would ordinarily occupy in its free or atmospheric state.

Free air, which we breathe or is in the atmosphere, is normally always under pressure because of the weight of the air above it. This pressure is 14.7 pounds per square inch at sea level, and it decreases as the altitude increases.

The normal atmospheric pressure of 14.7 pounds per square inch is usually ignored and the atmosphere is considered as being free air under no pressure. Thus, the pressure of compressed air is commonly indicated by stating the amount the pressure, in pounds per square inch. This is the reason air pressure gauges register zero when connected only to atmosphere.

FREE SPRING-----FREE AIR

The energy of compressed air is best compared to the energy of a coiled spring. A coiled spring in its free position is like air in its free or atmospheric state.

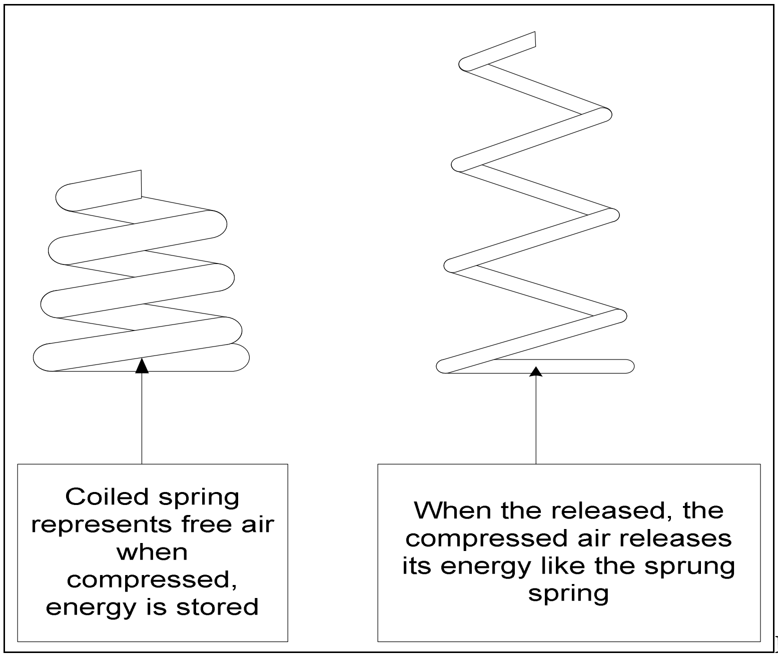


Fig. 5.18

COMPRESSED SPRING------COMPRESSED AIR

When the spring is compressed, as shown in Figure 5.18 above, energy is stored in it. Similarly when free air is compressed, energy is stored in the air. This energy can be used to do work, and due to the flexibility of air such energy can be stored in a relatively small space.

FUNDAMENTALS OF COMPRESSED AIR

If two reservoirs are connected, one containing air above atmospheric pressure and the other air at only atmospheric pressure, air will flow from the reservoir charged with higher pressure until the pressures in both reservoirs equalize or until the flow is interrupted by some outside force, such as the closing of a valve in the connecting line. This is similar to the action of liquids except that pressure is the controlling medium. Ordinarily, the force of gravity would be the controlling medium in the case of liquids.

If a reservoir No. 1 has a volume of six cubic feet, and the compressor forces another six cubic feet of free air into it, the gauge pressure of the air in the reservoir, which originally read zero, rises to 14.7 pounds. It follows that the more air that's forced into any reservoir, the higher the air pressure in that reservoir will be, and that each time a quantity of free air equal to the volume of the reservoir is forced into it, the gauge pressure will rise another 14.7 pounds per square inch.

If compressed air is admitted to an air tight chamber behind a movable object, the compressed air will cause the movable object to move until it encounters a resistance equal to the force developed by the compressed air. Because the air pressure is based on pounds per square inch, it follows that the compressed air will develop a force in pounds on the movable object equal to the product of the air pressure multiplied by the effective area of the movable object. Thus, if a piston or a flexible diaphragm has an area of ten square inches and air pressure of ten pounds per square inch applies a force of 100 pounds will be developed. Similarly, if air at only five pounds per square inch pressure is acting on the piston or diaphragm, the developed force will be only 50 pounds. One point to be remembered is that the quantity of air acting on the piston or diaphragm does not affect the force developed. The only factors involved are the air pressure and the area of the piston or diaphragm on which the air pressure is acting. Thus, by controlling the air pressure, the developed force is also controlled.

The pressure exerted by compressed air is not only developed in all directions, but it is also equal in all directions. The compress air in a reservoir exerts pressure equally in all directions against the entire inside surface of the reservoir, the pressure of the compressed air being overcome by the mechanical strength of the reservoir. Similarly, the force developed by the air pressure acting on one side of a piston or a diaphragm may be overcome by an opposing force acting on the opposing forces may be compressed or it may be mechanical. If the opposing forces are equal, a balance condition is reached and there is no movement of the piston or diaphragm. If the opposing forces are not equal, the piston or diaphragm will move, if possible, to assume a position where the opposing forces are equal.

This law of balanced pressures and force is the basic principle governing the design and operation of the control and actuating devices in an air brake system.

The Fundamental of Compressed Air Brakes

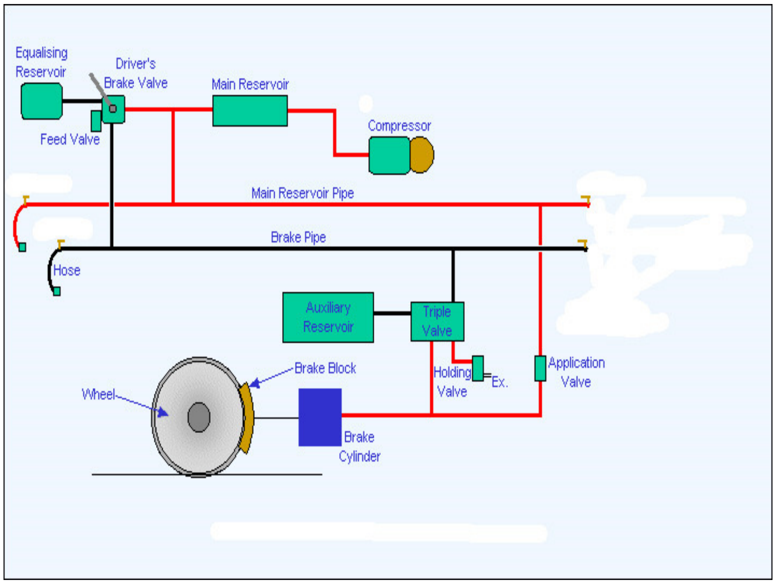


Fig. 5.19

COMPRESSOR

In an Air Brake system, the compressor furnishes the compressed air for brake operation by taking free air or atmosphere and compressing it to 100-120 PSI (Maximum pressure in an air brake system is generally 150 PSI.)

COMPRESSOR AND RESERVOIR

The compressed air passes from the compressor into the reservoir where it (and its energy) are stored until needed.

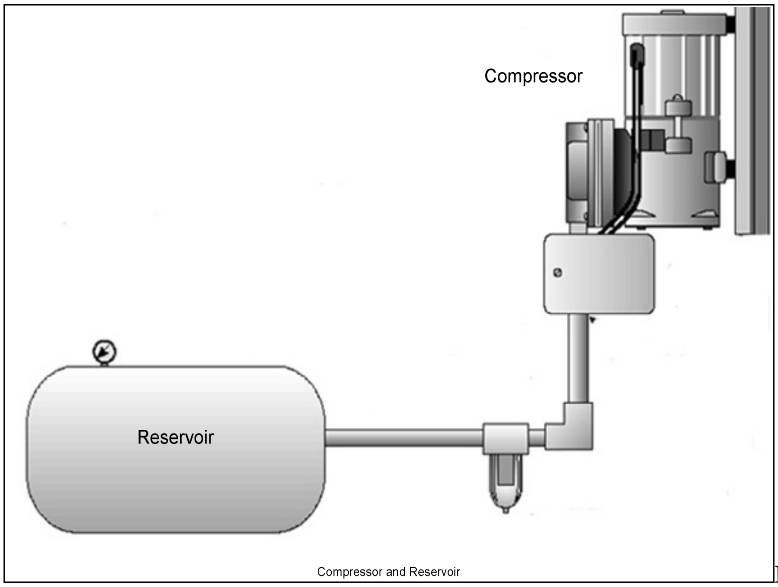


Fig. 5.20

COMPRESSOR, RESERVOIR, AND BRAKE VALVE

The compressor air is held in the reservoir until released by the driver operating air control valves.

SERVICE BRAKE SYSTEM

When the brake valve is operated by the driver, air flows to the chambers where its energy is transformed into the mechanical force and the motion necessary to apply the brakes.

BRAKING FORCES---EFFECT OF AIR PRESSURE

This control of the braking force by controlling the air pressure in the chambers creates a resulting force in pounds of various air pressures. The important point is that the air pressure in a brake chamber can be controlled, so the brake chamber will develop the required force.

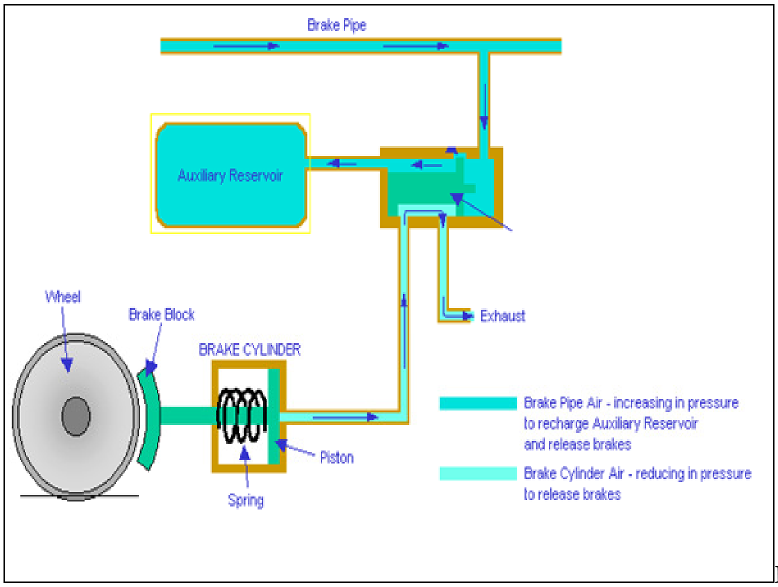


Fig. 5.21-Air Brake System in Release Position

BRAKING FORCES—EFFECT OF BRAKE CHAMBER SIZE

Different sizes of vehicles and different axles on the same vehicle may require different braking forces, depending on the weight of the vehicle or the weight distribution between axles of the same vehicle. These variations in the braking force are design variations, because the maximum and minimum force required must be properly provided before good performance can be obtained throughout the entire braking range.

When supplied with air pressure at 60 pounds per square inch, the effective area of the different brake chambers generally varies from six square inches to 36 square inches, and their developed force at 60 pounds air pressure generally varies from 360 pounds to 2,160 pounds. This permits the choice of a chamber size suitable for properly operating any size or type of foundation brake.

BRAKING FORCES---EFFECT OF SLACK ADJUSTER ARM LENGTH

With the same brake chamber force of 1,000 pounds, the torque on the brake camshaft can be increased from 4,000 inch pounds to 6,000 inch pounds merely by using a slack adjuster with a 6 inch arm instead of one with a 4 inch arm
In an S-Cam foundation brake, the full range of braking forces for any vehicle is provided for by the use of different sizes of brake chambers and slack adjusters.

A term which is used to express the relation of the brake chamber size and slack adjuster arm length is *"AL" factor*. The "AL" factor differs from torque or turning moment in that only the variable factors which determine the force are expressed. The reason for this is that an air pressure of 60 pounds is generally used in calculating air braking forces and therefore, is considered constant. The length of the slack adjuster lever arm and the size or effective area of the brake chamber acting on the slack adjuster are the two variables altered to meet braking requirements. The product of the effective use of the brake chamber and the length of the slack adjuster arm is expressed as the "AL" factor, which, when multiplied by the 60 pounds air pressure used in making brake calculations, determines the torque on the brake camshaft. As an example, if a brake chamber having an effective area of 16 square inches is acting on a slack adjuster having an arm length of five inches, the "L" factor is 80. The actual torque on the brake camshaft is therefore the "AL" factor (80) multiplied by the air pressure used in making brake calculations (60), or 4,800 inch pounds.

BRAKING—FORCES—WEDGE BRAKES

Wedge brakes use the wedge effect to accomplish force multiplication. This replaces the leverage and torque principle of the slack adjuster applied in the S-cam brakes. The wedge brake uses linear (straight line) motion to spread the brake shoes apart; unlike the S-cam brake which uses torque to turn an "S" shaped cam, spreading the brake shoes. The wedge angle determines the force multiplication factor. A thinner wedge and smaller wedge angle produces more force multiplication. For example, a 1,000 lb. chamber force produces 5,720 pounds of force into each shoe. An 18 degree wedge angle produces 3,184 pounds of force into each shoe. To tailor the braking forces to the requirements of any vehicle, chamber sizes and wedge angle combinations are varied. As chamber sizes increase and wedge angles decrease, the multiplication or power factor increases.

Review

1. All energy put into a hydraulic system must come out as:
   A. Heat Loss
   B. Work Gain
   C. Oil
   D. Both A and C

2. The basic hydraulic system has two parts:
   A. Tubing
   B. The Pump which moves oil
   C. The Cylinder which uses the moving oil to do the work
   D. Both B and C

3. What are the two basic types of hydraulics?
   A. Hydrodynamics is the use of fluids at high speeds "on impact" to supply power. Example: a torque converter.
   B. Hydrostatics is the use of fluids at relatively low speeds but at high pressures to supply power. Example: most hydraulic systems, and all those covered in this manual.
   C. Hydrofluence is the study of the flow of oil between parts.
   D. Both A and B

4. In a hydraulic system, Oil must be:
   A. Confined to create pressure for work. A tightly sealed system is a must in hydraulics
   B. Allowed to flow between pumps.
   C. Must be heated for smooth flow.
   D. Must be left alone.
5. If a moving body weighs 100 pounds, and a force of 60 pounds is required to keep it moving while it remains in contact with another body, the coefficient of friction between the two bodies would be
   A. 55% or .55
   B. 60% or .6.
   C. 75% or .75
   D. None of the above

6. If a vehicle is moving at the rate of 30 feet per second and is decelerating at the rate of ten feet per second, the stopping time will be:
   A. 5 seconds
   B. 3 seconds
   C. 4 seconds
   D. 30 seconds

7. If two reservoirs are connected, one containing air above atmospheric pressure and the other air at only atmospheric pressure, air will
   A. Flow from the reservoir charged with lower pressure until the pressures in both reservoirs equalize

B. Flow from the reservoir charged with higher pressure until the pressures in both reservoirs equalize or until the flow is interrupted by some outside force, such as the closing of a valve in the connecting line
C. Increase in pressure but remain where it is
D. None of the above

8. If air at five pounds per square inch pressure is acting on a 10 in^2 piston or diaphragm, the developed force will be:
   A. 10 pounds
   B. 30 pounds
   C. 40 pounds
   D. 50 pounds

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