



**Introductory Agricultural Mechanics
Complete Set-Agribusiness 121
(27 Student Material Topics)**

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Introductory Agricultural Mechanics

AGRISCIENCE 121

P R E F A C E

Fact 1: Young people need and want opportunities to develop and improve their hand-eye coordination.

Fact 2: Many junior high or middle school principals feel a need to offer a greater variety of electives for their students.

Fact 3: A large number of school districts already offer courses in agricultural science and technology.

These facts add up to a unique opportunity for student learning. *Introductory Agricultural Mechanics* is an educational tool that can be utilized to teach contemporary skills to middle school youth, showcase real-world applications, and develop pride in personal accomplishment. This opportunity can be realized by expanding existing programs and offerings, rather than re-inventing the wheel. All three facts can be addressed, and students can be served more effectively.

The purpose of *Introductory Agricultural Mechanics* is to help the student acquire essential knowledge and skills related to the basics of mechanized agricultural systems. Information presented includes hand and power tools and equipment, fasteners and building materials, buildings and equipment, paint and preservatives, water supply and sanitation systems, electric motors and circuits, electric and oxy-fuel welding and soldering, small engines, machinery and equipment, and fences.

The arrangement of the student material topics in this publication follows the units and topics of instruction listed in the *Curriculum Guide for Introductory Agricultural Mechanics* (IMS Catalog Number CG121).

Additional teaching and learning aids are available from the publisher to complement the information in this publication.

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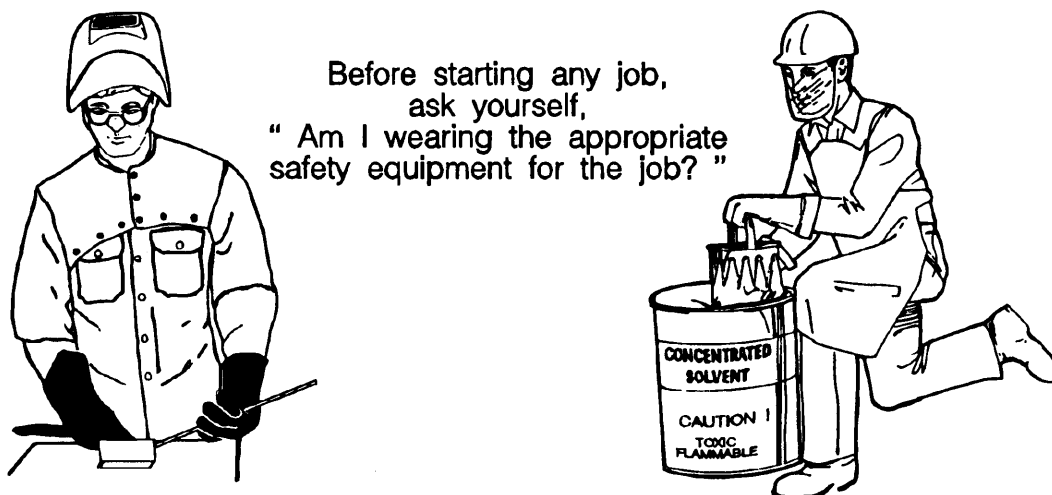
WORKING SAFELY IN AGRICULTURAL MECHANICS RELATED OCCUPATIONS

The broad industry of agriculture uses modern chemicals, mechanical technology, and power to help produce food, clothing, shelter, and other basic needs for the World's increasing population. Agricultural workers must have the knowledge and skills necessary to construct, repair, and maintain agricultural homes, buildings, machinery, electrical equipment, fences, etc.

Agricultural mechanics courses allow students to develop the ability to perform these skills. This allows them to: 1) reduce labor and material costs; 2) select and properly use the proper tools and equipment; 3) save time; 4) solve mechanical problems; and 5) be neat, accurate, and **safe** while completing the task.

IMPORTANCE OF RULES AND REGULATIONS

The society we live in has rules for most everything we do. There are safety rules for use in each agricultural related occupation. We are expected to follow them for the *safety and protection of ourselves, other people, and the environment around us*. The specific rules will vary with the tools, equipment, and chemicals used, and the task performed.



Wear Appropriate Safety Equipment

Wear the proper clothing and safety equipment for the job being done.

Always wear safety glasses whenever you are working with tools and equipment even if you are not in a shop. Other safety equipment includes welding helmets, goggles or face shields, aprons, boots, gloves, and respirators. Do not wear loose or torn clothing that can get tangled in machines.

Always keep the shop clean and the tools in their proper place. Every tool and piece of equipment in the shop has a place where it belongs. Always keep tools in their proper place when not being used. Work benches and floors must always be clean. Store fire hazards such as oily rags and sawdust in proper containers. A clean shop is usually a safe shop.

Always practice good shop manners. Scuffling or horseplay puts everyone in the shop in danger. Running, playing with tools, talking to or disrupting others, unnecessary loud noises, or disobeying other shop rules are all examples of poor shop behavior. One reckless worker can make the entire shop unsafe.

Pay attention to safety and warning signs. The safety signs may be printed signs, flashing lights, or color codes. The nine colors commonly used for safety color coding are:

Red = *danger* - identifies fire extinguishers, fire control equipment, signal words, or hazards.

Orange = *warning* - shows danger from moving parts, draws attention.

Yellow = *caution* - marks operating controls, aisles, hand rails, and other areas which could cause a worker to fall.

Yellow and Black = *caution signs and traffic lanes* - yellow and black stripes mark safety lanes through a building.

Light Green or Gray = *safety* - marks body parts of equipment which are safer.

Ivory = *spotlights or improves visibility* - marks edges of benches and equipment, and the inside of cabinets.

Safety Green = *safety or medical* - marks safety equipment and their locations.

Safety Blue = *information* - out of order or do not operate signs.

Safety Purple = *radiation hazards* - marks radioactive hazards, although they are not common in agricultural mechanics related occupations.

Use the proper tools or equipment for the job. Each tool is designed for a particular purpose. Improper use may result in accidents and broken tools. Check the condition of tools and equipment before using them. Do not use broken or damaged tools or equipment.

Always think or ask before you act. Make sure that you do not endanger yourself or anyone else while you are working. Most accidents can be avoided when people take the time to think about what they were doing, or ask for help.

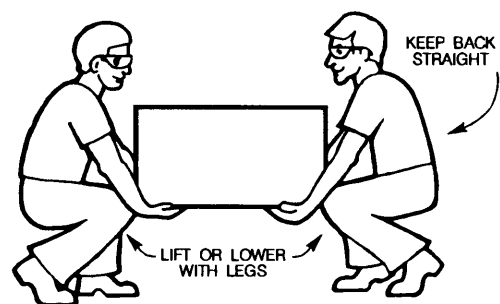
Everyone hopes to live a long, happy life that is free from injury. Businesses today want to hire workers that are safe and sensible. Many of the injuries workers can receive cause permanent disabilities which will affect the rest of their lives. Some of these disabilities will cause workers to lose their jobs and lower their standards of living.

SHOP SAFETY REMINDERS

The rules for a shop will help workers develop good work habits. They will help prevent injuries and increase productivity.

There are several methods used to move and place heavy materials in the shop. A lift or chain-hoist suspended from an A-frame or some other well-supported structure helps to move large, heavy objects. If a heavy object must be moved by hand, the following method should be used:

- * Lift with your legs to avoid back and stomach injuries.
- * Keep your feet apart, knees bent, and back straight when lifting.
- * Do not shift your hands or body while carrying the load.
- * Lower the load the same way it was lifted.
- * If the load is too heavy, **ask for help.**



Many injuries in the shop are caused by hand tools. The three main causes of injuries from hand tools are: 1) improper use of the tool, 2) using the wrong tool for the job, and 3) using damaged or worn tools.

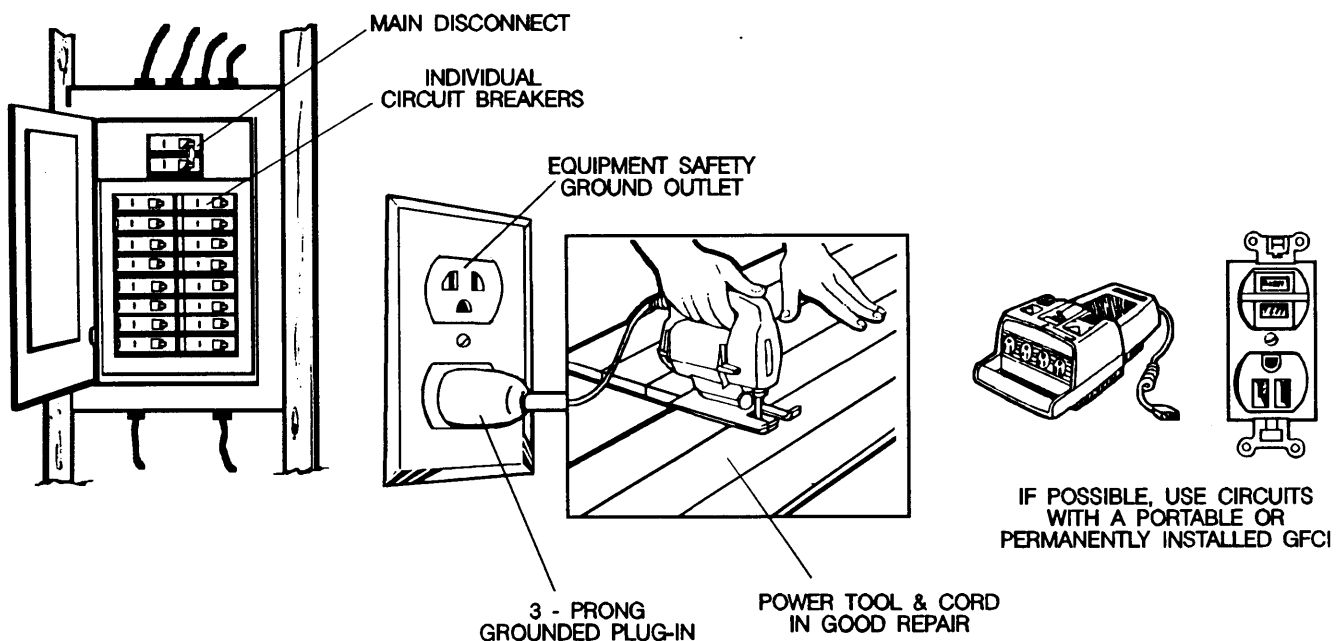
Some of the precautions which apply to the use of hand tools include:

- * Never leave tools laying around if they are not being used.
- * Do not carry tools in your pocket.
- * Secure small work; use a vise whenever it is possible.
- * If possible, make cuts and/or point tools away from your body.

IMS student topics #8147-B and #8147-C provide additional information on the proper use and care of hand and power tools.

Many occupations will require the worker to use electricity and electrical equipment. Some of the rules to follow when working with electrical equipment include:

- * Know the location of the main disconnect and branch circuit switches *before* using electrical equipment.
- * Use branch circuits equipped with equipment safety ground conductors and grounded receptacles.
- * When using portable electrical equipment outdoors or in damp areas, use a branch circuit equipped with a ground-fault circuit interrupter (GFCI).
- * Periodically, check the operation of the ground-fault circuit interrupter.
- * Check electrical tools and extension cords for damaged parts, plugs, insulation, and grounding prongs *before* using them.



- * Make sure the extension cord wire size is large enough to handle the electrical load (amps).
- * Do not place extension cords across aisles or under heavy objects, or drag them across sharp edges that will cut the insulation.
- * Never operate power tools in damp or wet areas, unless they are specifically designed for such use. If possible, wear rubber-soled shoes when using electrical equipment in damp areas.

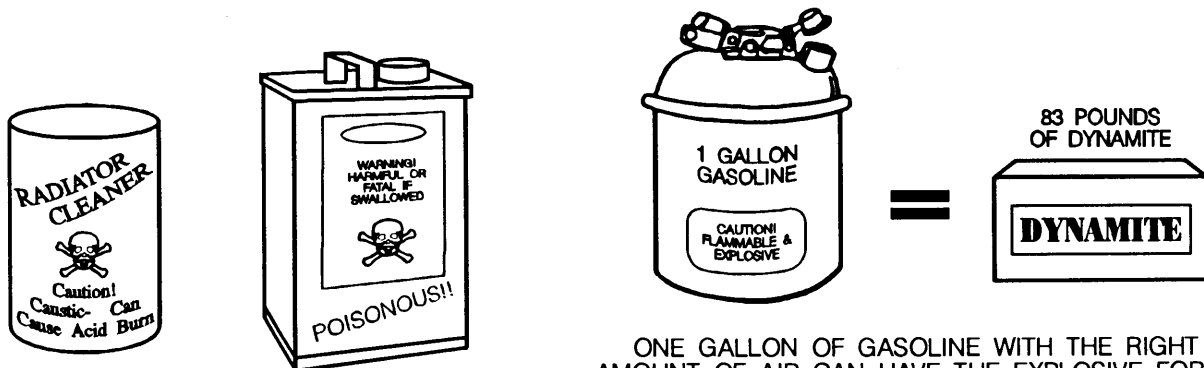
Some projects will require the use of different types of welding and cutting equipment. Each type will have a specific set of operating instructions that allows it to be operated safely. However, there are some general safety precautions which apply to all types of welding and cutting equipment.

- * Use an adequate ventilation system to remove any vapors and fumes produced by the cutting and welding equipment.
- * Wear welding helmets, gloves, "leathers", goggles, and other special safety equipment to protect you from the bright light and high temperatures produced when welding or cutting.

IMS student topics #8154-A, #8154-B, #8154-C, #8154-D, and #8154-E cover specific safety precautions for the welding and cutting processes.

SPECIAL SHOP HAZARDS

The use of chemicals such as paints, thinners, fuels, lubricants, cleaning solvents, etc., is increasing in all agricultural mechanics related occupations. Many of these chemicals are caustic and can cause acid burns to the skin. Some are flammable and/or explosive. Others are extremely poisonous or toxic. When used properly, these chemicals can be safe. Regardless of how harmless some chemicals may seem, they should be used *only* under the direct supervision of the proper authorities who know of their possible dangers.



ONE GALLON OF GASOLINE WITH THE RIGHT AMOUNT OF AIR CAN HAVE THE EXPLOSIVE FORCE OF 83 POUNDS OF DYNAMITE.

Companies who manufacture these chemicals provide specific instructions on how to properly use, handle, store, and dispose of them safely. This information is usually listed on the label attached to the can or container. Spilled or improperly used solvents and chemicals can injure you. They can also injure others and cause damage to the environment.

- * *Never* handle any hazardous chemicals without first receiving proper training and without using the proper safety clothing and equipment.
- * *Always* store chemicals in their original containers that are properly marked or labeled.
- * *Always* clean up a solvent or chemical spill immediately, using the method recommended by the manufacturer.

Compressed air or fluids can also be very dangerous. Practice extreme caution when using them to clean and/or paint equipment. Observe the following precautions when using compressed air or fluids:

- * Never point the nozzle directly at yourself or anyone else. Compressed air or fluids can damage eyes and ears, or penetrate the skin very easily.
- * Do not kink a hose to shut off or slow the flow of air or fluid. This could cause the hose to rupture and burst.
- * Do not use compressed air to blow fine metal shavings or fillings.
- * Do not use compressed air to remove grit or liquids from blind holes or confined areas.
- * Use the lowest possible pressure to complete the job.
- * Use only pressure-regulated, OSHA approved safety blow guns.

An agricultural science and technology laboratory can be a safe place to learn agricultural mechanics skills. It can also be a very dangerous place if safety rules are not followed. Remember, if one person does not follow the rules, others nearby are also in danger.

GLOSSARY OF TERMS

Poison - any substance ingested, inhaled, or developed within the body that causes or may cause damage or disturbance of natural functions of plants, animals, or people. (Poisonous - containing or being poison.).

Ground-fault circuit interrupter (GFCI) - a special electrical safety switch designed to automatically stop the flow of current through a circuit. It is used to protect humans and animals from electrical shock when very low levels of current which are leaking from the circuit are not sufficient to trip the circuit breaker or blow a fuse.

Solvent - a liquid capable of dissolving or dispersing other substances. A common solvent found in most agricultural mechanics shops is a special petroleum product used to clean equipment, parts, and other surfaces.

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Mr. Bradley J. Green, Graduate Assistant, Department of Agricultural Education, Texas A&M University and Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the material for this topic.

SUGGESTED STUDENT ACTIVITIES

SHORT ANSWER: Answer the following items in a sentence, phrase or short paragraph. (Use additional paper when needed.)

1. What are the purposes of shop rules and regulations?
2. What are the main causes of injury from hand tools?

3. When should a chemical spill be cleaned up?
4. Where can instructions on how to properly use a chemical normally be found?
5. What precautions should be followed when working with compressed air or fluids?
6. What piece of safety equipment must be worn at all times in the shop?

MATCHING: For each item in the left-hand column, select the best match from the right-hand column. After matching a pair, write the letter of the matching item in the space provided.

_____ 7. Red	A. caution signs and traffic lanes
_____ 8. Yellow	B. warning, danger from moving parts
_____ 9. Orange	C. danger, fire control equipment
_____ 10. Yellow and Black	D. caution, marks operating controls

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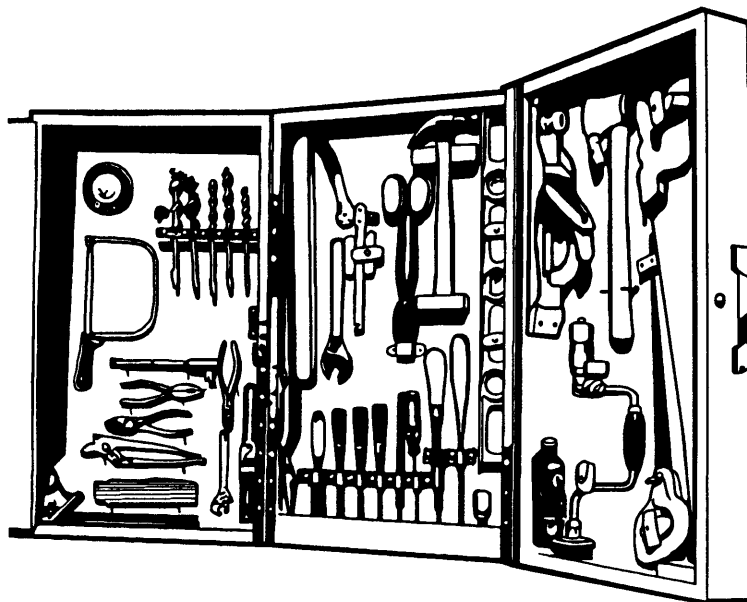
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IDENTIFYING AND SAFELY USING HAND TOOLS

Workers employed in any agricultural mechanics related occupation must use many different types of hand tools. They must be able to select the proper tools for the job as well as maintain and use them safely.

For example: Workers performing carpentry skills are required to select and use a variety of hand woodworking tools. Persons working in the area of concrete and masonry construction may also be required to use woodworking tools to build forms. In addition, they must select and use concrete and masonry tools to properly place and finish concrete.



Tool companies manufacture many sizes and shapes of hand tools in different price and quality ranges. A person should always buy the highest quality tools he or she can afford. High quality tools will usually last longer and do a better job than less expensive tools. It is true that lower quality tools usually cost less to purchase. However, always consider future repair costs and the expense of replacement when the lower quality tools break. The initial cost of top quality tools is often less than the total repair and replacement expenses of lower quality tools over a period of time.

Part of the proper selection and use of hand tools is to choose tools that fit your hand. The size and quality of the handle and/or grip on hand tools will vary greatly. If a tool feels comfortable in your hand, it is probably the right one for you. Many accidents occur because a person can not properly grip and control the hand tools.

HAMMERS

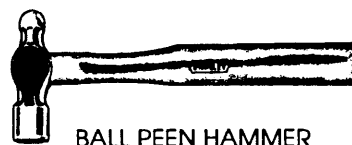
The **claw hammer** is one of the hand tools most commonly used by carpenters. The claw hammer is designed to drive and pull nails. Claw hammers weigh from 7 to 20 ounces. The standard claw hammer size is 16 ounces. Lighter hammers are used in finish carpentry to drive small nails in soft wood. Heavier claw hammers are used to drive large nails and spikes in rough framing and barn construction.

The heads of claw hammers are made of hardened steel. Handles are made of wood, metal, or fiberglass. The claw is the curved part of the head used to pull nails out of boards. The face of the hammer head is the part used to drive the nails. Claw hammers have different types of faces

and claw shapes. The face of a plain faced hammer is flat and normally used only for rough carpentry. It will leave a large mark or impression on the wood when used to drive nails flush.

A bell face is slightly rounded. It is harder to drive nails with the curved bell faced hammer. However, it will leave less marks on softer wood than the plain face hammer.

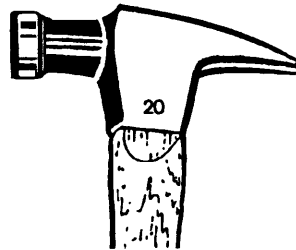
The **ball peen hammer** is the most common type of mechanic's hammer. The rounded peen is used to bend or shape light metal. The face of the ball peen hammer is used mainly to hit punches or chisels. It can also be used to bend or drive heavier pieces of metal. Ball peen hammers weigh between 1/4 and 4 pounds.



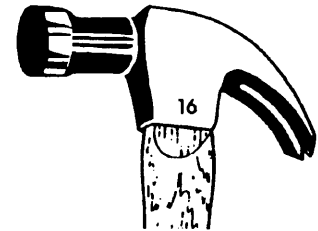
BALL PEEN HAMMER



SLEDGE HAMMER



20
RIPPING CLAW
PLAIN FACED HAMMER



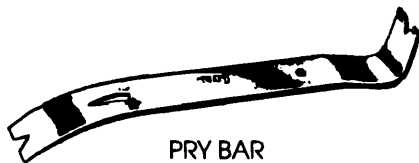
16
CURVED CLAW
BELL FACE HAMMER

Sledge hammers are used for bending and shaping heavy metal. They can also be used to break up old concrete, drive stakes for concrete forms, etc. Sledge hammers weigh between 5 and 20 pounds. An 8 lb sledge hammer is usually large enough for most work. For proper control and safety, a worker must use both hands when swinging a sledge hammer.

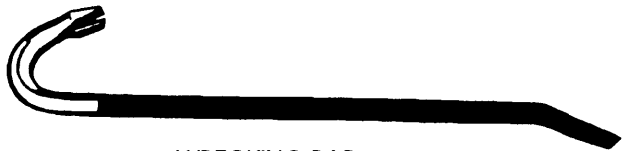
Always wear safety glasses or goggles when using any kind of hammer. *Do not* hit anything that is harder than the face of the hammer. Doing so could cause the face of the hammer to splinter and chip off. Flying metal chips can cause injury to you or someone nearby. *Always* select the correct hammer size and type for the work being done.

WRECKING BARS

Wrecking bars are used for pulling nails and dismantling wooden structures such as concrete forms or buildings. Some types of wrecking bars are also known as ripping, pry, or nail bars. A common wrecking bar is 24 inches long and 3/4 inch in diameter. A wrecking bar *should always* be used to safely pull large nails. Using a regular claw hammer to pull large nails causes extra strain on the handle and increases the chances of it breaking.



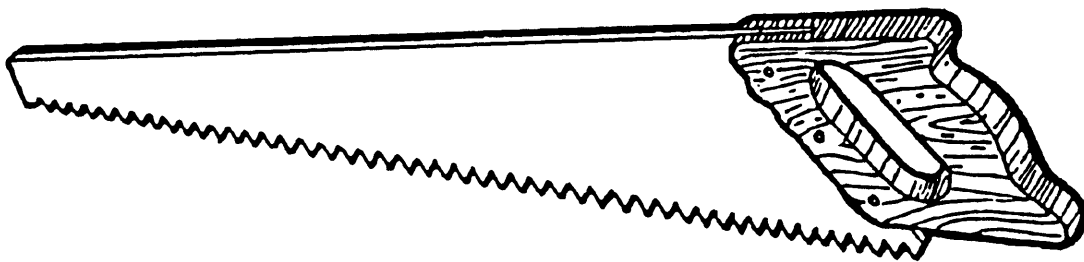
PRY BAR



WRECKING BAR

SAWS

Most tool kits and workshops will have **handsaws** in them. They are used when a small amount of cutting is needed, or when there is not enough room for a power saw. Two common types of wood handsaws are **crosscut** and **rip** saws. They are 18 to 26 inches long.



Handsaw

The **crosscut saw** is the most commonly used type of wood handsaw. As the name implies, it is designed to cut *across* the grain of wood. A common crosscut saw will have 8 to 11 teeth per inch. The teeth have angles on both sides to allow the saw to cut more quickly. Crosscut saws make a very rough cut.



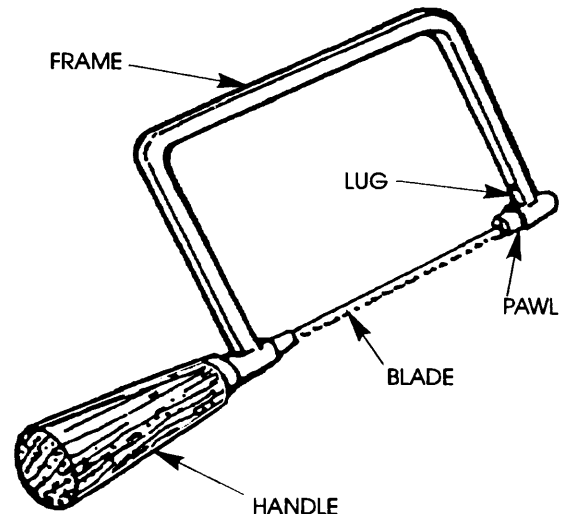
Rip Saw



Cross Cut Saw

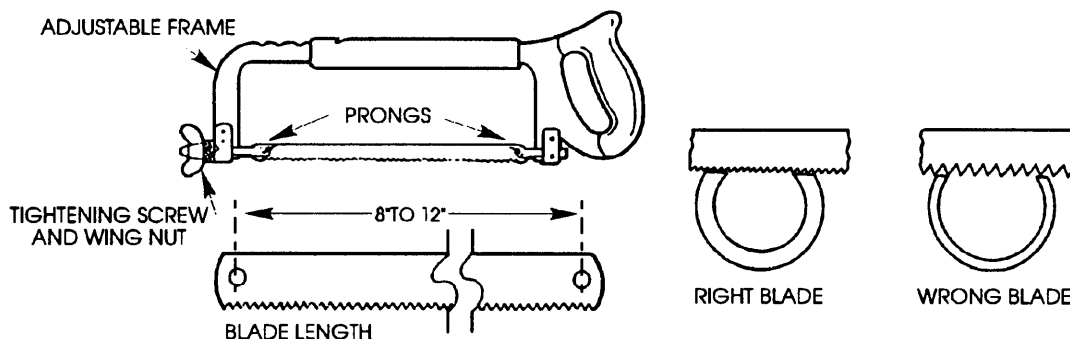
Rip saws cut with the grain of the wood. Their teeth have angles on only one side which makes a smoother cut. Rip saws have 5½ to 7 teeth per inch. It is harder to cut across the grain of the wood with a rip saw.

A **coping saw** is designed to cut thin, light wood, molding, plastics, plexi-glass, and some types of softer metals. The thin, metal blades for this type of saw are about 1/8-inch wide. The thin, narrow blade can be turned to different angles in the frame. This allows a coping saw to cut different directions for various curves, circles, scroll patterns, etc.



Coping Saw

Hacksaws are used to cut harder metals, plastic pipes, heavy electrical cables, etc. Hacksaw blades are made of hardened tool steel and come in 8-, 10-, or 12-inch lengths. They have 14 to 30 teeth per inch. Blades with a lower number of teeth per inch are normally used to cut thicker materials. Thin, light materials are best cut with blades that have a higher number of teeth per inch. *At least* two to three teeth should be in contact with thin materials when sawing.



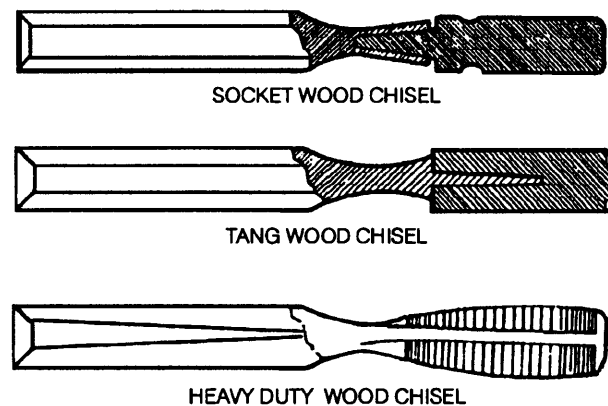
Using a Hand Hacksaw

The blades used for cutting hard, strong metals are completely hardened and are thus more expensive. Blades designed for cutting softer, mild steel, plastics, etc., may only have the tips of the teeth hardened. Some hacksaw frames are rigid and fit only one size blade. Others are adjustable to match different blade lengths for different uses. In most cases, it is better to buy an adjustable type of hacksaw frame.

When possible, secure any material that is being cut with a vise or clamp. This will: 1) allow you to make a more accurate cut; 2) protect you and others from possible injury; and 3) help prevent bending and/or breaking the blade.

CHISELS

A **wood chisel** is an important tool for the carpenter's tool kit or shop. It is used to cut various joints and shapes in wood that can not be easily cut with a hand or power saw. Chisel blades are made of high quality, tempered steel and are sharpened to a 25° to 29° bevel. They range from 1/8 to 3 inches in width and 3 to 6 inches in body length.



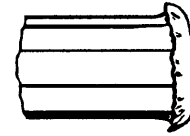
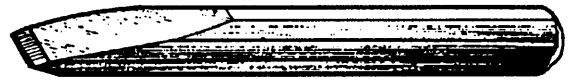
Types of Wood Chisels

Wood chisels may be identified by the way the handle is attached. A common type of wood chisel used in carpentry is the **socket chisel**. A wooden handle fits into a metal socket. It can only withstand moderate blows from a wooden or raw-hide mallet. Socket chisels are used for general woodworking and framing.

Tang chisels have the tang of the chisel inserted into the handle. The tang is a square piece of metal attached to the end of the chisel. These chisels cannot be hit as hard as socket chisels. Usually, hand pressure or a very light tap with a mallet is the only force that can be applied to make a cut with this type of chisels.

Heavy-duty wood chisels have a solid metal head or cap on the end of the handle. The steel shank often runs completely through the molded plastic or wooden handle to the head. A steel hammer can thus be used to strike the chisel handle head without damaging it. This type of wood chisel is used for heavy cutting and shaping.

Cold chisels are designed to cut soft metals. The metal being cut *must always* be softer than the chisel or it will chip and break. Most cold chisels are made of eight-sided tool steel that is shaped and hardened on one end. The two-sided cutting edge of cold chisels should be sharpened to a 60° to 75° bevel. The cutting edges range in widths from 1/4 to 1½ inches and the chisel body in lengths from 5 to 18 inches.



MUSHROOMED CHISEL HEAD

Cold Chisel

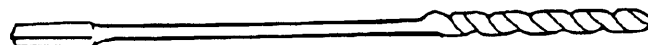
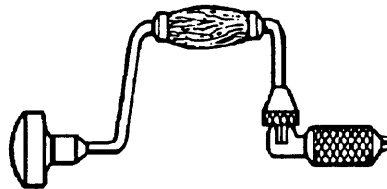
Many injuries caused by chisels are the result of poor maintenance. The cutting edge should always be sharp and free from nicks so only minimum force is required to make the cut.

The handle of the chisel *should not* be allowed to "mushroom." This is a common problem for cold chisels and metal punches. Pieces of the mushroomed handle will eventually break off. The flying metal can easily penetrate an eye or the skin and cause a serious injury. Periodically, grind and reshape the head of a cold chisel or metal punch.

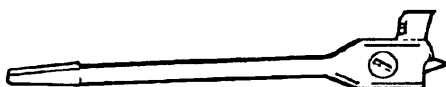
DRILLING TOOLS

Brace

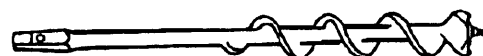
The **ratchet-type bit brace** is a commonly used hand drilling tool. The ratchet allows holes to be drilled in places where a full handle turn cannot be made. The ratchet can work both ways to force the bit forward or backwards as needed. A brace and bit are normally used only for drilling wood or other soft materials.



WOOD TWIST BIT



EXPANSIVE BIT



AUGER BIT

Hand Bit Brace and Bits

Bits

The **bits** used with a hand ratchet brace have a square end called a tang. The jaws of the brace clamp onto the tang and hold the bit. One of the most common types of bits used with a brace is the **auger bit**. Auger bits range in size from 1/4 to 1 inch. The size of the bit is stamped on the tang. The tip of an auger bit has tapered screw threads. The screw threads help pull the bit into the soft material being drilled as the bit turns.

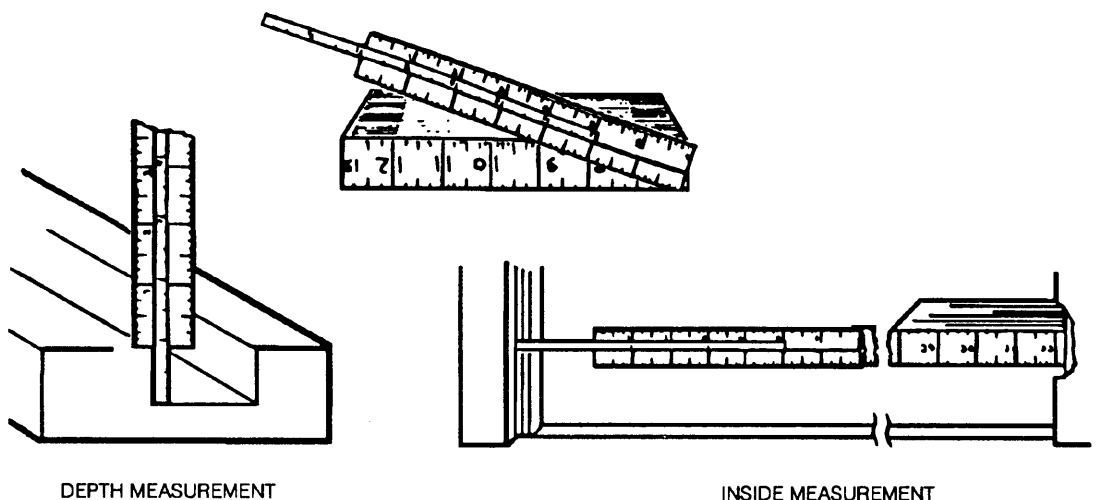
Two other common types of bits used with braces are **expansive bits** and **wood twist bits**. Expansive bits have adjustable blades which are used to bore holes ranging from 1 to 4 inches in diameter. Wood twist bits make smaller, more precise holes than the other types of bits. They range in size from 1/8 to 1/2 inch.

MEASUREMENT AND LAYOUT TOOLS

Accurate measurements are an important part of any construction job. A person must have the proper measuring and layout tools, and know how to use them to do a good job.

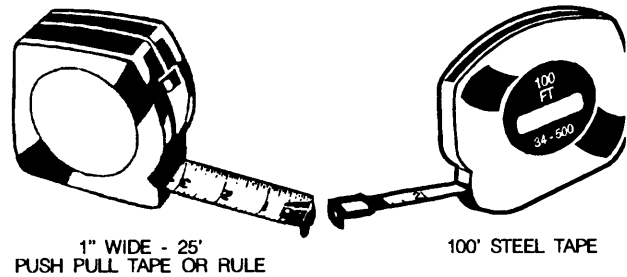
Rules and Tapes

The **folding extension ruler** is often used by carpenters to make precise measurements. The ruler is 6-feet long and 1/2-inch wide. A folding ruler folds in a zig-zag pattern for easy storage. The extension ruler has a **brass slide** in the first joint that can be extended. It is used to make more precise inside and depth measurements during construction.



Folding Extension Rule

Push-pull tape rulers are probably the most common type of measuring tools used today. Some push-pull tape rulers are not as precise for accurate wood and metal construction as a folding ruler. This is because the hook or sliding tab on the end of the tape bends and the rivet holes wear with continued use. However, they are still accurate enough for most general wood and metal construction. Push-pull tape rulers or "tapes" are available in lengths up to 30 feet with 1/16-inch increments.

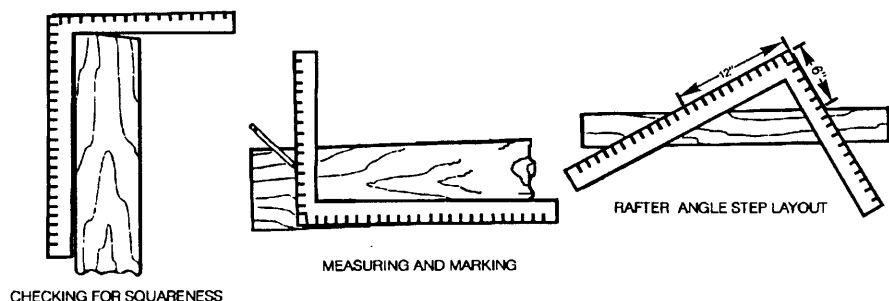


Steel tapes are available in lengths of up to 200 feet and are marked in 1/8- or 1/4-inch increments. Steel tapes are usually made of spring steel and are thin and flexible. These tapes have a ring or hook on the end to help anchor the tape while measuring. The tape case is usually round in shape with a winder on the side. *Always* pull the tape straight out of the case to uncoil it. A steel tape can be easily damaged or broken if it becomes kinked or is folded backwards. The tape must be wiped regularly with a light film of oil to keep it operating properly. Steel tapes must lay flat and be pulled tight for accurate measurements.

The **steel straightedge rule** that is 18 to 36 inches long has many marking and measuring functions. Since it is made of harder steel, it is not as easily damaged as other measuring tools. A steel straightedge rule is commonly used during sheet metal layout and construction to accurately measure short distances and allow precise lines to be marked.

Squares

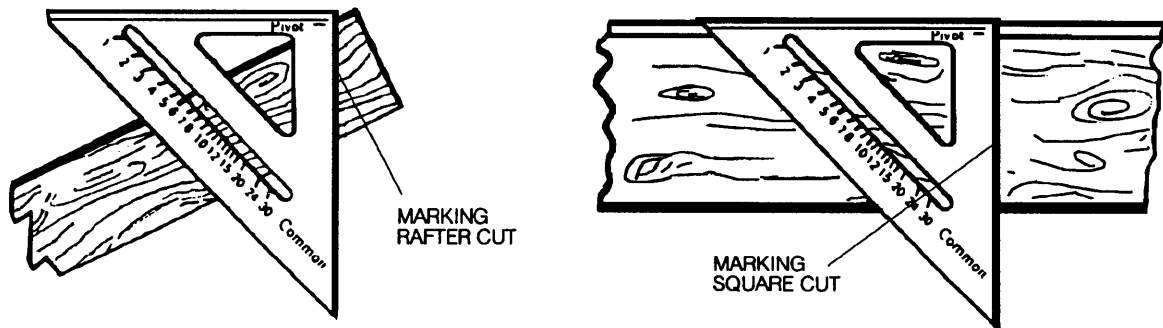
Framing squares are used to measure, mark, and check building materials for squareness. The long side is called the blade and the short side is called the tongue. Different tables are often



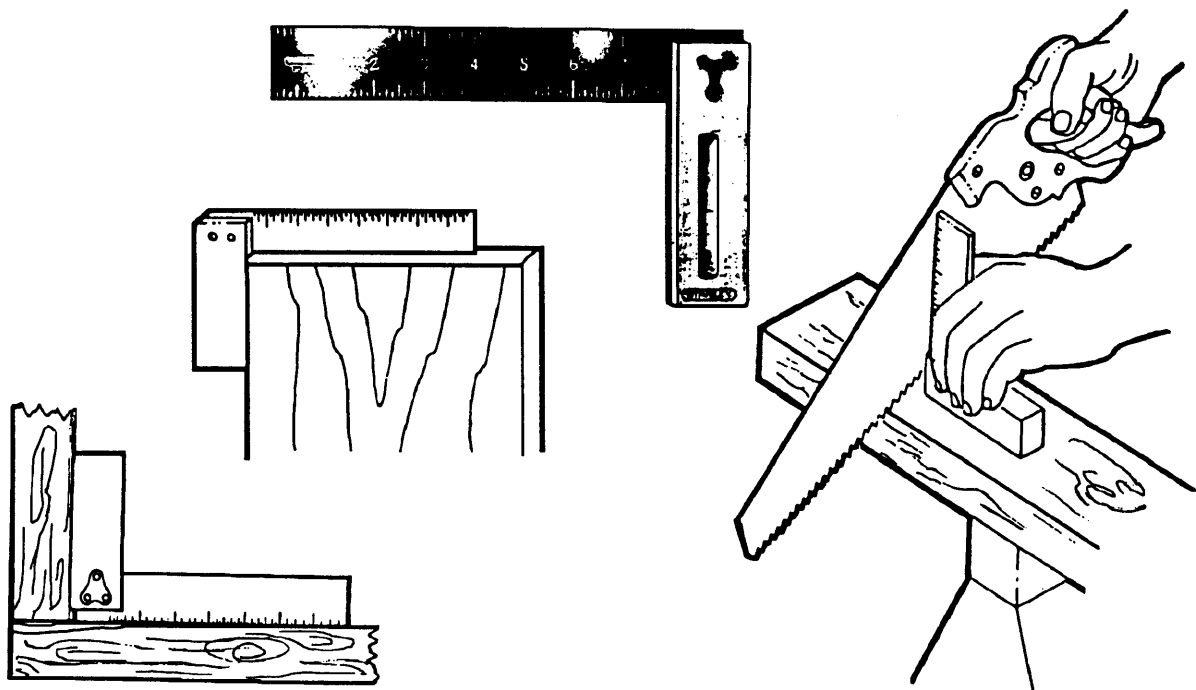
Using a Framing Square

printed on the blade and tongue. Some tables provide the lengths for common types of rafters and braces. Other tables are used to calculate board feet.

A **speed square** can do many of the same jobs the framing square can do. However, it does not contain rafter length tables. They are usually provided in a small printed book that is supplied when the speed square is purchased. Most speed squares will have different roof slopes and angle degree marks included. These are handy for quickly marking angle cuts on rafter ends and other building materials.



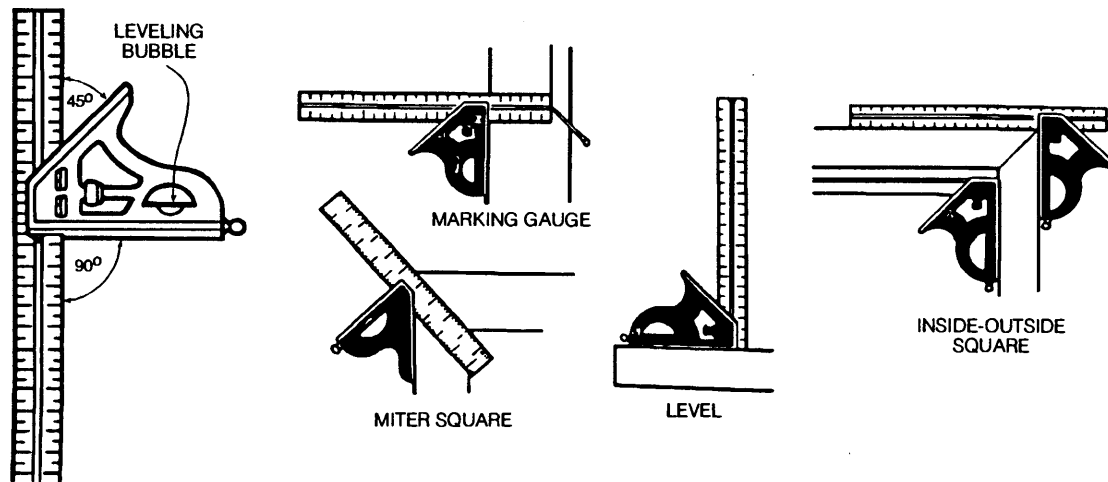
USING A SPEED SQUARE



USING A TRY SQUARE

The **try square** is commonly used to check for squareness of small pieces of lumber and to check saw position. It looks like a small framing square with a wooden or metal handle or base. Do not use the metal handle as a hammer. This will cause it to bend and lose its squareness.

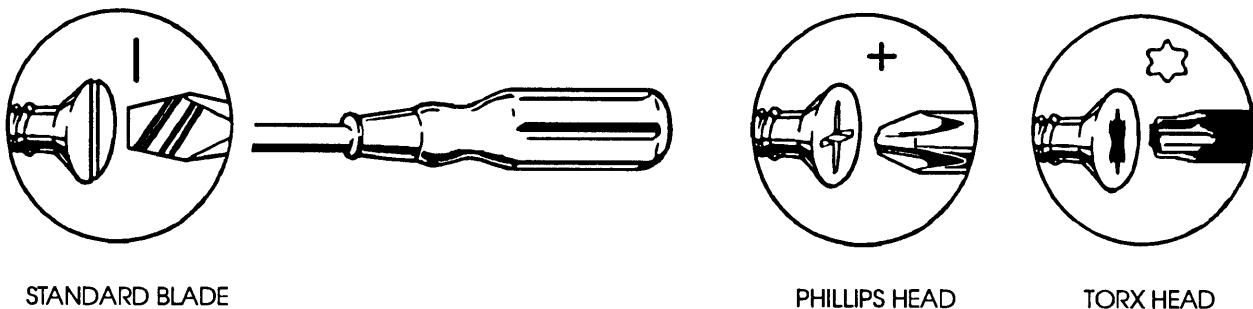
The **combination square** performs many of the same functions as other squares. It has a moveable head which allows it to also act as a depth gauge, straightedge, or marking gauge. It can be used to lay out 45° angles. The leveling bubble in the head can be used to plumb or level surfaces. Plumb means to make straight up and down.



Using a Combination Square

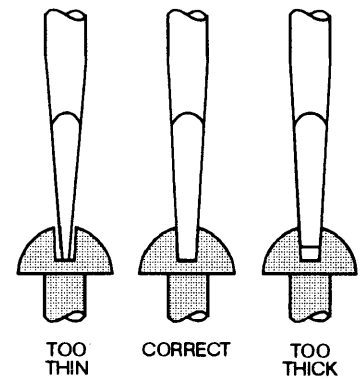
SCREWDRIVERS

Screwdrivers vary in length and diameter of the shanks and the types and sizes of the tips or bits. The ends of the tips are heat treated to make them harder and tougher. Three common types of screwdriver tips are: 1) standard blade, 2) phillips head, and 3) torx head.



Standard blade screwdrivers have a single flattened end which fits into the straight slot in the screw head. **Phillips head screwdrivers** have four small blades which meet at the end of the tip to form a cross or X pattern. **Torx head screwdrivers** have six small blades that form a six-pointed, star-shaped pattern. Torx type screws and screwdrivers are stronger and will not strip out as easily.

They are increasing in popularity. Other types of screw heads and screwdriver tips are available for special purpose applications. The type and size of the screwdriver tip must be matched to the same size and type of screw head. Using the wrong size or type of screwdriver will damage both the screw and the screwdriver.



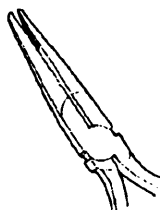
Use Correct Size and Type Screwdriver

Screwdrivers are not substitutes for other tools. They are not chisels, punches, or pry bars. Hammering on a handle can split it and damage the tip. This destroys the tool and can cause an injury. The shank may bend or the tip may break if the screwdriver is used as a pry bar. Bent shanks are hard to straighten and make it difficult to keep the screwdriver centered in the screw. *Do not* use pliers to grip the handle or a round shank on a light duty screwdriver. For heavy work, select the correct size heavy duty screwdriver with a square shank. Use a small wrench to turn the screwdriver.

Plastic and rubber coated screwdriver handles *are not* designed to work on electrical equipment while the electrical power is turned on. *Always* turn off the electrical current before attempting to install or repair any electrical equipment. *Do not* use a screwdriver to check and see if an electrical circuit is "hot." *Be careful* when using a screwdriver on an object that is being held in the palm of your hand or is being supported on your lap. If the screwdriver should slip, the tip could cause a serious injury.

PLIERS

Pliers come in many sizes and styles to do specific types of work. **Long nose or needle nose pliers** are used for reaching into tight places and for handling small parts. **Diagonal cutting** and **lineman pliers** are commonly used for cutting stiff wires and for electrical work. **Slip-joint** and **channel-lock pliers** are used for general grasping and holding objects.



LONG NOSE



DIAGONAL CUTTING



LINEMAN



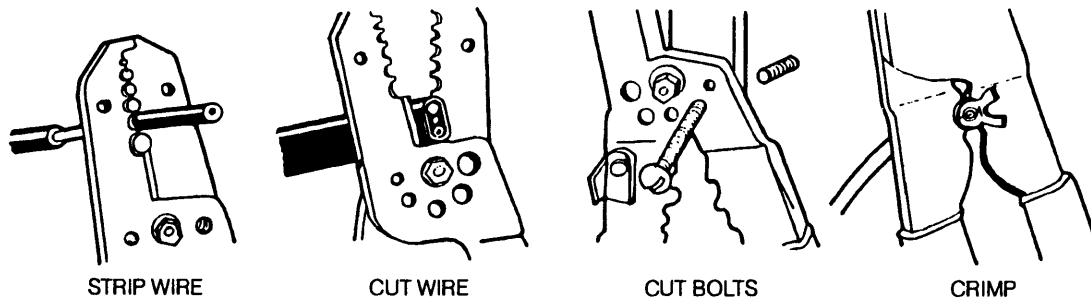
SLIP JOINT



CHANNEL-LOCK CURVED JAW

Common Types of Pliers

Electrician's multi-purpose pliers are special purpose pliers. They vary slightly in size and shape. Most are designed for: shearing small screws or bolts, stripping wire insulation, cutting soft electrical wire, and crimping electrical terminal ends. **Note:** The cutting edges on most electrician's multi-purpose pliers are only designed to cut soft copper or aluminum wire. They may be damaged if used to cut harder steel wire.



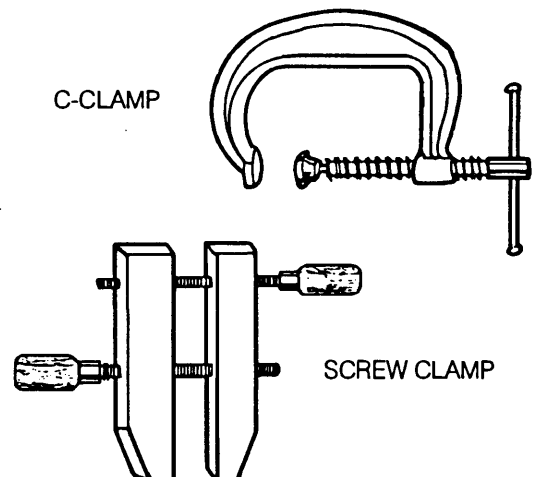
Electrician's Multi-purpose Pliers

Plier handles may be bare metal or they may be covered with plastic or rubber grips. As with screwdrivers, plastic or rubber covered handles and grips are designed primarily for comfort. They provide *only limited protection* from accidental electrical shock. They *are not* designed to allow a person to work on equipment while the electrical power is turned on.

SPECIAL PURPOSE TOOLS

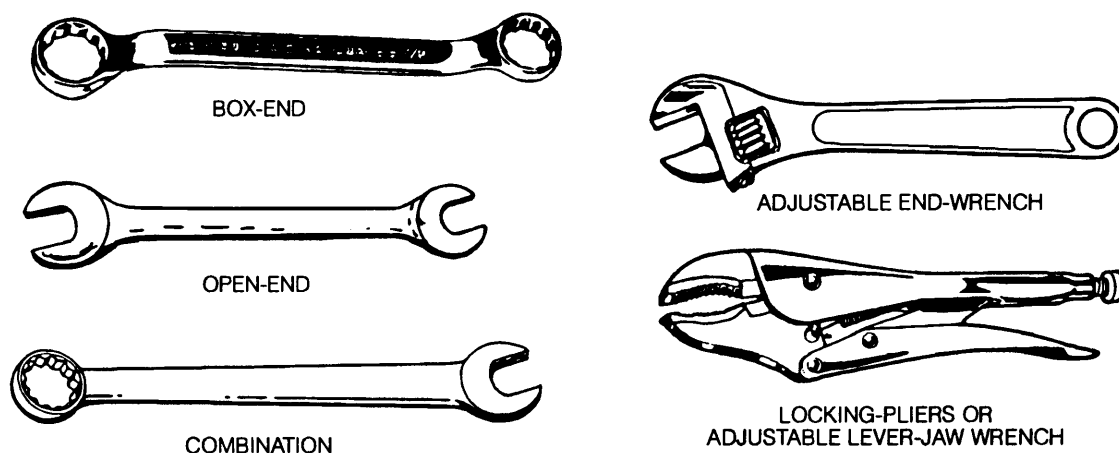
Clamps

Clamps temporarily hold two or more parts together so they can be aligned and fixed in place permanently. C-clamps and screw clamps are two of the more common types of clamps found in the shop. **C-clamps** are used for both metal and wood work. They normally range in size from 3 to 18 inches. **Screw clamps** are more popular for carpentry work. They have broad jaws that are less likely to leave marks on the surface of the wood.



Wrenches

Workers use different types of wrenches to turn nuts and bolts during assembly and to take equipment apart for cleaning and repair. Box-end, open-end, or combination wrenches are commonly used hand tools. **Box-end wrenches** are less likely to slip, because they fit all the way around the nut or bolt head and make contact on each corner. However, this design requires the wrench to be fitted over the nut or bolt.



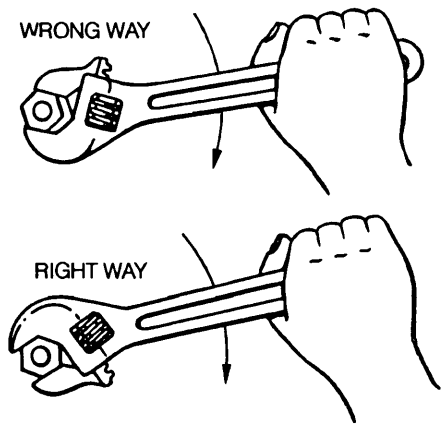
Common Types of Wrenches

Open-end wrenches surround only three-fourths of the nut or bolt head. The jaws of open-end wrenches can spread slightly when excessive force is applied. This increases the chances of the wrench rounding the corners of the nut, slipping off, and causing an accident. However, an advantage of using an open-end wrench is that it can be quickly placed on the bolt or nut from the side.

A **combination wrench** has a "box-end" on one end and an "open-end" on the other. The box-end can be used to first loosen the nut or for final tightening. The open-end can be used for speed and convenience to run the nut up or down the threads. It can also be used when there is not enough room above or below the nut for a socket or box-end wrench.

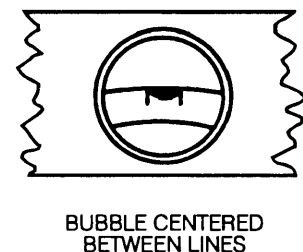
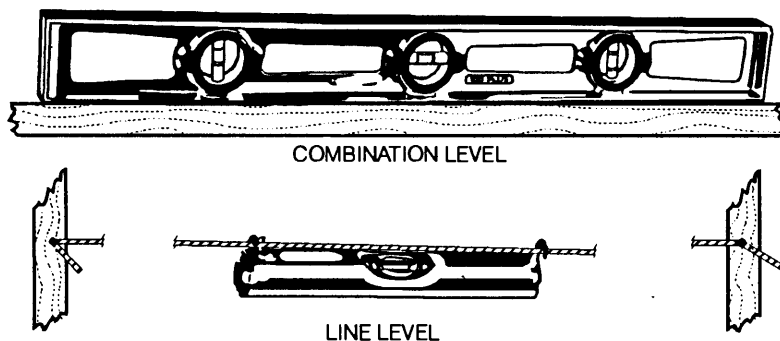
Other common wrenches are the **adjustable end-wrench** and the **adjustable lever-jaw** or **locking-pliers**. Locking-pliers have an adjustable lever that locks the lower jaw in place. Adjustable end wrenches have a movable lower jaw and are often called "crescent wrenches." Locking-pliers are often called "vise-grips." However, both are actually popular brand names of these types of wrenches instead of their common names.

When using an adjustable end-wrench or a pair of locking-pliers, always place the adjustable or movable jaw on the side in the direction you want the nut or bolt to turn. This places the greatest stress on the stationary jaw and reduces the chances of the wrench slipping.



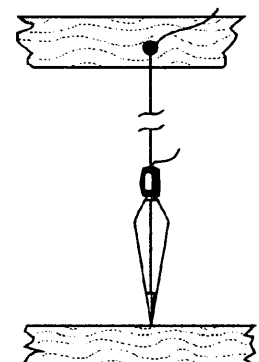
Leveling and Marking Tools

A **combination level** is used to level and plumb walls, fences, concrete forms, and other construction projects. Other names for a combination level are **plumb rule**, **spirit level**, or simply "**level**." Levels range in size from less than 1 foot to over 6 feet in length. A small **line level** attached to a tightly stretched string can be used to level two points that are a further distance apart.



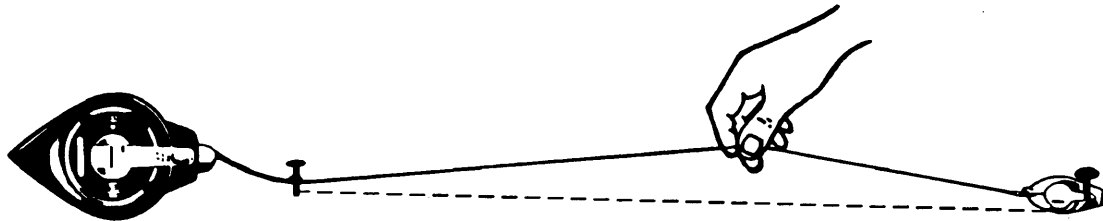
A small bubble floats inside a vial filled with a special liquid. A level may have one or more vials that are calibrated at the factory. The vials may be positioned across, length-wise, or at a 45° angle in the level. When the bubble in the appropriate vial is centered between the two small marks, the *level* is either in the flat level position, the plumb position, or at a 45° angle.

A **plumb bob** is used to find a point directly below another point above it. The sizes of plumb bobs range from 2 to 16 ounces. They are usually made of brass and have sharp steel tips. The plumb bob is suspended by a string from a particular overhead point and hangs down. The sharp tip points to a spot directly below, or *plumb*, to the overhead point.



Plumb bob

There are many different types of marking tools used to mark cuts and layout projects. A **chalk line box** is used to easily and accurately mark a long, straight line between two points. The chalk covered string is stretched tightly across the surface to be marked. The string is then picked up in the middle and allowed to "snap back" into place, leaving a straight chalk mark. Some chalk line boxes can also serve as plumb bobs.



Snapping a Chalk Line

Carpenters often use a square **carpenter's pencil** to make precise marks. This type of pencil can be sharpened at a slight angle, so it will fit flush against the side of a straight edge. Metal is ordinarily marked with a **soap stone** or **silver stick** marker. These are actually a combination of materials which are easy to see on metal. They are heat-resistant so they do not burn off easily with a torch or welder.

Additional information on the selection and safe use of these and other hand tools may be found in IMS student topics #8412 and #8600.

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- Cooper, Elmer L., *Agricultural Mechanics: Fundamentals and Applications*, Delmar Publishers, Inc., Albany, N.Y.
- Phipps, Lloyd J., *Mechanics in Agriculture*, The Interstate Printers and Publishers, Inc., Danville, IL.

Acknowledgements

Mr. Bradley Green, Graduate Assistant, Department of Agricultural Education, Texas A&M University and Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service developed and organized the information for this topic.

SUGGESTED STUDENT ACTIVITIES

TRUE OR FALSE: Circle "T" if the statement is true; circle "F" if the statement is false.

- T F 1. Lower quality hand tools that cost less to purchase are always the best buy over a long period of time.
- T F 2. The size and quality of the grip or handle on hand tools are not major concerns when selecting tools.
- T F 3. A 20-ounce, ripping-claw, plain-faced hammer would be appropriate for rough framing and barn construction.
- T F 4. A rip saw is a type of hand wood saw that is designed to cut with the grain of wood.
- T F 5. When using a hack saw to cut thin materials, select a blade that allows only 1 to 2 teeth to be in contact with the material at a time.
- T F 6. A ratchet type bit brace and expansive bit can normally be used to drill holes in mild steel.
- T F 7. A framing square has tables printed on the tongue and blade and can be used to lay out rafters and braces.
- T F 8. Because a steel tape is made of spring steel, it can be twisted, bent, or kinked backwards without danger of breaking.
- T F 9. Screwdrivers can be safely used as a substitute for chisels, punches, and pry bars.

FILL-IN-THE-BLANK: Place the correct word in the space provided.

- _____ 10. A _____ head is a common cause of injuries while using a cold chisel.
- _____ 11. A _____ chisel is designed to cut metal.
- _____ 12. _____ and _____ pliers are commonly used for cutting stiff wire and for electrical work.
- _____ 13. When using an adjustable end-wrench or a pair of locking-pliers, always place the _____ or _____ jaw on the side in the direction you want the nut or bolt to turn.

SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph. (Use additional paper when needed.)

14. Which type of hammer should be used to drive a cold chisel?
15. What are some of the uses of a wrecking bar?
16. What two types of wood chisels should not be struck with heavy blows from a heavy metal hammer?
17. What is the purpose of the brass slide on a folding extension ruler?

18. What is included on a speed square that makes it handy for laying out rafter ends?
19. List some of the jobs that can be performed with a combination square.
20. What jobs can be performed with an electrician's multi-purpose tool?
21. Why should an open-end wrench or an adjustable end-wrench *not* be used to loosen a tight nut or be used for the final tightening during equipment assembly?
22. Where should the bubble be located in the vial on a "level" if something is level or plumb?
23. Why is soap stone or silver stick commonly used to mark metal?
24. Briefly explain how a chalk line box can be used to mark long, straight lines across building materials.

MATCHING: For each item in the top list, select the best option from the bottom list. After matching a pair, write the letter of the matching option in the space provided.

- _____ 25. a type of screwdriver with four small blades which meet at the end of the tip to form a cross or X pattern.
- _____ 26. a type of screwdriver that has a single flattened end which fits into a straight slot in the screw head.
- _____ 27. a type of screwdriver that has six small blades that form a six-pointed, star-shaped pattern.
- _____ 28. a type of pliers that is used for general grasping and holding of objects.
- _____ 29. a type of pliers that is used for reaching into tight places or handling small objects.
- _____ 30. a type of wood chisel used for heavy cutting or shaping.
 - a. torx head
 - b. long nose or needle nose
 - c. standard blade
 - d. slip-joint or channel-lock
 - e. heavy-duty
 - f. phillips head

ADDITIONAL SKILLS AND ENHANCEMENT ACTIVITIES: Perform the following activities or skills as assigned by your instructor.

1. Visit a local tool or hardware store. Compare the price, quality, and the size of the handle or grip of common types of hand tools.

2. Look through the hand tools in your home shop, tool box, or the school laboratory. See how many hand tools you can recognize. Ask yourself these questions: 1) "Do I know the common name of each tool?" 2) "Do I know what each hand tool should properly be used for?" 3) "Do I know how to safely use each tool?" If the answer is "*No*" for any tool, ask your instructor to demonstrate the proper procedure and/or provide you with the proper owner/operator's instruction manual *before* you attempt to use that tool. Your safety and the safety of others many depend on it.

3. Demonstrate the safe use of hand tools while performing a construction or repair project.

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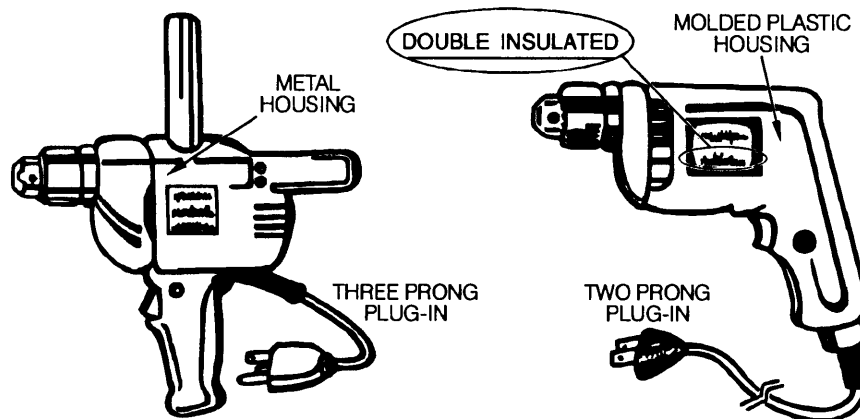
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IDENTIFYING AND SAFELY USING POWER TOOLS

Power tools allow workers to complete jobs faster than they could if they were using only hand tools. Power tools may be "powered" by: 1) electric motors, 2) compressed air (called pneumatic power tools), 3) hydraulic pressure, or 4) small engines. As a general rule, power tools can be more dangerous than hand tools if not used properly. Any time speed and power are involved, the chances for accidents and injury increase. It is the responsibility of the operator to *make sure* he or she completely understands all safe operation and adjustment procedures *before* attempting to use any power tool. Always wear approved eye protection and appropriate clothing when operating any type of power tool.

When using any power tool, remain in as comfortable a working position as possible. Working in an awkward position can cause muscles to cramp. A person can suddenly lose his or her grip or balance. On some power tools, the spring-loaded, on-off trigger switch can be locked in the on-position. *Do not* lock the switch "on" unless specified in the owner/operator's manual. Serious injuries can occur if a person loses control of a power tool while the switch is locked on.

Many new light-duty or consumer models of electrical powered hand tools are equipped with hard plastic housings. Internal electrical parts are insulated or separated from the operator by special insulation.



Heavy-Duty VS Light-Duty Consumer Models

The plastic housing and special insulation provide "double insulation" against accidental shock. Tools with these features are called **double insulated power tools**. Less-expensive, double insulated power tools are usually equipped with only a two-wire power cord and a two-prong plug-in.

Heavy-duty and industrial models of electrical power tools may have a combination of steel, aluminum, and/or plastic housings. All models that have any exposed metal on the housings or handle areas should be equipped with a three-wire grounded power cord and a three-prong grounded plug-in. When properly connected, this equipment safety ground wire provides protection against electrical shock. Some heavy-duty models are equipped with both the double insulation *and* the equipment safety ground wire for additional protection.

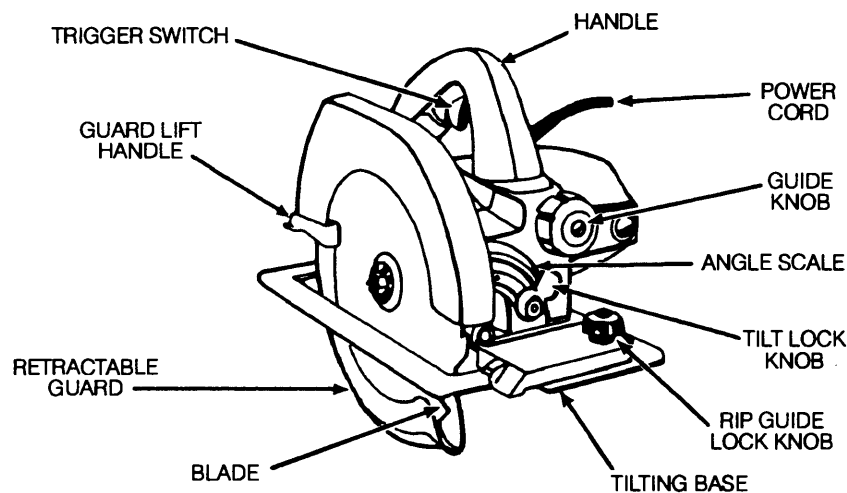
Always make sure electrical power tools used are *either*: clearly marked "double insulated," *or* that they are equipped with a three-wire power chord and three-prong plug-in. *Never* cut the equipment safety ground prong from a three-prong plug-in. *Always* plug a three-prong plug-in into a grounded outlet or use an appropriate adapter. If possible, use circuits equipped with ground fault circuit interrupters (GFCI).

Remember! The first safety rule when operating any power tool is to *always* read and follow instructions listed in the **owner/operator's manual**. Although many power tools may look similar, the specific operating instructions depend upon: 1) the specific brand and model of the tool, 2) the attachments installed, and 3) the type of job being performed.

SAWS

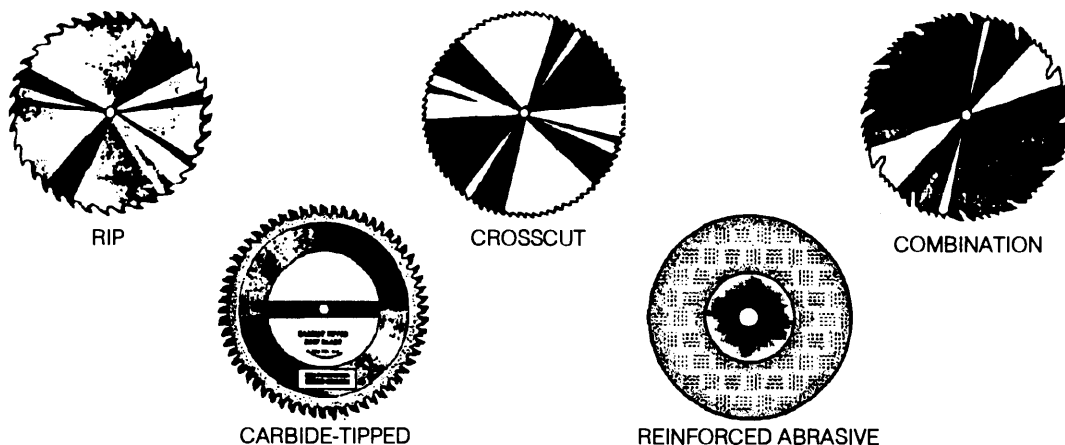
Portable Circular Saw

A **portable circular saw** is one of the most common labor-saving power tools used in wood construction. It can be used for ripping or crosscutting, and for cutting angles and bevels. For many jobs, it is faster and more accurate than a hand saw and less expensive than a large table saw.



Portable Circular Saw

Different types of circular saw blades are used to perform specific types of jobs. **Crosscut blades** make smooth cuts across the grain of the wood. Fine-tooth crosscut blades or special purpose **plywood blades** are used for plywood and wafer board. Large-tooth **rip blades** make smooth cuts with the grain. A **combination blade** will make cuts either with or across the grain of the wood. Some blades are **carbide-tipped**. These blades are more expensive, but will stay sharp longer. They are used to cut hard wood lumber, lumber with hard knots, or used-lumber that may have an occasional nail. **Reinforced abrasive blades** are used to cut soft metals and masonry.

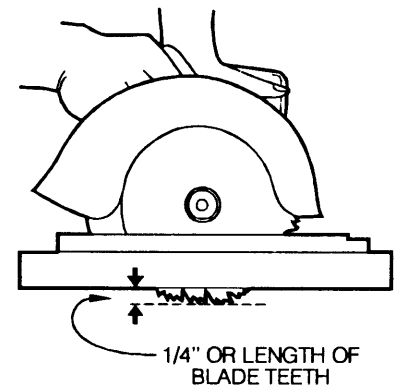


Types of Circular Saw Blades

Proper procedures for using portable circular saws include:

1. Select the correct type of blade. Make sure it is sharp. Install it so the bottom teeth point toward the front of the saw.

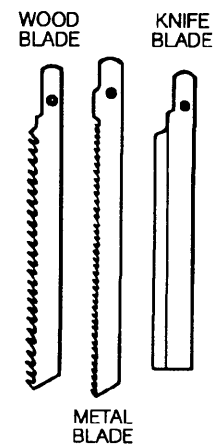
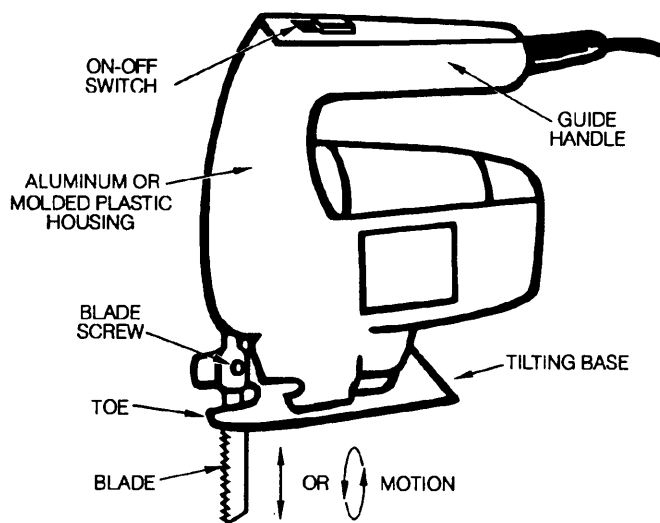
2. Adjust the saw blade cutting depth so that approximately $\frac{1}{4}$ inch or the length of the saw blade teeth extends below the bottom of the material. Make sure the power cord is behind the saw and the saw path is clear of any other objects.
3. Support the material so that it does not bind the blade while sawing. If necessary, place a small wedge in the saw kerf when making long rip cuts to prevent the blade from being pinched.
4. Stand in a safe position and start the saw before it contacts the material being cut.
5. Only saw in a forward direction. Guide the saw in a straight line. Use both hands to guide the saw if needed.
6. At the end of the cut, release the trigger switch and allow the retractable blade guard to cover the blade as the saw is lifted away from the work.
7. *Never* place a hand directly in front of, or behind a saw. The saw could kick back and cause an injury.



Adjust Saw Blade
Cutting Depth

Sabre Saw

Sabre saws are also known as **jig saws** or **bayonet saws**. They cut by rapidly by moving a small narrow blade up and down. Some more expensive models of sabre saws have a slight orbital up and down motion. This motion allows the blade to make a cut on the upward stroke and release the chips on the downward stroke. This reduces blade drag and heat build up. Because of the small narrow blade, a sabre saw can be used to cut small irregular shapes, patterns, and circles.



Sabre or Jig Saw

The sabre saw can cut wood, sheet metal, plastics, fiberglass, leather, and other materials. Some sabre saws have variable speed adjustments which allow smoother cuts in some types of materials. **Knife, metal cutting, and wood cutting** are three common types of sabre saw blades. Knife blades do not have teeth and are used for cutting leather and plastics. Wood cutting blades have 6 to 12 teeth per inch, while metal cutting blades have 16 to 32 teeth per inch.

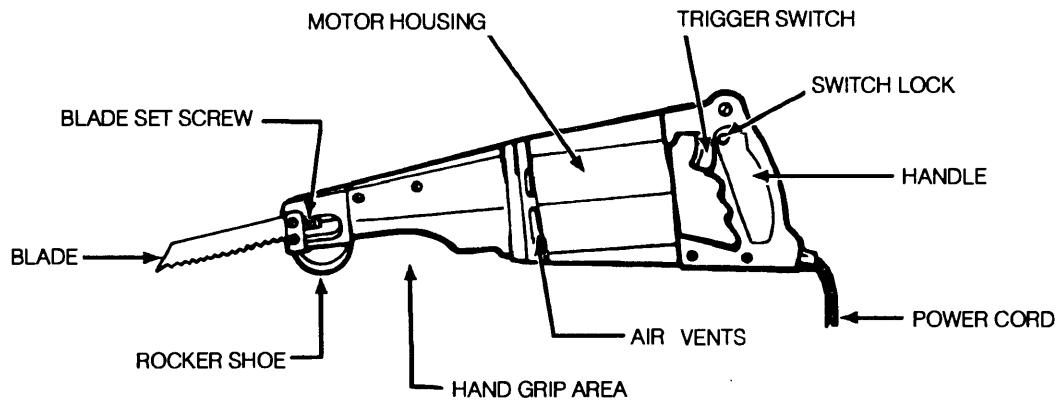
Proper procedures for using a sabre saw include the following:

1. Properly secure the material and firmly grip the saw. The rapid up and down motion creates vibration. The material and the saw will jump around if not properly held.
2. Select the proper type of blade and install it with the teeth facing the front of the saw.
3. Place the front edge of the saw shoe on the material, turn on the switch, and slowly push the blade into the material to be cut.
4. To make a plunge cut, tilt the saw forward on the toe of its base until the blade clears the material. With the motor running at full speed, slowly lower the back of the saw so the blade will smoothly enter into the material. Once the base is fully seated, move the saw forward to cut the material.
5. Do not force the saw to cut too fast. Forcing the saw will break the blade or cause it to overheat and warp.
6. Turn the saw off and remove it from the work once the cut has been completed.

Reciprocating Saw

A **reciprocating saw** is larger and more versatile than the sabre saw. A reciprocating saw may be considered a heavy-duty, all-purpose saw for remodeling, rough-in, or barn construction. It is capable of cutting large timbers, poles, mild steel tubing or angle iron, and/or used-lumber that contains nails.

The blade is attached to the end instead of on the bottom. This makes it easier to cut in different directions in tight locations. Most reciprocating saws have a high speed for cutting wood and other soft materials and a low speed for cutting hard materials. The blades vary in length from 2½ to 18 inches. Wood blades have from 6 to 10 teeth per inch. Metal blades have from 18 to 24 teeth per inch.



Reciprocating Saw

Proper procedures for using a reciprocating saw include the following:

1. Select the proper size and type of blade.
2. Secure the material to be sawed with the finish side down.
3. Grip the saw with *both* hands. Hold the rocker shoe firmly against the material to be cut without allowing the blade to touch.
4. Start the saw and select the proper speed, *then* slowly move the blade into the material.
5. Continue to hold the rocker shoe firmly against the material as the cut is made. Because of its speed and power, a reciprocating saw can jump around if the rocker shoe is not held against the material.
6. Allow the saw to do the work, do not force the cut.

Table Saw

A **table saw** is also called a **bench saw**, or **circular table saw**. It is mainly used for straight-edge cutting, such as ripping and crosscutting. On some table saws, the blade can be tilted to cut bevels. A table saw uses the same types of blades as a portable circular saw. The capacity of the table saw is determined by the maximum diameter blade that can be installed.

The angle of the blade is adjusted with the **tilt handwheel**. The blade angle is read on the **tilt scale**. The blade height is adjusted with the **raising and lowering handwheel**. Adjust the blade height so it is approximately $\frac{1}{4}$ inch or the length of the blade teeth above the top of the material being cut. Make sure that all locking knobs are secure before operating the saw.

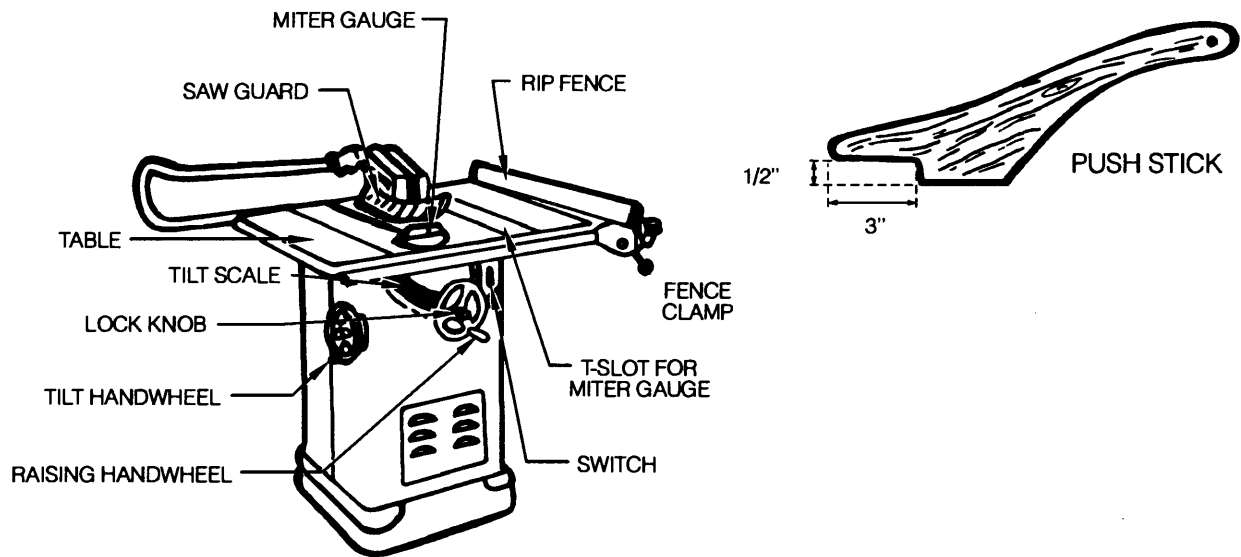


Table Saw

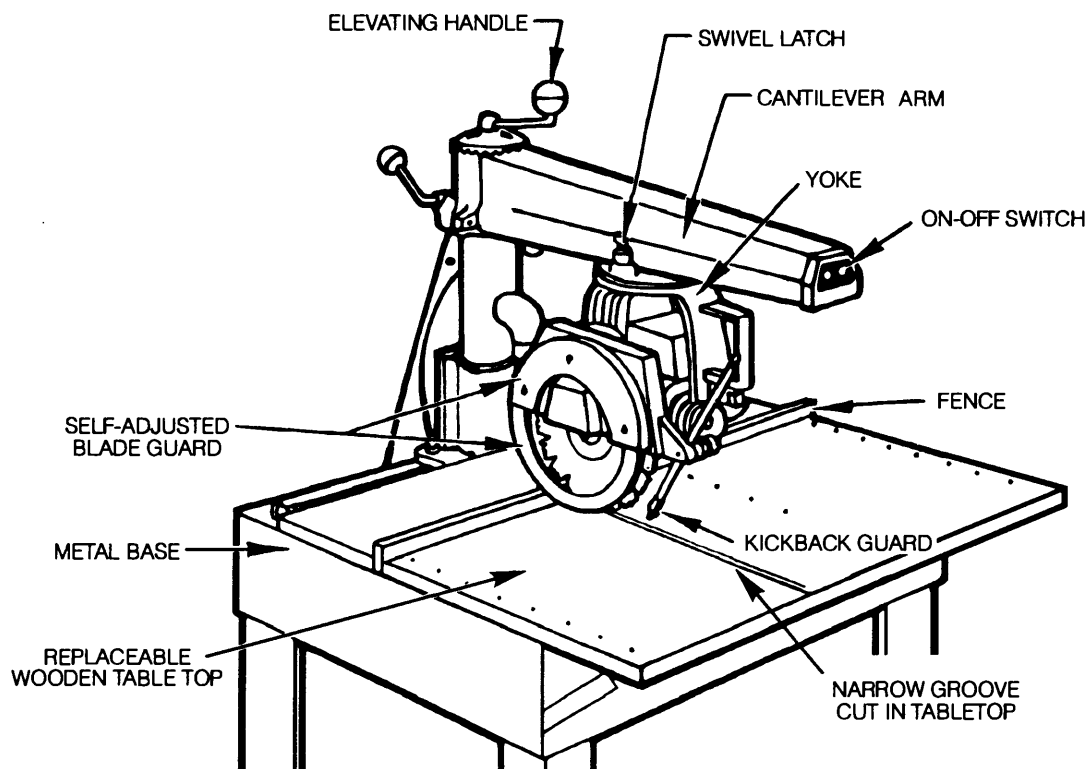
The **rip fence** can be moved back and forth across the table. It serves as a width guide when ripping materials lengthwise. The **miter gauge** is used to determine the angle when making crosscuts. To make a crosscut, remove the rip fence. Set the desired angle on the miter gauge. Hold the material against the front of the **miter gauge** with one hand. Use the other hand to push the miter gauge which then pushes the material across the table into the blade. *Do not* use the rip fence and the miter gauge at the same time when crosscutting. Material may get wedged between the fence and the blade and be kicked back with enough force to cause serious injury.

Keep both hands away for the rotating blade. Never saw small pieces of material "freehand." *Always* use either the rip fence or the miter gauge as a guide. Most table saws will be equipped with guard that covers the saw blade. It will ride up and over the material as it is pushed across the table.

Get someone to assist you when ripping or cross cutting material that is longer or wider than the saw table top. Use **push sticks** when ripping small, narrow pieces of material. If a small piece of material is left on the table top after a cut, *always* allow the blade to stop *before* reaching to pick it up.

Radial Arm Saw

A **radial arm saw** is a very versatile saw. It has the **motor** and **blade** suspended on a movable **cantilever arm** over a **cutting table**. The cutting table is covered with a replaceable wooden cover. The radial arm saw performs many of the same jobs as a table saw such as: ripping, crosscutting, mitering, beveling, and dadoing. For most work, the material remains stationary on the table top. The saw itself rolls back and forth from above on the cantilever arm. The motor is adjusted up or down by the **elevating handle** so that the blade cuts through the material and slightly into the wooden table top. The cantilever arm can be moved from side to side to make miter cuts. The motor can be turned at an angle in the **yoke** to make bevel-crosscuts. **Blade guards** are installed to help prevent the operator from accidentally touching a rotating blade.



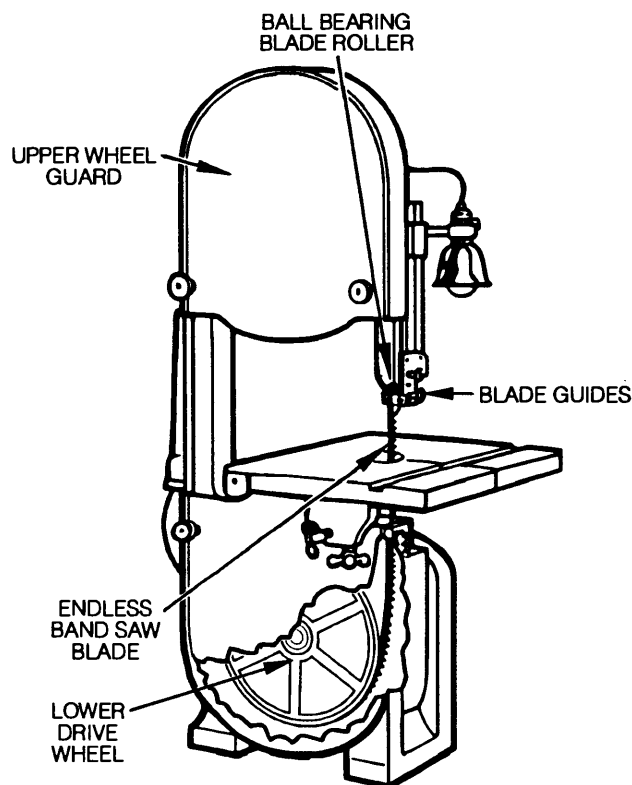
Radial Arm Saw

To make crosscuts, the material is held against the **fence** with one hand. The motor and blade are slowly pulled across the material with the other. After the cut is made, the saw *should be immediately* returned to the back of the cantilever arm *behind* the fence. The motor should then be turned off *before* the material is removed. Because the blade is attached directly to the motor, it can "free wheel" for a minute or longer. Some radial arm saws can be equipped with safety kits that will immediately stop the blade rotation when the motor switch is turned off.

To make rip-cuts, the motor is turned at the yoke so that the saw blade is parallel to the fence. The motor is locked into position to maintain the desired ripping width. When rip-cuts are made, **anti-kickback fingers** and **blade guards** *must be* installed. Material is *slowly* fed into the saw from the side where the blade teeth are on the **up-cut**. *Do not* feed the material from the wrong side where the blade teeth are cutting down. The rotating blade may suddenly grab the material, jerk it under, and throw it out of the other side. For convenience and safety, extensions are often built onto each side of the table for crosscutting or ripping long pieces of material.

Band Saws

Vertical band saws are usually designed to cut wood and other soft materials. **Horizontal band saws** are usually designed for hard materials such as steel. A band saw cuts with an **endless steel band or blade** with small hardened teeth along one edge.

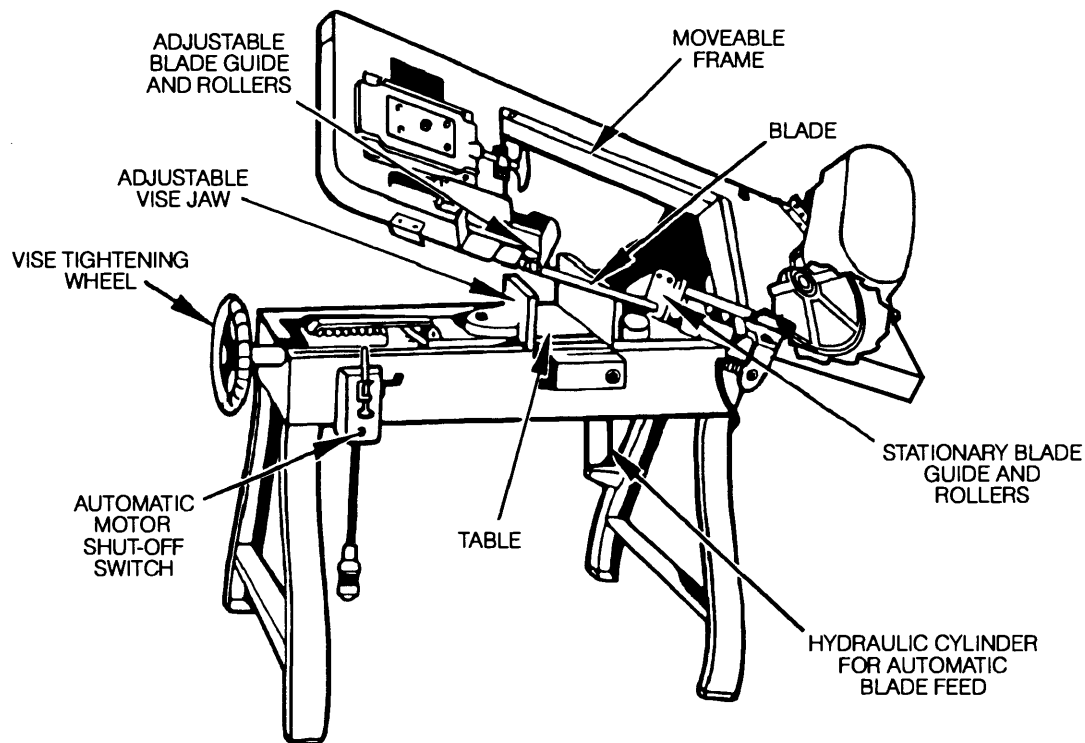


Vertical Band Saw for Wood

The narrow blade rotates continuously around two large wheels. The material must be fed into the rotating blade slowly and gently. Band saws are equipped with **blade rollers and guides**. These guides and rollers stabilize the blade to keep it from twisting and breaking. They should be adjusted as close to the material being cut as possible.

Band saw blades for wood have four to seven teeth per inch and run at a high rate of speed. A vertical band saw can be used to cut freehand shapes, curves, or circles in wood. The width of the band blade determines how sharp a curve or radius can be cut. Straight cuts can also be made if the saw table is equipped with a ripping fence or miter gauge. *Always* keep fingers at least two inches away from the rotating blade when using a band saw.

The blade used on a horizontal metal band saw normally has 10 to 24 teeth per inch and rotates much slower. On most horizontal band saw models, the blade wheels are mounted on a moveable frame. The metal being sawed is firmly clamped into position under the frame. The frame is slowly lowered either manually or automatically to feed the rotating blade into the metal. If the metal being sawed is allowed to move, or if the frame is lowered too fast, the blade may bind and break.

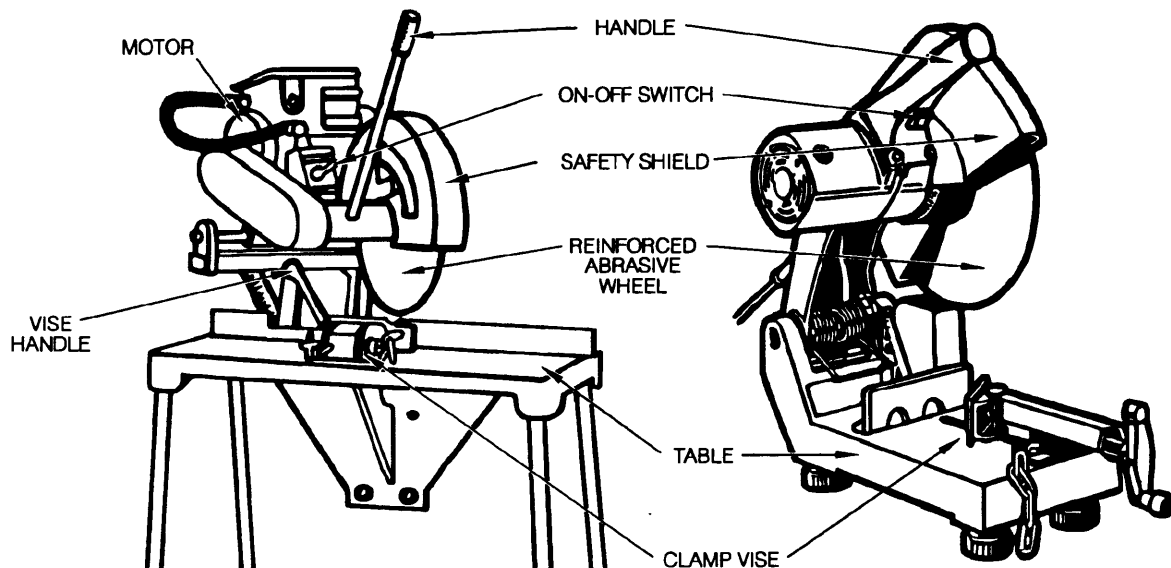


Dry Cut Horizontal Band Saw for Metal

Some metal band saws are equipped with a small pump and reservoir that recirculates a water-soluble oil onto the blade. The oil cools and lubricates the blade while cutting hard metals.

Abrasive Cutoff Saw

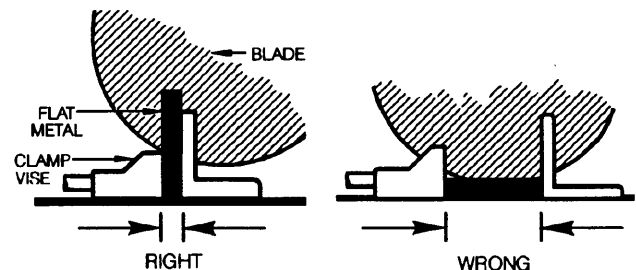
An **abrasive cutoff saw** is used to cut metal with a high-speed revolving abrasive wheel. The **abrasive wheel** is a thin grinding disk reinforced with fibers to help prevent it from shattering while in use. The abrasive wheel actually cuts by grinding away a narrow strip of metal. Use extreme caution when using an abrasive cutoff saw. The sparks can easily set flammable materials on fire. The operator should wear long-sleeved protective clothing, gloves, and a face shield at all times. Make sure the metal is firmly clamped in the vise and that the ends of long pieces are properly supported *before* starting the saw. When operating a cutoff saw, the blade should reach full speed before it is lowered into the metal. Apply steady, even pressure while cutting.



Portable and Stationary Models of Abrasive Cutoff Saws

Metal should be positioned in the saw vise so that there is a minimum of contact with the blade at any one-time. The more metal in contact with the blade during the sawing operation, the more heat buildup. The more heat, the slower the blade will cut, and faster the blade will wear away.

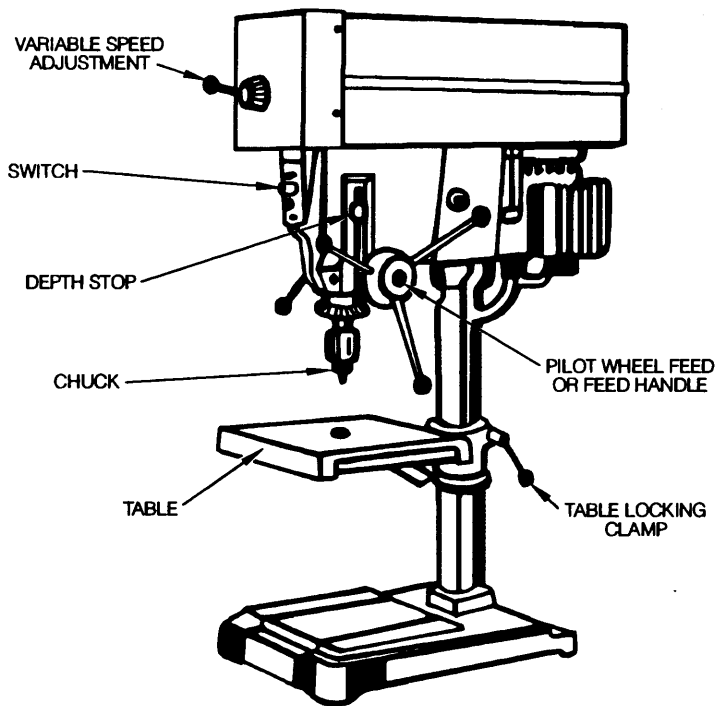
Always keep all safety shields installed and *stand to one side of the blade* during operation. The blade can break very easily if it is pinched or the metal is allowed to move. Because of the high speed rotation, broken blade parts, sparks, or abrasive grit can fly off and cause serious injuries.



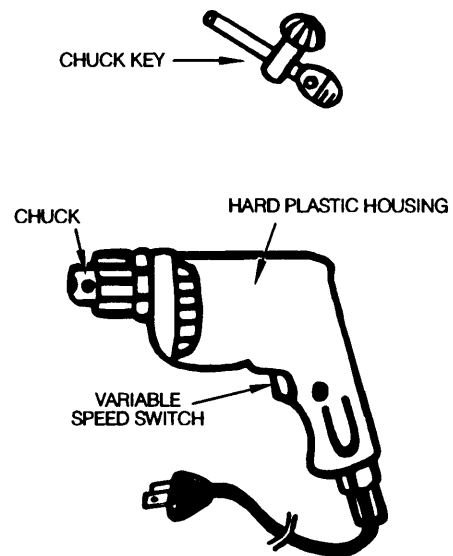
DRILLS

Portable Drill

Portable drills are used to drill holes in metal, wood, plastics, and other materials. The size of portable drills is determined by: 1) the largest diameter drill bit shank that can be inserted in the **chuck** and 2) the power of the motor. The three most common electric drill sizes have 1/4, 3/8, or 1/2 inch capacity chucks. Normally, the larger the drill chuck size, the more powerful the motor. Some portable drills are equipped with variable speed and/or reversible motors.



Drill Press



3/8" Portable Drill
(Double Insulated)

Drill Press

A **drill press** can be used to drill precise holes in materials that are supported by or clamped to the **adjustable table top**. The chuck is raised and lowered, and pressure applied to the drill bit by turning the **pilot wheel** (also called the **feed handle**). Most drill presses have a 1/2 inch chuck and some type of variable speed adjustment. The lower speeds are for drilling in metal, while the higher speed are for drilling wood. As a general rule, the larger the diameter of the hole to be drilled and the harder the material, the slower the drill bit should turn.

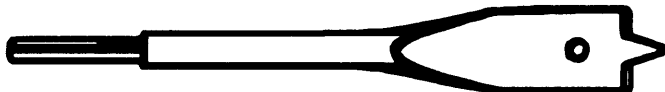
Bits for electric drills come in many different shapes and sizes. The shank of most bits are either round or hex shaped so they can be clamped in the drill chuck. Special spur-tip **wood twist drills** are commonly used to drill precision holes in wood or other soft materials. **Spade bits** are less expensive and are also used to drill holes in wood and other soft materials. **High speed twist drills** can be used for boring holes in wood, metal, or other hard materials. Larger holes may be drilled with a **hole saw**. This type of bit uses a small twist drill for a center pilot hole with interchangeable, round saw blades to cut the larger outside hole. **Carbide-tipped drill bits** are used for drilling into masonry and ceramics. Other types of special purpose bits, reamers, sanding pads, etc can also be used with portable drills and drill presses.



HIGH-SPEED TWIST DRILL



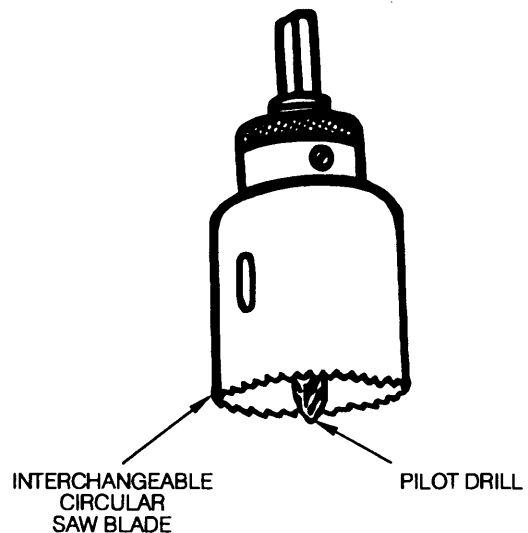
CARBIDE-TIPPED MASONRY BIT



SPADE BIT



SPUR-TIP WOOD TWIST DRILL



Hole Saw

Common Types of Drill Bits

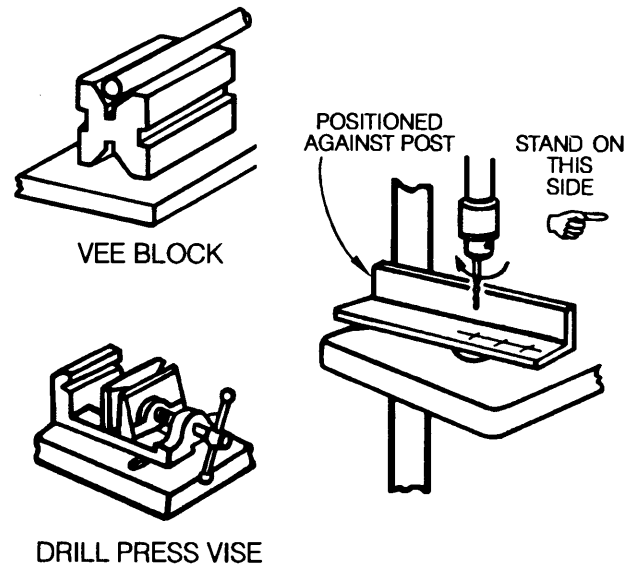
A **chuck key** is used to tighten or loosen the jaws of the chuck. To securely tighten a chuck, insert the chuck key in at least two of the three holes and twist the key as firmly as possible. The extra effort of tightening in two or three places instead of just one will help prevent the bit from spinning in the chuck and damaging the shank.

Use a center punch or scratch awl to make a small impression at the center of the hole to be drilled. The impression will help keep the bit point from "crawling" when drilling is first started. When drilling wood, a backup board can be placed under the hole location. This will prevent the point of the bit from splintering the wood as it breaks through the hole.

When using any drill, apply smooth, even pressure to bore the hole. It may be necessary to occasionally lift the bit out of the hole to clear it of chips and shavings. Cutting oil should be used to cool and lubricate the bit when drilling hard metal. It will lengthen the life of the bit and improve the finish of the hole.

When boring large holes in hard metal or materials with high speed twist drills, a small pilot hole should first be drilled. The pilot hole should be 1/3 to 1/2 the diameter of the finished hole size.

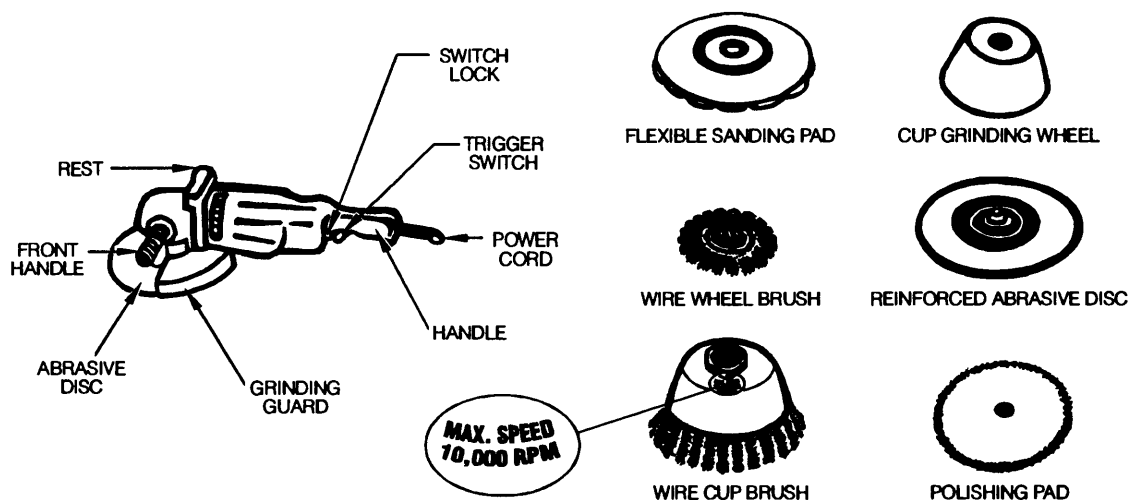
Always use proper holding devices. Secure all small and odd-shaped objects with a **clamp** or **vise**. A **Vee block** can be used to hold round stock. Larger objects should be supported and positioned against the **column** or **post** of the drill press. *Always* stand to the right side of the object being drilled. Reduce pressure on the drill just as the bit penetrates the bottom side of the material to help prevent it from binding. If a bit seizes or binds, it can: 1) break, 2) cause a portable drill to suddenly turn in the operator's hand, and/or 3) cause the material being drilled to start spinning if it is not properly secured.



GRINDERS

Portable Sander-Grinder

Various types and sizes of **portable sander-grinders** are used to clean, smooth, or shape wood, metal, and other materials. Portable sander-grinders are also known as "right angle sander-grinders." They range in size from compact, high-speed models that operate at 10,000 RPM, to large, heavy-duty models that operate at 5,000 RPM or less.



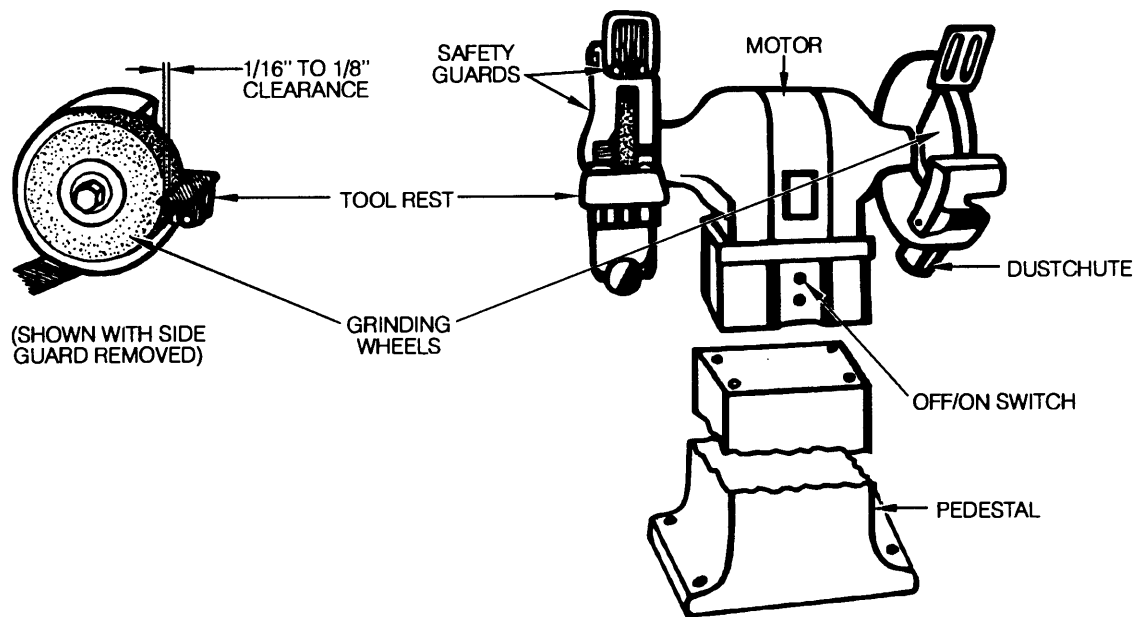
Portable Sander-Grinder and Different Attachments

Portable sander-grinders are also classified by the diameter of the attachments that can be installed. Normally, the faster the operating speed, the smaller the diameter of the attachments that should be installed. Attachments include: 1) flexible sanding pads, 2) wire wheel brushes, 3) wire cup brushes, 4) cup grinding wheels, 5) flat reinforced abrasive discs, and 6) buffing and polishing pads.

Stationary Grinder

A common purpose for stationary grinders is to sharpen the cutting edges used on other shop tools and equipment. However, they can also be used to clean and shape other types of metal parts. Stationary grinders attached to the top of work benches are commonly called "bench grinders." Some models can be mounted to stands attached to the floor and are called "pedestal grinders." Most stationary grinders have output shafts on each end of the motor. This allows grinding wheels or wire brush attachments to be mounted on each end.

Each size and type of grinding wheel, brush or other attachment is designed for a maximum, safe operating speed. The maximum RPM rating should be permanently marked on each attachment. **For example:** Most buffing and polishing pads for portable sander-grinders are designed to operate at 3,600 RPM or less. If low-speed attachments are installed on high-speed portable grinder-sanders, they may break, fly apart, and cause serious injury or damage. *Always* consult the owner/operator's manual to determine the size, type, and speed ratings of attachments that can be used. *Also, make sure* the proper guards are installed.



Stationary Grinder

The abrasive material used in grinding wheels, sanding pads, etc is often called **grit**. The degree of coarseness is indicated by a **grit number**. This corresponds to the approximate size and number of grit particles per linear inch. A higher grit number indicates smaller grit particles, while a lower grit number indicates coarser grit particles.

The lower the grit number (the coarser the grit), the faster the grinder wheel or sanding pad will "grind" or remove material. Also, the coarser the grit, the rougher the finish. A 60-grit grinding wheel is commonly used for general purpose grinding and tool sharpening.

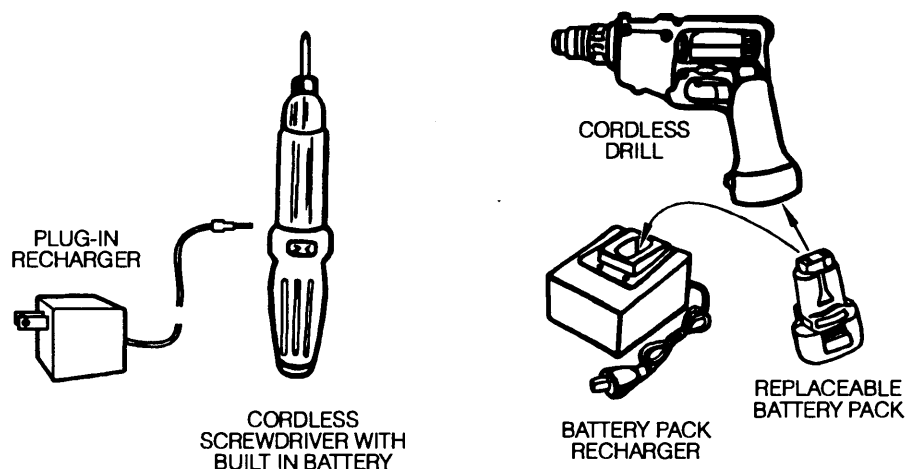
Do not use excessive pressure when sanding or grinding. The speed in which material is removed or "ground away" is determined by the size of the grit and the operating speed, *not* the pressure applied.

When using a portable grinder-sander, secure small objects with a clamp or vise. *Always* grip portable sander-grinders with both hands. *Never* use a grinding wheel or other attachment that you suspect is cracked or broken, or that causes excessive vibration. *Always* adjust the **tool rest** on stationary grinders so there is only 1/16 to 1/8 inch clearance from the face to the grinding wheel. When using a bench or pedestal grinder, *never* grind on the side of the grinding wheel. Side pressure on this type of grinding wheel could cause it to break and fly apart.

Always wear gloves, protective clothing, and a face shield when using any grinder. Pieces of the abrasive material, sparks, broken brush wires, metal, or other materials are thrown off by grinders. These flying particles can cause serious eye and skin injuries. *Never* use grinder wheels or discs that have worn to less than $\frac{1}{2}$ of their original diameter. *Do not* grind around highly combustible materials or discharge sparks toward others. *Never* use a grinding wheel or other attachment that you suspect is cracked or that causes excessive vibrations.

CORDLESS POWER TOOLS

The use of **cordless power tools** is increasing. Engineers have designed more powerful electric motors and **rechargeable nickel-cadmium batteries**. Cordless screwdrivers, drills, portable circular saws, jigsaws, power rackets, and other small power hand tools are now available. Depending upon the type and size of the power tool, **rechargeable battery packs** range in size from 2.4 to 24 volts. On some cordless power tools, the battery pack is permanently installed in the handle or body. To recharge, a power cord from the **battery charger** is plugged into the tool, or the complete tool is placed on the charger stand.



Other models are equipped with a replaceable battery pack that is inserted into the tool handle during operation. When not in use, the battery pack is removed and inserted into a separate charger/storage stand. This allows a person to purchase multiple battery packs. One battery pack can be used while others are being recharged.

It is recommended that the battery pack be completely "*run down*" the first time it is used. The battery pack should then be *completely* recharged *before* reusing.

Note! Most rechargeable battery packs cannot ever be fully recharged if used after receiving only a partial recharge. Do not interchange battery packs and chargers without making sure they are compatible. Different chargers have different voltages and charging rates. Using the wrong charger could cause the battery pack to explode causing serious injury. If a battery pack should leak liquid, neutralize it with lemon juice or vinegar. Wash skin immediately with soap and water. *Always* refer to the owner/operator's manual for specific operating and recharging procedures.

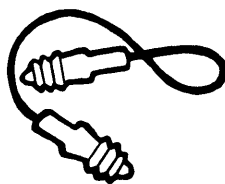
HEARING PROTECTION

High noise levels in agricultural mechanics laboratories and construction sites are a growing concern. The Occupational Safety and Health Act (OSHA) requires hearing protection be worn when working around noises that average over: 90 decibels (dB) throughout an 8-hour working day; 95 dB for 4 hours; 100 dB for 2 hours; or when peak noise levels reach 115 dB for 15 minutes. A **decibel** is a standard unit of noise measurement and can be easily measured with a decibel meter.

Many hand and power tools produce noises at or above these levels. Because they may not be used continuously, the average noise level is usually below present OSHA standards. **For example:** A portable sander/grinder or a metal cutoff saw can produce peak noise levels over 110 decibels. However, they are normally used for only a couple of minutes at a time. Some research has shown permanent ear damage can result even when sudden peak noise levels near 115 dB occur for only short periods of time.



FOAM EARPLUGS



RUBBER EARPLUGS



HEARING PROTECTION
EAR MUFFS

Most industrial quality **earplugs** and **earmuffs** have a noise reduction rating of between 20 to 30 dB. If you are working in an area where the average noise level is 100 dB, a pair of ear plugs properly worn can lower the noise entering the ear canal to approximately 75 dB.

It is strongly recommended that personal ear protection devices be worn when working around noisy hand and power tools. However, *do not* reduce hearing to the point where you can not safely communicate with others working around you *or* hear the tools you are operating. Part of the safe operation of tools and equipment is to monitor variations in the normal noises they make.

As previously discussed, *always* receive proper instruction and/or read and understand the owner/operator's manual *before* operating any power tool. Be sure to disconnect power tools and equipment from their power sources *before* changing any blades or bits, or making any adjustments. Additional information concerning the safe operation and use of power tools is provided in IMS student topic # 8601-A and in other student topics that deal with specific skill areas.

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Wakeman, T.J., "Modern Agricultural Mechanics", The Interstate Printers & Publishers, Inc., Danville, IL.

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Power Tool Safety and Operation, Hobar Publications, St. Paul, MN.

Cooper, Elmer L., *Agricultural Mechanics: Fundamental and Applications*, Delmar Publishers Inc., Albany NY.

Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, and Mr. Bradley Green, Graduate Assistant, Department of Agricultural Education, Texas A&M University developed and organized the information for this topic.

SUGGESTED STUDENT ACTIVITIES

TRUE OR FALSE: Circle "T" if the statement is true; circle "F" if the statement is false.

- T F 1. A reciprocating saw uses a rotating band or blade to cut wood or metal.
- T F 2. A person operating an electric power tool equipped with a spring-loaded On-Off switch *should always* lock it in the "On" position.
- T F 3. Carbide tipped circular saw blades are less expensive blades designed for cutting soft wood.
- T F 4. A rip fence on a table saw serves as a width gauge when ripping material.
- T F 5. It is a safe practice to "freehand saw" materials with a table saw.

- T F 6. A high speed twist drill would be appropriate for drilling holes in masonry or ceramics.
- T F 7. It is usually OK to partially recharge the batteries for cordless power tools if you are in a hurry to get back to work.
- T F 8. Because most power tools that produce noise levels over 90 decibels are normally used for only a few minutes at a time, there is no need to be concerned about wearing earplugs or earmuffs.
- T F 9. The more pressure applied against an abrasive grinding wheel or disc, the faster it will grind away material.

SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph. (Use additional paper.)

10. What is the first safety rule to remember and practice when operating power tools?
11. When using a portable circle saw, how far below the bottom of the material should the blade cutting depth be adjusted?
12. What is the purpose of blade rollers and guides on vertical and horizontal band saws?
13. After a crosscut is made with a radial arm saw, what are the first two things that should be done?
14. Explain how wood should be fed into the saw blade when using a radial arm saw to make rip-cuts.
15. Explain why it is important to properly position and secure metal when using an abrasive cutoff saw.

ADDITIONAL SKILLS & ENHANCEMENT ACTIVITIES: Perform the following activities or skills as assigned by your instructor.

1. Complete the Agricultural Mechanics Power Tools Safety Test #8108 for those tools on which you have received training. Discuss the safe operating procedures and uses for each of the power tools in the shop.
2. Demonstrate the safe use of power tools while completing construction projects.

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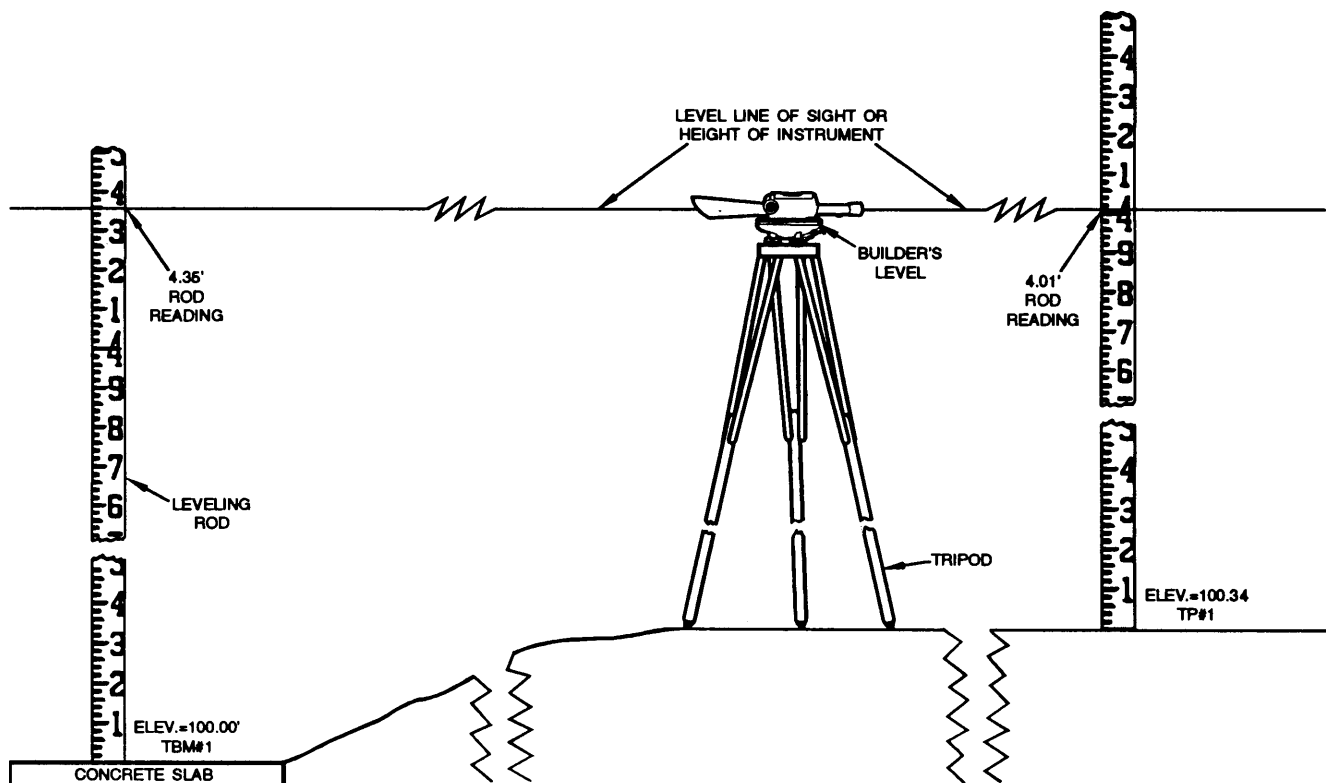
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College Station, Texas 77843-2588

N1992

USING THE FARM OR BUILDER'S LEVEL

Common uses of leveling equipment include determining elevation changes in land surfaces, determining the height of one object or point in comparison to another, and setting up and leveling batter boards or concrete forms. Some leveling equipment can also be used to measure angles in horizontal and vertical planes. Most leveling instruments operate on the basic principle that a **line of sight** is a straight line that neither dips, sags, nor curves. Any point along a **level line of sight** will be the same height as any other point. The line of sight can be used as a reference line to determine the difference in elevation of points that fall directly above or below it.



Using a Level Line of Sight to Determine the Difference in Elevation

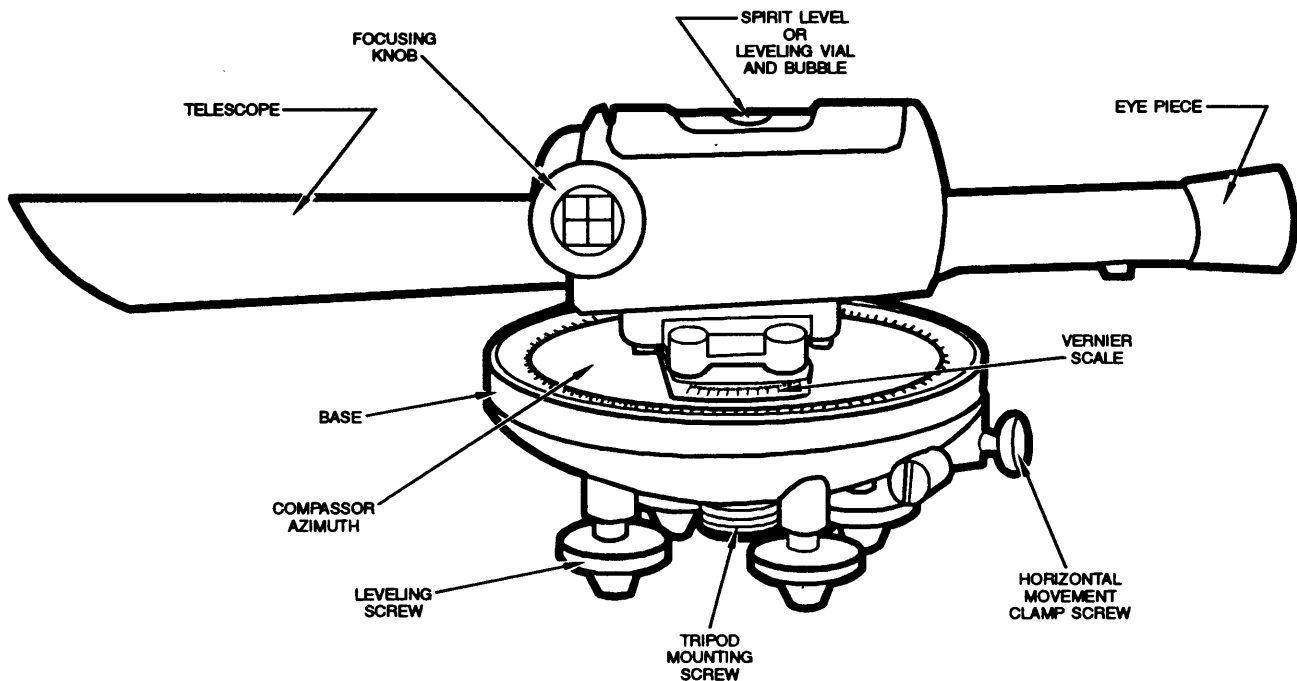
LEVELING INSTRUMENTS

For general discussion, there are three basic types of leveling instruments commonly used in agricultural applications: 1) builder's level, 2) level-transit, and 3) laser beam levels.

Builder's Level

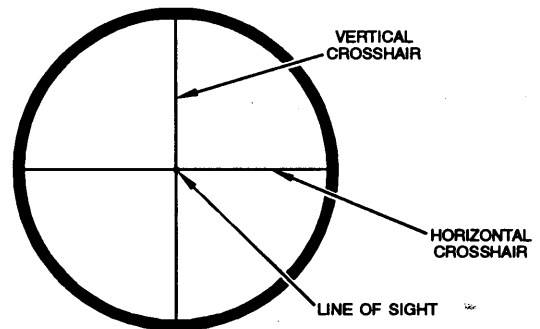
A **builder's level** is used to sight level lines and to lay out or measure angles only in the horizontal plane. The **telescope** is designed to rotate on a **base**. An **azimuth** or **compass** is built into the base. The azimuth is graduated into 360°. Any angle in a horizontal plane can be laid out or measured using the azimuth.

On more expensive models of builder's levels and level-transits, the azimuth is equipped with a **vernier scale**. The vernier scale is used to further divide each degree into smaller fractions for more accurate measurements. For additional information concerning the vernier scale, see student topic # 8234-A.



Builder's Level

When sighting through the telescope, the **focusing knob** is adjusted until the image is clear. The exact **height of the instrument** or the "line of sight" is indicated by the **cross hairs**. The vertical cross hair indicates direction while the horizontal cross hair indicates the flat plane. Where they cross is the line of sight. Most builder's levels and level-transits are equipped with a 20X power telescope. This means the object will appear twenty times closer than it actually is.

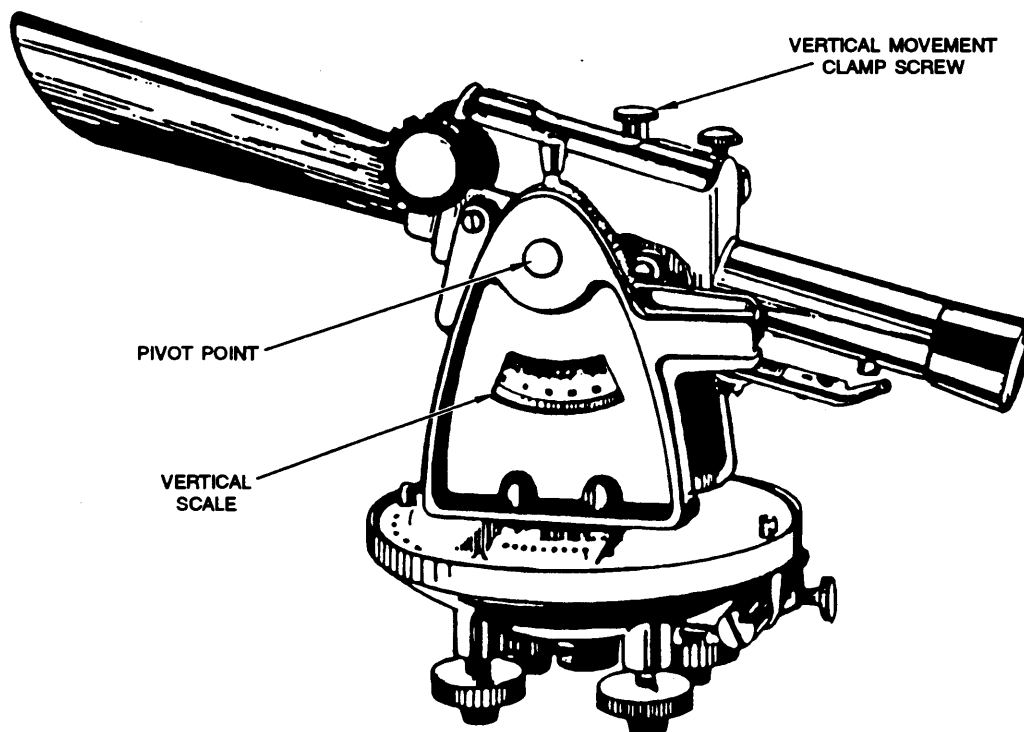


Sighting Through the
Telescope

A **farm level** is generally considered a less expensive model of a builder's level. It is easy to operate and is generally accurate enough for most leveling and layout work in farm or agricultural applications.

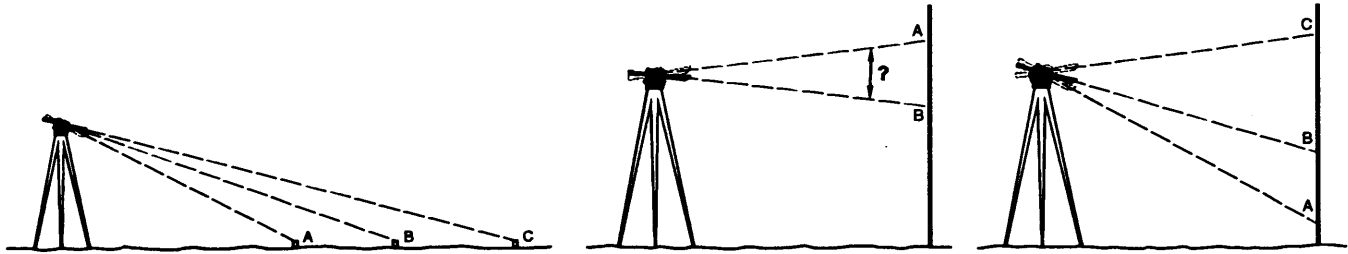
Level-Transit

As well as the functions of horizontal layout and leveling, a **level-transit** can be used to lay out vertical lines. In addition to the horizontal rotation, the level-transit is designed so that the telescope will pivot up and down.



Level-Transit

The level-transit is equipped with a **vertical scale** to measure vertical angles. When the vertical scale is on 0° , the telescope is in the level position. With the vertical scale at 0° and the **vertical movement clamp** locked, the instrument can be turned on its horizontal plane and used similarly to a builder's level.



Using a Level-Transit to Align Stakes, Lay Out Vertical Points,
and Check Vertical Angles

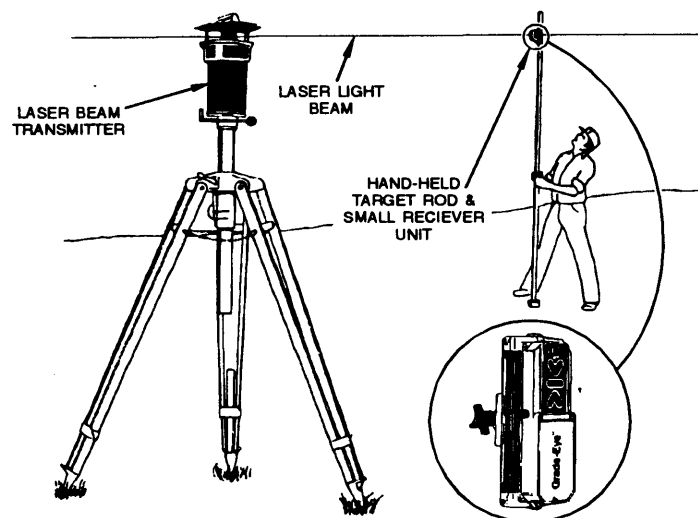
However, when the horizontal rotation clamp is locked and the vertical movement clamp is loose, the telescope can be pivoted up or down. The level-transit can then be used to plumb vertical lines and to lay out stakes in a row, especially when they vary in height.

Laser Beam Level

Modern technology has brought about the use of **laser beam levels** in agricultural leveling and surveying operations. A tripod is positioned in a safe and convenient location at the job site. An **electronic laser level transmitter unit** is attached to the tripod and the base leveled.

A rotating prism within the transmitter emits a very thin beam of **laser light**. **Note!** The intensity of the laser light beam used is not high enough to be harmful to humans or animals. The

prism rotates at approximately 600 RPM to give a contact grade reference or level horizontal plane over the job site. The laser light beam is usually invisible to the naked eye except at night or under very dark conditions.



Electronic Laser Level Transmitter and
Receiver Unit

The **receiver unit** consists of several light sensitive electronic sensors. The light sensors are connected to a small microprocessor which is connected to audible alarms and/or signal lights. The small receiver unit is usually attached to a conventional target rod.

The receiver unit is then raised or lowered on the rod until a sensor is activated. This indicates the sensor is at the same height as the laser light beam being projected over the job site. If a top sensor is activated, it would signal that the receiver needs to be raised slightly. If a lower sensor is activated, a signal would indicate that the receiver unit needs to be lowered slightly. When the laser light beam activates the middle sensor, it sets off another audible alarm and/or a signal light indicating the receiver unit is "on the same grade" and the rod reading can be taken.

Most new laser transmitter and receiver units are accurate to ± 0.01 foot within a 1,000-foot radius around the transmitter. A major advantage of using a laser beam leveling system is that only one person is needed. Once the transmitter is set up and leveled, it can be left unattended to provide a constant grade reference.

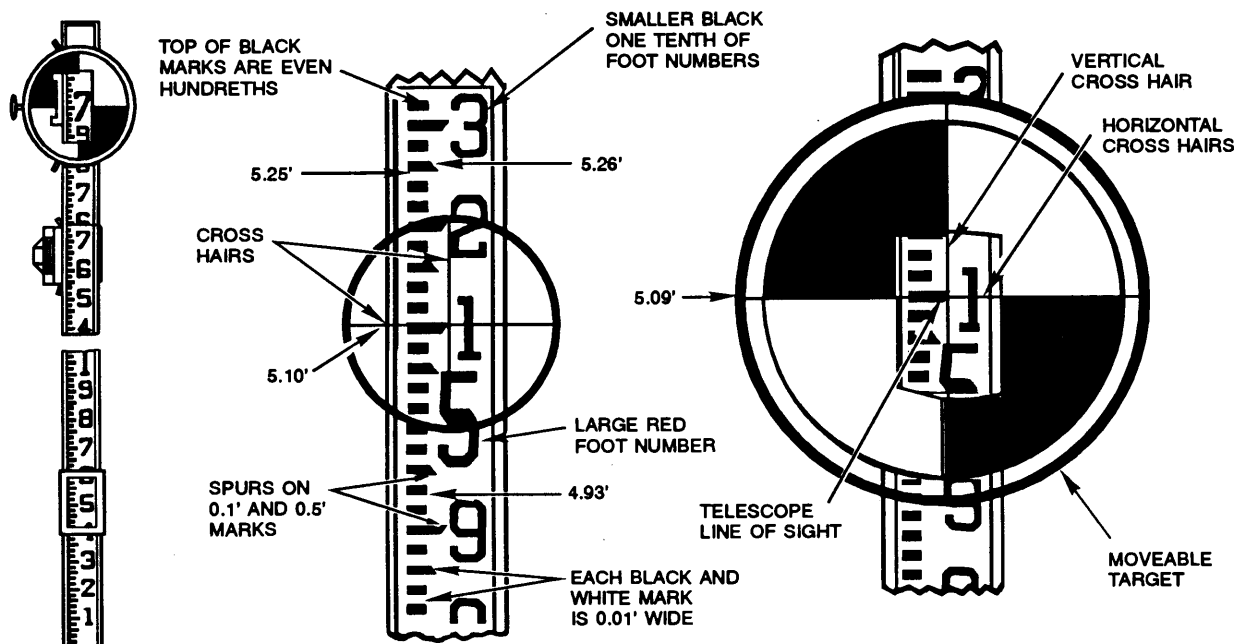
Some of the more expensive models of builder's levels, level-transits, and laser beam levels are now equipped with self-leveling bases. Other models of the laser beam levels can also be adjusted to produce a sloping plane if desired. Leveling instruments and equipment are very delicate and must be handled with extreme care. The specific operating procedures will vary with different brands and models. Always read and study the instructions carefully.

LEVELING ROD

The **leveling rod** is used with the leveling instrument to take vertical measurements. The measurements are used to determine the elevation of a point or to compare the heights of objects in their relationship to the height of the leveling instrument.

One of the most popular types of leveling rods is the **Philadelphia Rod**. It is a combination self-reading and target rod. A **self-reading** rod means that for most work, the graduations on the rod can be read through the telescope and recorded by the instrument person.

The rod is painted with alternating white and black spaces each 0.01' wide. The top of the black lines are even 100ths of a foot. The 0.1' and 0.05' graduations are further marked by spurs extending from the black marks. The tenths of a foot marks are also usually designated with black numbers while the foot marks are designated with red numbers.



Reading a Leveling Rod

The Philadelphia Rod can also be equipped with a circular shaped target. Alternating quadrants of the target are painted different colors. The **target rod** is used for long-distance work when the instrument person is unable to read the number through the telescope. The instrument person signals to the rod person to raise or lower a target until the cross hairs and the target marks are aligned. The rod person then takes and records the readings.

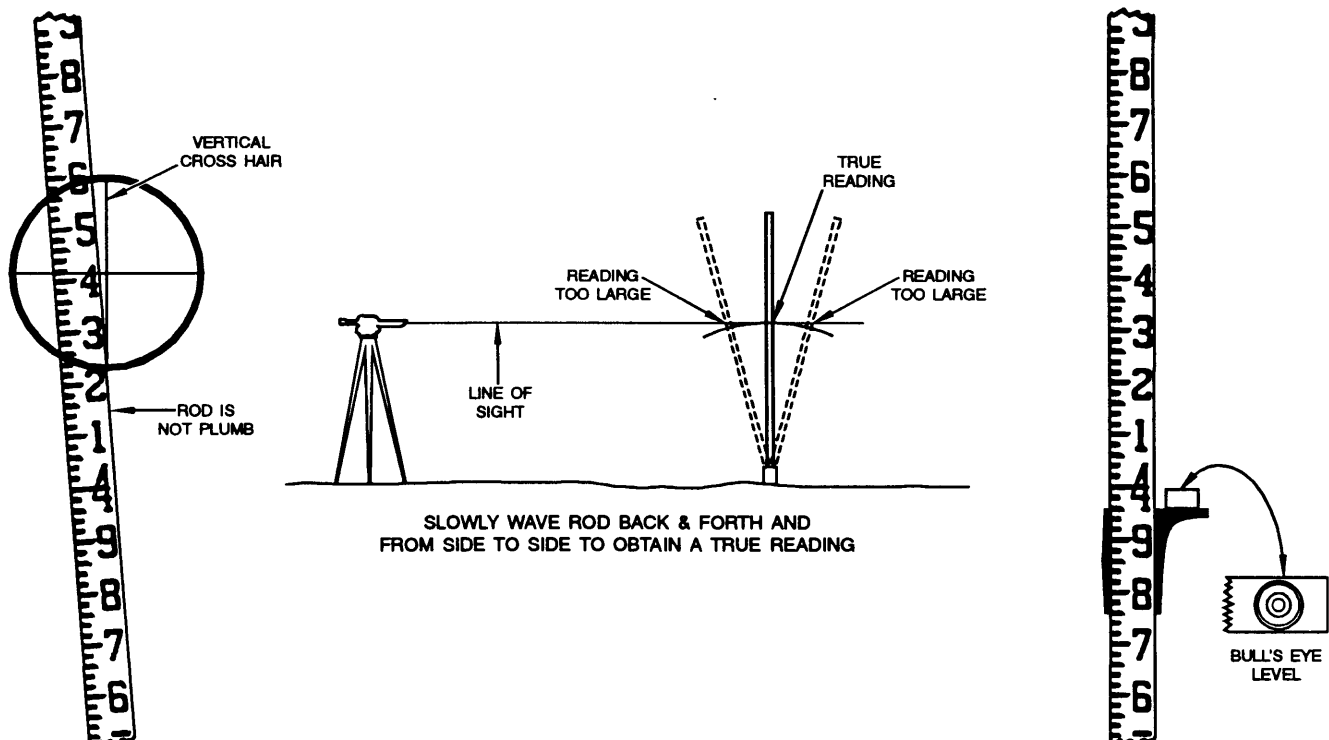
Most leveling rods consist of two or three sections of seasoned hardwood. The sections can be extended to approximately 13' in height. When using a leveling rod with the sections in the extended position, always properly position and clamp each section. This will ensure that the continuous scale can be read correctly from one section to the next.

Proper placement of the rod is important. Several tenths of a foot variation in elevation can be obtained by taking a reading with the rod placed in a small depression rather than setting it on top of a small dirt clod or rock. Unless it is required that a reading be taken from an exact location or object, try to pick a spot that is the average height of the immediate surrounding area.

One exception may be when performing layout or survey work in loose sand or freshly plowed soil. In this case, the rod should be placed in a "footprint." A more accurate reading can usually be obtained because the soil has been settled back down slightly.

When taking measurements from a soil surface, readings to the nearest tenth of a foot may be all that are required. Unless the ground is extremely smooth and firmly packed, readings to the hundredth of a foot will often give a false accuracy. However, readings are generally taken to the nearest one hundredth of a foot when measuring from the top of a stake, form board, concrete slab, footing, etc.

The rod should be held in a plumb position. **Plumb** means exactly perpendicular or vertical; at right angles to the horizon or floor. However, it is difficult for the instrument person and/or rod person to know when the rod is held correctly. One method for the instrument person to check for accuracy is to try to align the side of the leveling rod with the vertical cross hair. However, this checks for accuracy in only one direction. After an initial reading is taken, the instrument person can signal for the rod to be waved slowly back and forth in each direction through the vertical position. This will allow the minimum reading to be observed when the rod is at "true vertical," which will be the **true reading**.



Plumbing the Leveling Rod

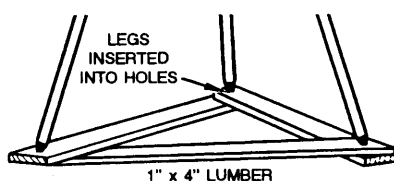
Another method is to purchase an inexpensive **bull's-eye level**. It consists of a simple L-shaped bracket and a small bull's-eye bubble that is attached to the side of the rod. The rod person simply centers the bubble in the circle and holds the rod still.

Architect leveling rods are available with graduations in feet and inches. Since most building materials are also measured in feet and inches, architect leveling rods are commonly used when laying out buildings and setting batter boards, forms, etc. When sighting from distances of less than 100', a regular folding rule can often be used. It can be held against a thin board and read directly through the instrument telescope.

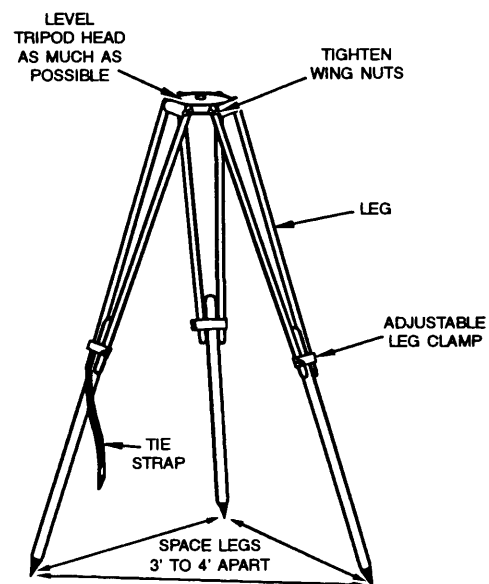
SETTING UP AND USING TRIPOD AND FARM OR BUILDER'S LEVEL

To set up a **tripod**, loosen the wing nuts on the legs. Spread the legs 3 to 4 feet apart and push them firmly into the ground. Adjust the legs accordingly so that the head of the tripod is as level as possible. If the ground is sloping, place two legs on the down slope and one up slope. Some tripods may be equipped with telescoping legs to make setting up on uneven terrain easier. Tighten all wing nuts to secure the legs.

If a tripod must be set up on a firm surface, such as concrete, a simple base frame can be made. Lay out three 1" x 4" boards - 4' long in the shape of a triangle. Lap the corners and secure them with nails or screws. Drill a 3/4" to 1" hole in the center of each corner at a slight inward angle. The tips of the tripod legs can then be inserted into the holes.



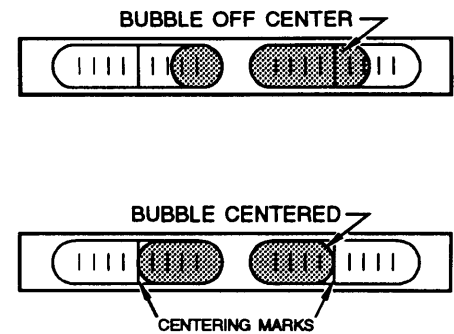
Tripod Base Made of
1" x 4" Lumber



Setting Up and Leveling A Tripod

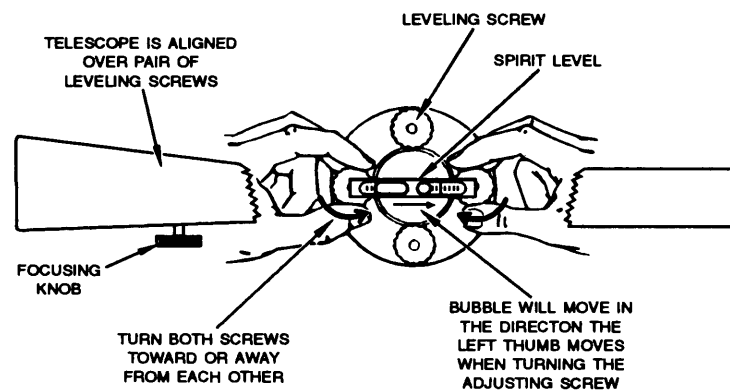
Remove the instrument from the case. Always pick up and handle the instrument by its base to prevent possible damage to the delicate telescope and mounting. Attach the instrument to the tripod and tighten firmly. Remove the lens protection cups and install the sunshade if equipped.

A builder's level or level-transit is equipped with a **leveling vial and bubble**. It may also be referred to as a **spirit level**. The leveling vial is used to level the instrument base during setup and to recheck for accuracy each time a reading is taken. For the instrument to be level, the bubble must be centered between the **centering marks**.



Leveling Vial and Bubble

To level an instrument, first, line up the telescope so it is directly over an opposite pair of the **leveling screws**. Hold the two screws between the thumb and forefinger with each hand. Always turn both screws the same amount at the same time. The bubble in the leveling vial will travel in the direction that you move your left thumb.



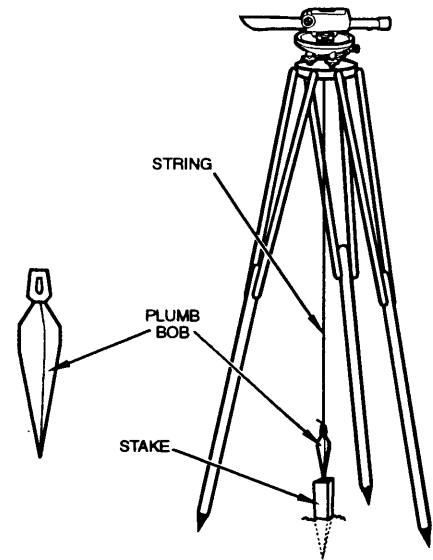
Adjust Leveling Screws to Center Bubble in Leveling Vial

Always turn both screws toward each other or away from each other depending upon the direction the bubble needs to move. Keep turning the adjusting screws slowly until the bubble in the leveling vial is centered between the graduation marks. Never try to raise or lower one end of the telescope by turning just one screw. Do not overtighten the leveling screws, or the instrument may be damaged.

When the bubble is centered, rotate the telescope 90° so that it is over the other set of leveling screws. Repeat the leveling operation. When the instrument has been leveled in that direction, rotate the telescope another 90° and recheck. Repeat the leveling operation if needed. When the instrument is properly leveled and set up, it should be possible to turn the telescope in any direction without changing the position of the bubble in the leveling vial.

The rod readings will not be accurate unless the instrument is level throughout the complete work session. The bubble in the leveling vial should be checked before and after each reading to ensure that the tripod has not been bumped or that the instrument is not out of adjustment.

A **plumb bob** is a weighted device with a sharp point. It is attached with a string to the center of the tripod base. The point of the plumb bob is used to center the instrument over an exact location, such as a corner stake in a building layout.



Using a Plumb Bob to Center an Instrument Over a Station

DIFFERENTIAL LEVELING

Differential leveling is the process of determining the "difference" in elevation between two or more points by measuring the vertical distance from a reference mark. The points may be any distance apart and may or may not be in a straight line.

A **permanent bench mark (PBM)** is a permanent marker of known elevation (above or below sea level) used as a legal reference point for surveying or leveling purposes. Permanent bench marks have been established throughout the country and certified by local, state and/or federal authorities. They are usually small concrete structures buried in the ground with a small brass plate attached. Inscribed on the brass plate is the exact legal location and elevation of the point.

A **temporary bench mark (TBM)** is an object, such as a rod or stake, driven into the ground, or a specific point marked on the top of a concrete structure that is used as a reference point. Actually, any object could be used as a temporary bench mark as long as its elevation and position are not likely to change during the surveying process. For purposes of calculation, the elevation of a temporary bench mark is usually assumed to be 100.00'. The **height of instrument (HI)** is the elevation of the level line of sight or of the cross hairs of the instrument in relationship to a bench mark.

A **backsight (BS)** is a rod reading taken on a point or station of known or assumed elevation. A backsight is also known as a **plus sight**. The backsight rod reading is always added to the elevation of the last known point to determine the elevation of level line of sight, or **HI**.

A **foresight (FS)** is a rod reading taken at a point or station of unknown elevation. A foresight is also called a **minus sight**. The foresight rod reading is subtracted from the **HI** to give the elevation of the new point. It is a good practice to set the tripod in a location so that the line of sight distances from the instrument to backsight, and from the instrument to the foresight are approximately equal. This will help to balance out any errors in the accuracy or adjustment of the instrument.

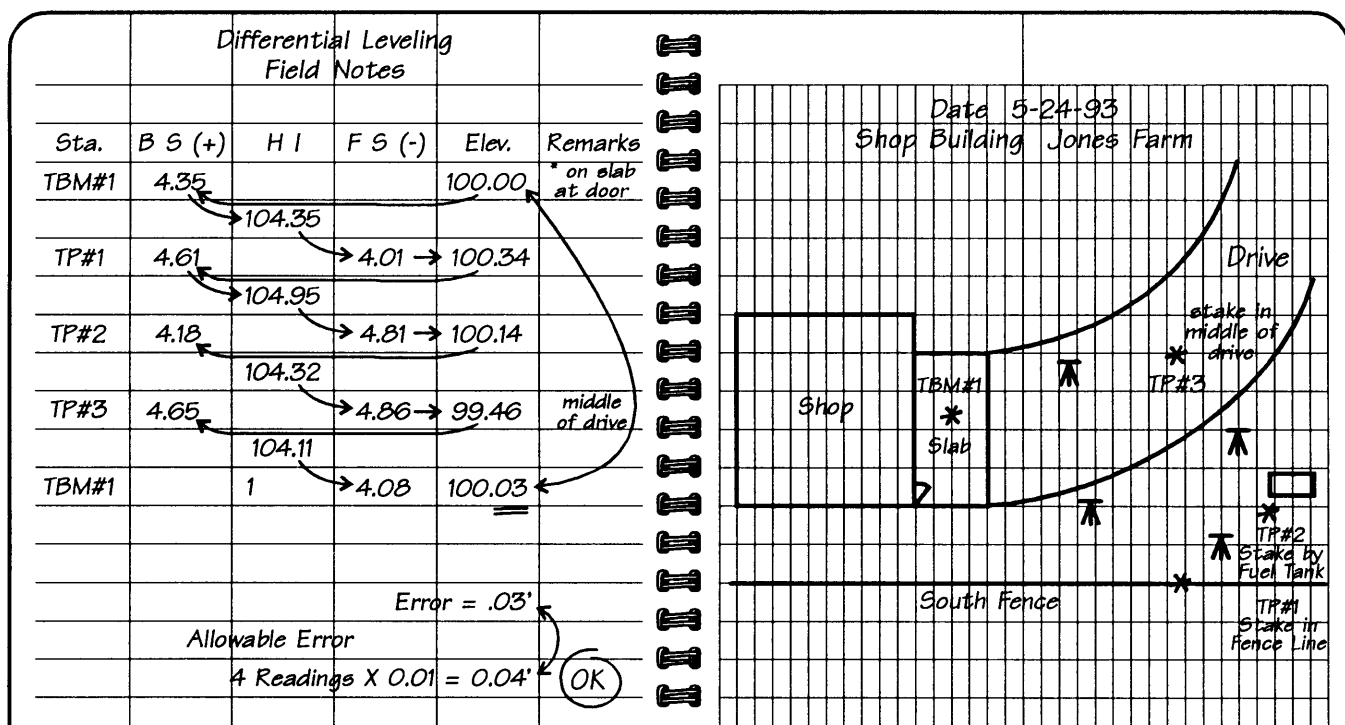
A **station (STA)** is the point on the ground or on top of an object from which the rod reading is taken. For future reference and for recording field notes, each station should be marked with a wooden stake or other object. Each station should be identified using some type of lettering and/or numbering system.

A **turning point (TP)** is an identifiable, temporary point or station, first of unknown elevation, and then of known elevation. The elevation is determined by subtracting a foresight reading from the height of the instrument. Turning points are often marked with stakes and identified as **TP1**, **TP2**, and so forth. Once the elevation of a turning point is determined, it can then serve as a new "temporary bench mark of known elevation." The elevation of the "**TP**" is used to calculate a new "**HI**" when the instrument must be moved to a new location for continuous differential leveling.

Field notes of all rod readings and observations must be taken to complete necessary calculations. Organize and label columns and lines as shown on the following page. It is suggested to use the left side of a notebook to record rod readings. The opposite page can then be used to keep reference notes and a rough map of the survey area. All information and calculations are then readily available for future reference.

Simple formulas to remember when performing differential leveling exercises are:

$$\begin{aligned}\text{HI} &= \text{Elevation of BM or TBM} + \text{BS} \\ \text{Elevation of Sta} &= \text{HI} - \text{FS}\end{aligned}$$



Example of Field Notes

Most leveling rods are numbered from the bottom -- up. In the examples shown, a BS reading of 4.35' at TBM #1 and a FS reading of 4.01' at station TP-1 shows a difference in elevation between the two points to be 0.34'. TBM #1 is actually lower than station TP-1, but has the higher rod reading.

To perform a complete differential leveling process, the survey should be continued until a **complete circuit** is made. That is, the last FS reading is actually taken at the beginning BS reading, which is the BM or TBM #1. This is necessary to check the accuracy of the survey.

In most cases, the final elevation of TBM #1 will not be exactly the same as the beginning elevation (100.00'). A rule of thumb for the **allowable error** is 0.01 feet multiplied by the number of times the instrument was moved and set up in the circuit.

In the example shown, the instrument was moved and set up four times during the circuit. Four setups multiplied by 0.01' equals 0.04' (4 setups x 0.01' = 0.04'). Since there was only 0.03' difference between the first and last elevation readings, this differential leveling circuit was acceptable.

Profile leveling is the process of determining the difference in elevation between two or more points a given distance apart along an established line. The **slope** of a land area is the rise or fall in elevation between two points that are a specified horizontal distance apart. For additional information concerning differential leveling, profile leveling, and determining a slope, see student topic #s 8771, 8234-A, and 8234-B.

HAND SIGNALS

During the leveling or surveying process, it is necessary for the persons operating the instrument and rod to communicate with each other. Because of the distance between them and surrounding noises, shouting is usually not practical. Two-way radios are an alternative, but may be too expensive for only occasional use.

Hand signaling is a common method of communicating between members of the survey party. The signals used may be varied to fit the situation, but their meanings must be understood in advance. Some common hand signals are:

Lower Target or Move Down the Slope - The right arm is extended out with the hand down. The right arm is slowly lowered to indicate downward movement.

Raise Target or Move up the Slope - The right arm is extended out with the hand up. The right arm is slowly raised to indicate upward movement.

Move Rod to the Right or Left - The hand is extended outward in the direction the rod is to be moved. The arm is moved slowly in a sweeping motion. A short sweeping motion indicates to move a short distance while a longer sweeping motion indicates a longer distance.

Plumb the Rod - Extend the arm full-length above the head and move slowly in the direction required as shown by the vertical cross hair in the telescope.

Lean Rod Slowly from Side to Side and Forward and Backward - Hands are held together above the head. Bending at the waist, the upper body is moved slowly from side to side. The instrument person then observes the smallest reading through the telescope.

All Right, Move on, or Understood - Both arms are extended out sideways, with palms forward. Arms are waved up and down several times.

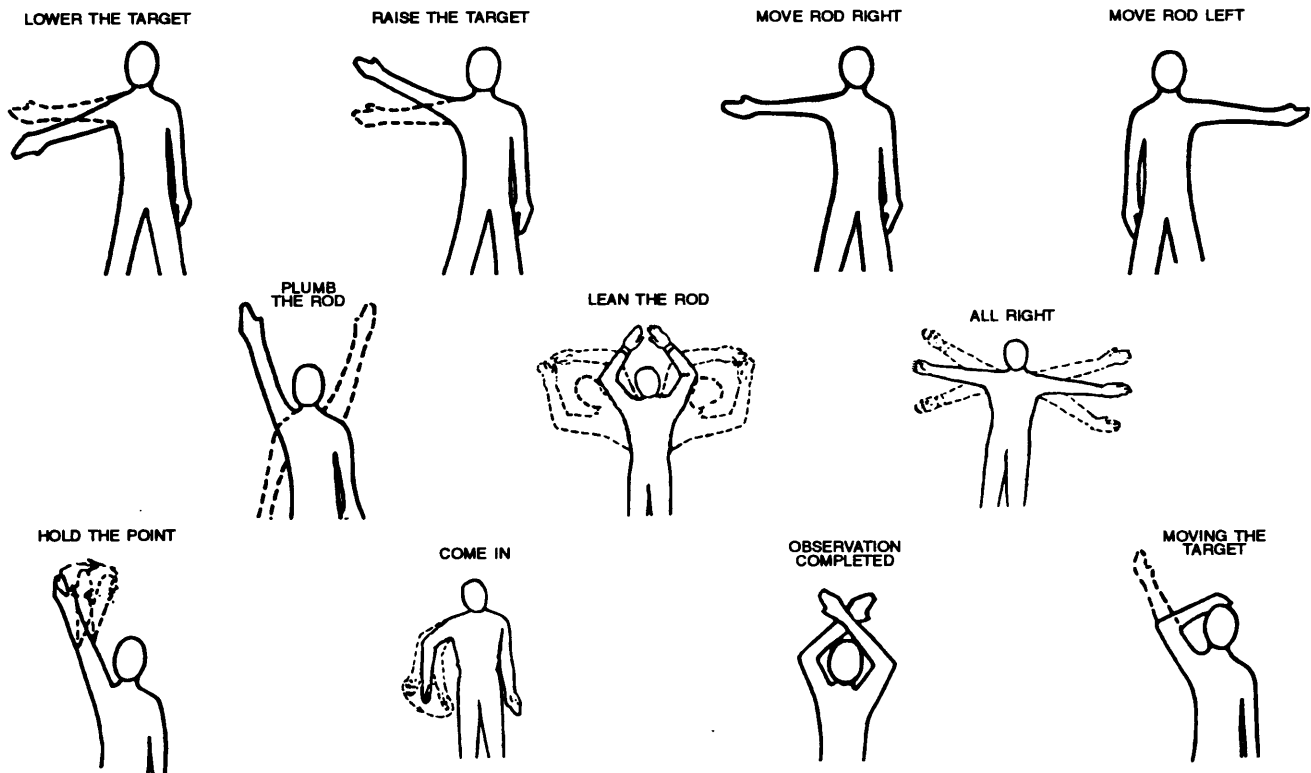
Take a Turning Point, Hold the Point, Do Not Move Rod - The right arm is extended above the head and waved in a circle. May be used to indicate that the instrument person is going to move the instrument to a new location.

Come In - Arm is held away from the body slightly with fingers pointing down.

The arm is waved in a circular motion.

Observation Completed - Both arms are extended above the head and crossed.

Target Has Been Moved - The right arm is extended upward, then the hand is placed on top of the head; used by the rod person to signal back to instrument person.

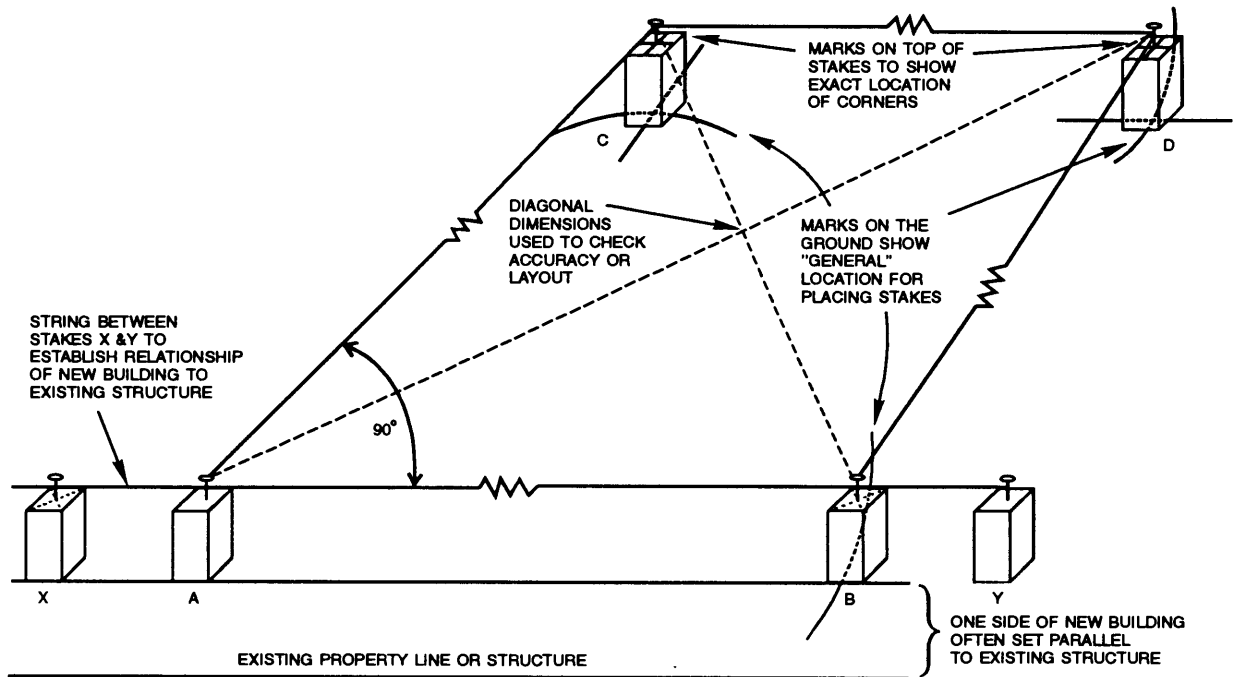


Common Hand Signals

LAYING OUT BUILDING LINES

Building lines are the lines marking where the outside walls of a building will be. To lay out building lines, first determine where the new building will be in relationship to other structures, property lines, fences, etc. It is often helpful to set two stakes and stretch a string between them to give a perspective of where the new building will set. The stakes should be set a little further apart than the length of the side of the building (shown as stakes X & Y in the example). If the new building is to be set parallel to an existing structure, measure the same distance back from the stakes to the fence, property line, or other object. Set stakes X & Y at the same elevation.

Locate corner **A** directly under the string line. Hold the string line over and drive a 2" x 2" stake. The top of the stake should be the same elevation as the string line. Drive a small nail in the top of the stake next to the string line to mark the exact location of corner **A**. Hook a steel tape on the nail in the top of stake **A** and measure the length of side **AB**. Make a sweeping mark on the ground under the string line to mark the "general location" of corner **B**. After stake **B** is in place, remeasure the length of side **AB**. Drive a nail in the top of stake **B** next to the string line to mark the exact length of **AB** and the exact location of corner **B**.



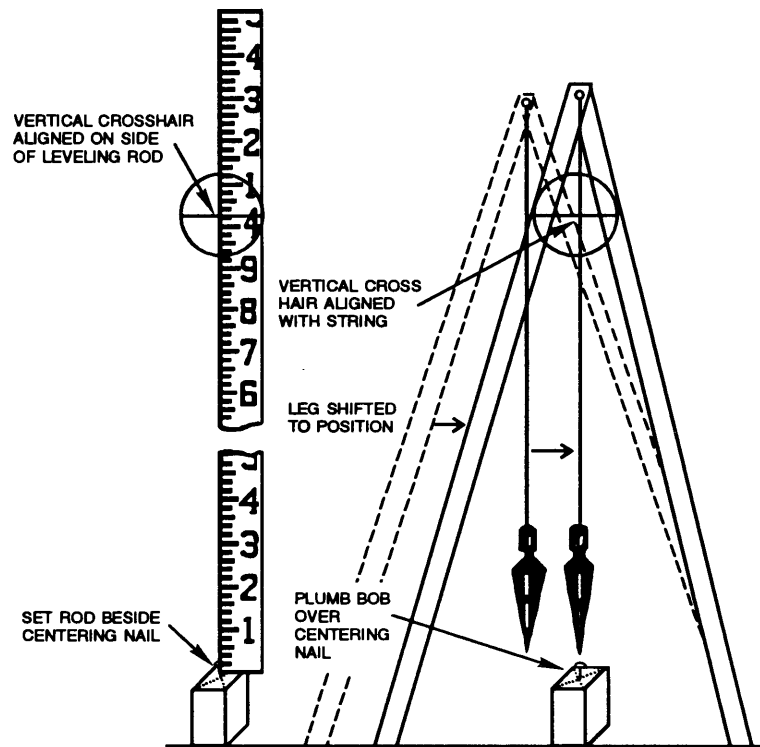
Laying out Building Lines

Using a plumb bob, set up the builder's level directly over corner **A**. Shift the tripod legs until the base is as level as possible and the point of the plumb bob is directly over the nail. Finish leveling the instrument before proceeding. Align the line of sight directly over corner **B**.

This may be done by setting a leveling rod on top of the stake next to the nail. The vertical cross hair is then aligned on the same side of the leveling rod as the nail. An alternative to trying to align and plumb the leveling rod is to use two small boards, a short section of bright colored string or small rope, and a plumb bob. The small boards are attached at one end with a small bolt so that they will pivot. A plumb bob is attached to the string and suspended from the bolt. The weight of the plumb bob will hold the string in a "plumb" position. Either leg can be shifted from side to side to align the point of the plumb bob directly over the nail. The vertical cross hair can then be aligned on the string.

When the line of sight is directly over corner **B**, lock the horizontal rotation clamp. Set the azimuth to 0° . Unlock the horizontal rotation clamp and turn the telescope exactly 90° in the direction of corner **C** and again lock the horizontal rotation clamp.

From the nail in corner stake **A**, measure the length of side **AC** and place a mark on the ground. Locate corner **C** on this length mark by aligning the plumb bob string or leveling rod with the vertical cross hair. Set corner stake **C** at this point at the same elevation as stakes **A** & **B**.



For accuracy, remeasure the length of **AC** and place a pencil mark on top of corner stake **C**. Recheck the alignment of side **AC** on the top of the stake and place another mark. Place a nail in the top of the stake where these marks cross to indicate the exact location of corner **C**.

Move the builder's level to corner **C** and set it up directly over the nail. Sight back to corner **A**. When the line of sight is directly over corner **A**, lock the horizontal rotation clamp and set the azimuth to 0° . Unlock the horizontal rotation clamp and turn the telescope exactly 90° in the direction of corner **D** and again lock the horizontal rotation clamp.

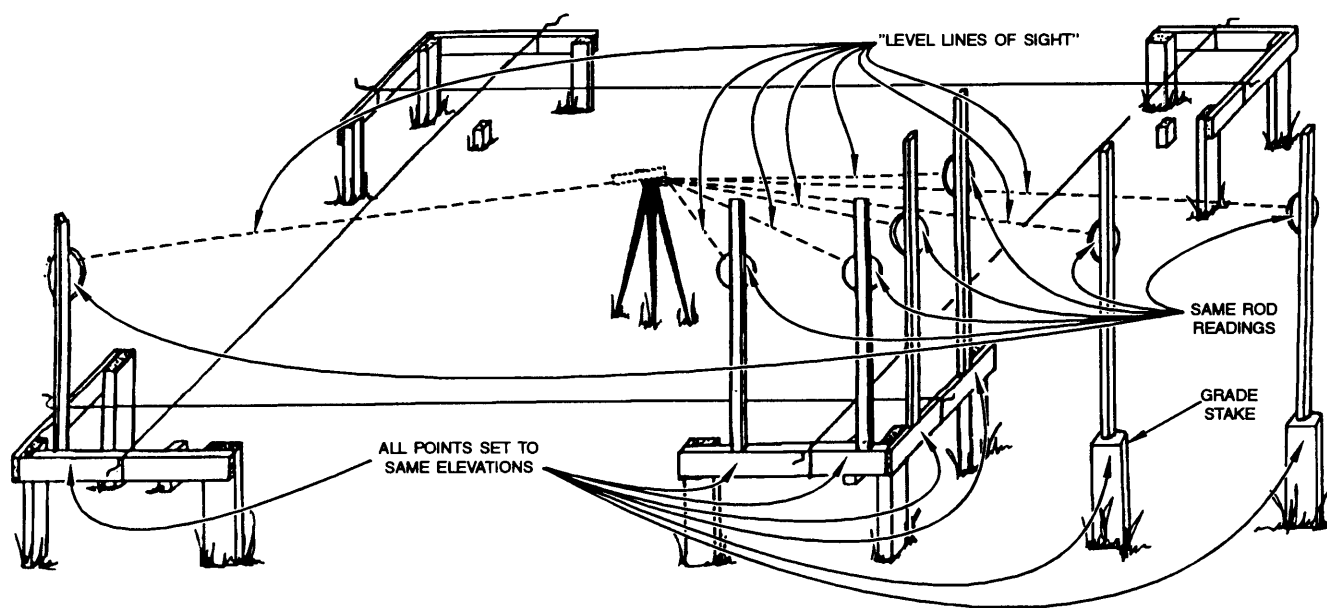
From the nail in corner stake **C**, measure the length of side **CD** and place a mark on the ground. Align the plumb bob string or leveling rod with the vertical cross to locate corner **D** on this length mark. Set corner stake **D** at this point to the same elevation as the other stakes.

Remeasure the length of **CD** and place a pencil mark on top of corner stake **D**. Recheck the alignment of side **CD** and make a mark on top of the stake. Place a nail in the top of stake **D** to indicate the exact location of corner **D**.

To check the accuracy to the layout, compare the measurements of side **AB** with **CD** and **AC** with **BD**. Also compare the diagonal dimension of **AD** with **BC**. Minor adjustments can be made if needed and the dimensions rechecked.

ESTABLISHING POINTS AT THE SAME ELEVATION

A builder's level or level-transit and a target rod are frequently used to set objects such as grade stakes, batter boards, concrete forms, etc., at the same elevation. To establish points at the same elevation, the leveling instrument is first set up in a safe and convenient location. If possible, this should be in the center of the building site. **Caution!** Be aware of others who may be operating equipment or working in the same area. It is not uncommon for leveling instrument to get accidentally bumped or damaged when set up in the middle of a construction site.



Using a Builder's Level and Target to Set Objects to the Same Elevation

Determine the required elevation of the objects to be set up and leveled. The bottom of the target rod (leveling rod with target) is held at this point. The instrument person then focuses on the rod and signals for the rod person to slowly raise or lower the target until the horizontal cross hair (level line of sight) bisects it. The target is then clamped in this position. The rod reading is recorded for future reference during the work session.

The leveling rod with the target still clamped in the same position can then be moved to other locations and set on top of the forms, batter boards, grade stakes or other objects to be leveled. At each location, the object is raised or lowered until the target is again bisected with the horizontal cross hair. A common practice is to attach batter boards or form boards to stakes slightly higher than the desired elevation. The stakes can then be carefully driven deeper into the ground until the tops of the boards are at the proper height. It is easier to drive the stakes deeper rather than trying to pull them up a fraction of an inch.

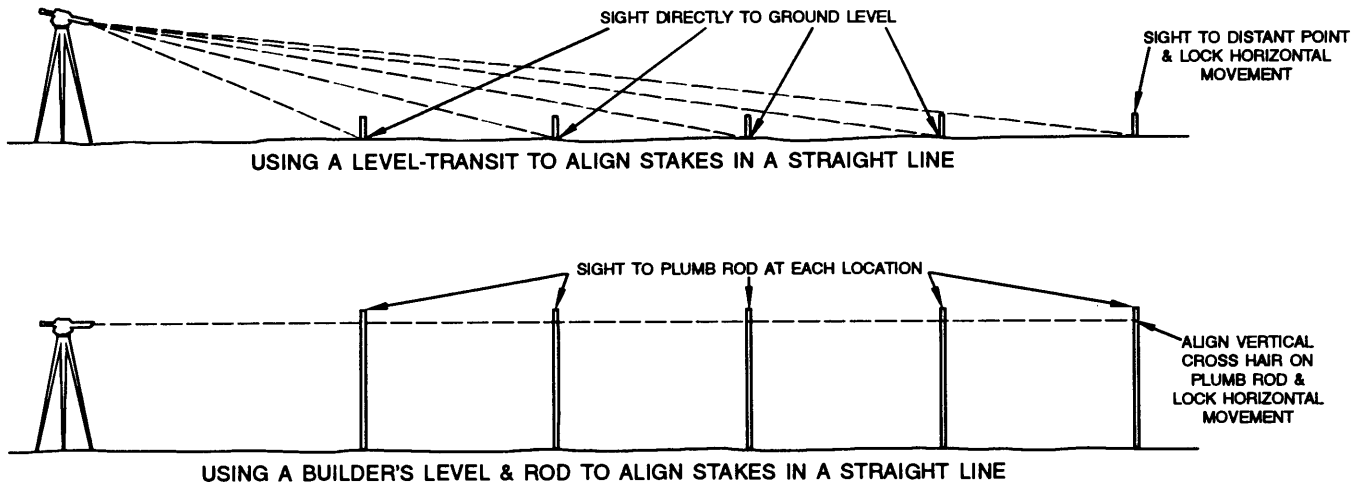
As long as the instrument remains set up in the same location and the same **HI** maintained, as many points as needed can be set to the same elevation using this rod reading. For accuracy, the bubble in the leveling vial should be checked before and after each reading.

It may become necessary to move the instrument for other construction procedures or at the end of a workday before all leveling is completed. Because the **HI** or "the exact elevation of the level line of sight" changes each time the instrument is moved and set up, the same rod reading can not be used as before. Simply set up the instrument in a new location; take a backsight rod reading from a point or object that was previously set to the desired elevation; record the rod reading and clamp the target; and continue the leveling procedure.

STAKING OUT A FENCE OR STRAIGHT-LINE

A level-transit is ideal for staking a fence or other straight-line over a long distance. Using a plumb bob, the tripod and instrument is centered and set up over a point where the fence or line is to start. With the horizontal and vertical movement clamps both loose, the vertical cross hair in the telescope is then focused on a stake or point at ground level at the opposite end of the fence. The horizontal rotation clamp is then locked. The telescope can then be pivoted up or down to sight points in a straight line. The instrument person sights right along ground level and indicates where stakes are to be set.

To use a builder's level, the tripod is set up over a point and the instrument is leveled as before. A leveling rod is held in the plumb position at the opposite end of the line. With the horizontal rotation clamp loose, the telescope is pivoted until the vertical cross hair is focused on the rod. The horizontal rotation clamp is then locked in this position.



At each stake or fence post location, the instrument person then signals for the rod to be moved right or left until it is aligned with the vertical cross hair. The rod must then be plumbed and alignment rechecked. The "two-board frame and plumb bob" can also be used. Either leg can be shifted from side to side to bring the string into alignment with the vertical cross hair. The plumb bob would be directly over the point where a stake or fence post is to be located.

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Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

Fill-In-The-Blanks: Complete the following statements by inserting the correct word(s) in the blanks.

- _____ 1. Most leveling instruments operate on the basic principle that a _____ is a straight line that neither dips, sags, nor curves.
- _____ 2. Any point along a _____ line of sight will be the same height as any other point.
- _____ 3. A _____ is generally considered a less expensive model of a builder's level.
- _____ 4. A _____ can be used to lay out and plumb vertical lines.
- _____ 5. The exact height of the instrument or the line of sight is indicated by the _____ in the telescope.
- _____ 6. _____ means exactly perpendicular or vertical; at right angles to the horizon or floor.

SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph. (Use additional paper when needed.)

7. What is a major advantage of using a laser beam leveling system?
8. Briefly describe the difference between a self-reading leveling rod and a target leveling rod.
9. Briefly describe three methods that can be used to "plumb the leveling rod to obtain a true reading."

10. Briefly describe the procedures used to level an instrument.

11. Explain why hand signaling is a common method of communicating between members of a survey party.

12. What are the three basic types of leveling instruments commonly used in agricultural applications?

A. _____

C. _____

B. _____

MATCHING: Match the statement in the right column with the word in the left column.

_____ 13. Station (STA)

A. The process of determining the difference in elevation between two or more points by measuring the vertical distance from a reference mark.

_____ 14. Backsight (BS)

B. An object driven into the ground or a point on top of a structure that is used as a reference point.

_____ 15. Foresight (FS)

C. The point on the ground or on top of an object from which the rod reading is taken.

_____ 16 Profile leveling	D. The process of determining the difference in elevation between two or more points a given distance apart along an established line.
_____ 17. Differential leveling	E. A marker of known elevation used as a legal reference point for surveying and leveling operations.
_____ 18. Turning point (TP)	F. The elevation on the level line of sight or the horizontal cross hair.
_____ 19. Temporary bench mark (TBM)	G. A rod reading taken at a point or station of unknown elevation.
_____ 20. Permanent bench mark (PBM)	H. A rod reading taken at a point or station of known or assumed elevation.
_____ 21. Height of instrument (HI)	I. An identifiable, temporary point or station, first of unknown elevation, and then of known elevation.

TRUE OR FALSE: Circle the "T" if the statement is true; circle the "F" if the statement is false.

- T F 22. The vertical cross hair indicates direction while the horizontal cross hair indicates the flat plane.
- T F 23. A builder's level is equipped with a vertical scale to measure vertical angles.
- T F 24. The rotating prism within the transmitter of an electronic laser level emits a very thin beam of ultraviolet light.
- T F 25. The receiver unit used with an electronic laser level transmitter unit contains several light sensitive electronic sensors.
- T F 26. A Philadelphia leveling rod is a combination self-reading and target rod.
- T F 27. Philadelphia leveling rods are graduated in feet and 10ths and 100ths of a foot while architect leveling rods are graduated in feet and inches
- T F 28. Most instruments are accurate enough so that once they are set up and leveled, there is no need to recheck them for accuracy and/or re-level until after they are moved to a new location.
- T F 29. A back sight is also known as a minus reading.

PROBLEM SOLVING: Use the formulas found in the topic and the information given to solve the following problems. Show your work.

$$\text{TBM} = 100.00'$$

$$\text{BS} = 4.59'$$

$$\text{FS \#1} = 4.26'$$

30. What is the height of instrument (HI) _____ ?

31. What is the elevation of station #1 _____ ?

ADDITIONAL SKILLS AND ENHANCEMENT ACTIVITIES: Perform the following activities as assigned by your instructor.

1. Call or write to a local land surveying company and determine the location of permanent bench markers in your community.
2. Demonstrate your ability to set up and level a builder's level or farm level.
3. Contact several different building contractors and/or land surveying firms in your community. Determine how many are now using new electronic laser beam level systems. If possible, arrange for a demonstration of the new system.
4. Demonstrate your ability to layout building lines for a structure you or someone you know is planning to build.
5. Demonstrate your ability to perform a differential leveling exercise.

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N1993

IDENTIFYING AND SAFELY USING FASTENERS

Fasteners are an easy and economical way of joining material together. The reasons for using fasteners include:

1. They make construction and manufacturing easier by allowing two or more individual component parts to be held together.
2. They simplify repairs by allowing components to be taken apart, then reassembled.
3. They provide safety. Some fasteners are designed to decrease the chances of joined materials accidentally coming apart.

To ensure long lasting service, fasteners must have certain characteristics. In general, fasteners must be able to: resist vibration, corrosion, temperature changes; be easy to install and remove; and maintain adequate holding power.

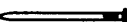
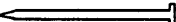
NAILS

Nails are the simplest type of fasteners used to assemble wood products. They are also the most widely used. They can be quickly driven into place to form a strong joint. The holding power of a nail comes from the pressure of wood fibers pressing against it. In order to select the proper type of nail, it is essential to be familiar with the basic characteristics of nails. The basic characteristics used to identify and select nails are: 1) appearance or the way they are made, 2) their name, and 3) their intended use.

The two types of nails are wire and cut. **Wire nails** are cut and shaped from steel wire. Wire nails are used for both rough carpentry and finish work. **Cut nails** are sheared from flat plate. They are mainly used for rough carpentry and concrete work.

Nails have different types of finishes, coatings, and treatments. **Bright nails** have a bright, uncoated steel finish. They are used where corrosion resistance is not required. **Cement-coated nails** have an adhesive or resin coating applied to them. As the nail is driven into the wood, the heat produced by friction melts the adhesive. This increases the holding power of the nail. **Galvanized nails** have a protective coating which is resistant to corrosion. **Quench-hardened nails** are heated, quenched, and tempered to increase their resistance to bending. They are commonly used to join hardwood or masonry materials.

The size of a nail is determined by its **length** and the **gauge** (diameter) of the wire from which it is made. The "penny" system for sizing nails came from England.

	Penny(d)	Length(")	Gauge
2d 	2	1	15
3d 	3	1 1/4	14
4d 	4	1 1/2	12 1/2
5d 	5	1 3/4	12 1/2
6d 	6	2	11 1/2
7d 	7	2 1/4	11 1/2
8d 	8	2 1/2	10 1/4
9d 	9	2 3/4	10 1/4
10d 	10	3	9
12d 	12	3 1/4	9
16d 	16	3 1/2	8
20d 	20	4	6
30d 	30	4 1/4	5
40d 	40	5	4
50d 	50	5 1/2	3
60d 	60	6	2

Nail Sizes

The letter "d" was the English symbol for their penny. Originally, so many nails of a certain size were weighed and sold for a penny. A penny system is still used today. However it only refers to nail length.

Nails smaller than 1 inch are measured by a fraction of an inch. The penny system starts with a 2d nail which is one-inch long. An additional $\frac{1}{4}$ inch is added for each penny size up to a 12d nail which is $3\frac{1}{4}$ inches long. A 16d nail is $3\frac{1}{2}$ inches long. Spikes or nails larger than 20d are identified by their actual length in inches.

There are also variations in the size and shape of nail heads, points, and shanks. These differences determine the common usage for each type of nail. In general, sharper pointed nails are easier to drive. However, they are more likely to split the wood than a dull point. The holding power of a nail is dependent partly on the size of the head, and partly on the size and type of shank. Large, flat nail heads have more holding area than smaller heads. Nails with smaller heads are used on finish work where strength is not a major concern. The head can be countersunk, or driven below the surface. The smaller hole in the wood surface is easier to fill or cover up.



FLAT



CUPPED



DUPLEX



BRAD

COMMON TYPES OF NAIL HEADS



SMOOTH



BARBED



FLUTED



SPIRALED



ANNULAR-RINGED

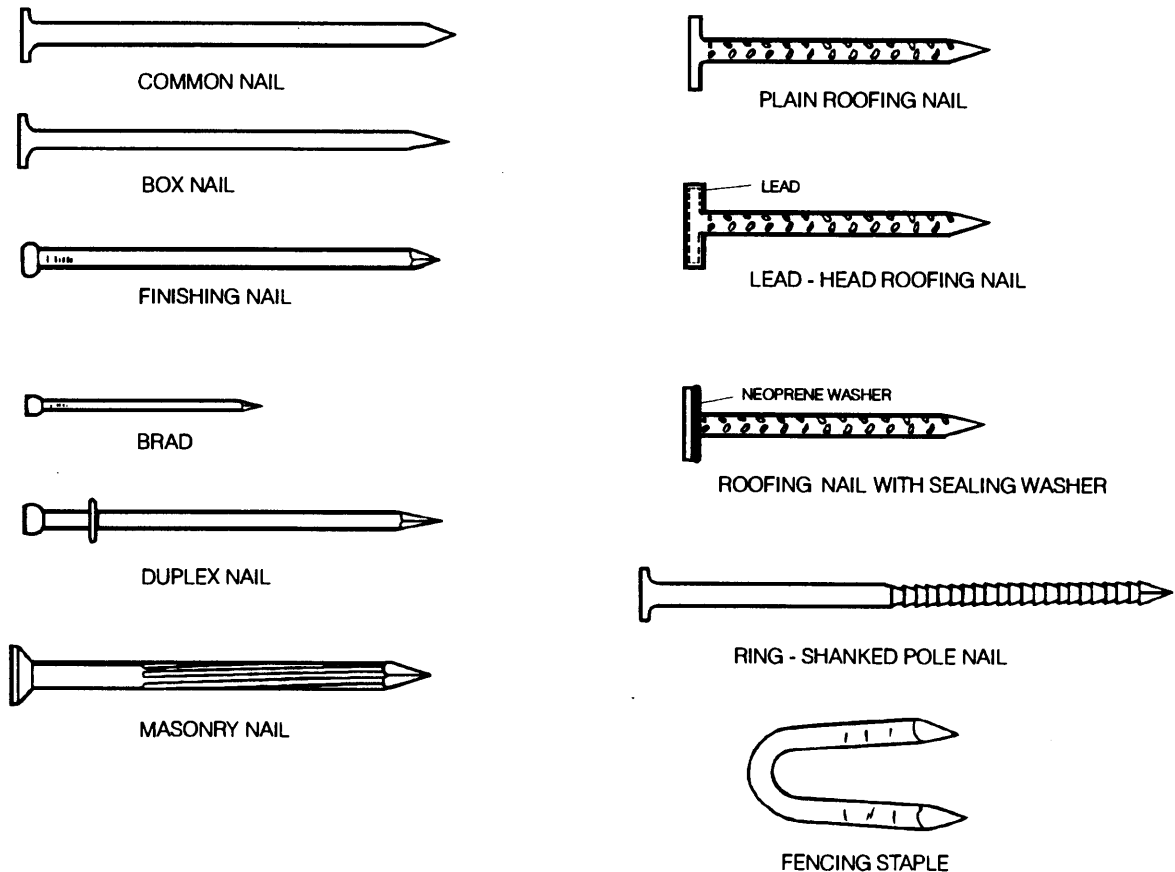
COMMON TYPES OF NAIL SHANKS

The shanks of some nails are ringed, spiraled, cement-coated, or barbed. Nails with special shanks will have more holding power than those with a smooth shank. The advantage of using special shanked nails is that smaller, shorter, and fewer nails can often be used to obtain the same joint strength. However, nails with special shanks are more difficult to remove.

Additional considerations when selecting the proper nails for a job include:

- 1) Types of materials receiving the nails
- 2) Stress and strain placed on the nailed materials
- 3) The conditions (weather, chemicals, heat, etc.) that the nails are exposed to
- 4) Appearance when the job is finished

Types of Nails



Common Types of Nails

Common nails have a large, flat head that is about twice the diameter of the shank. They are used for general carpentry and wood framing, and range in size from 2d to 20d.

Box nails have a flat head which has the same diameter as the common nail head, but thinner. The shanks are also smaller in diameter. Box nails are used in general construction where splitting may be a problem. Sizes from 2d to 20d are available.

A **finishing nail** has a small, cupped head that is only slightly larger than the shank. The head can be concealed below the surface of the wood without making a large hole. Sizes from 3d to 10d are used for installing wood trim and for cabinet construction.

Brads are small, lightweight nails that have practically no head at all. They are used for light finishing work and are easily concealed beneath the surface. Their sizes are usually 2d and smaller.

Duplex nails have two heads, one above the other. They are used for work that must be disassembled later such as concrete forms. The nail is driven only to the lower head. The upper head is left above the surface to allow easy removal with a wrecking bar. Common sizes include 8d to 16d.

Masonry nails are quench-hardened with a flat head and a diamond point. They are used to fasten wood to masonry products. Masonry nails may be either cut steel or specially hardened wire.

Roofing nails have large, flat heads for securing roofing materials and siding. They may have smooth, ring, or barbed shanks in lengths up to two inches. Some types of roofing nails, called **lead-heads**, have a lead coated head for sealing. **Note!** Lead-head roofing nails are not as popular today because of the concern of lead poisoning. Other roofing nails have a rubber washer on the bottom side of the head. This also creates a watertight seal when the nail seats.

Spikes are larger versions of common nails. Spikes commonly range in size from 30d to 16 inches.

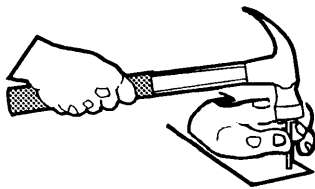
Pole Barn Nails are actually quench-hardened common nails with some type of ring or spiral shank. They are used in pole barn construction and range in size from 16d to 60d.

Staples range in length from 3/8 inch to 2 inches have a crown width up to one inch. Fencing staples attach fencing material to wooded posts or frames. They are usually driven with a hammer or fencing pliers. Fencing staples are usually galvanized and have special shanks to improve holding power.

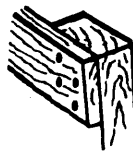
Other types of nails are available with special heads and/or shanks for specific applications.

Procedures for Driving Nails and Staples

After selecting the proper nail, hold it firmly near the head with the thumb and index finger. Strike a *light* blow with the hammer to set the nail for driving. Strike the nail square on the head with even blows. If more than one nail is needed in the same area, place the nails in a **zig-zag pattern** to keep the wood from splitting. When driving nails into hardwood, drill a pilot hole slightly smaller than the nail shank to prevent splitting.



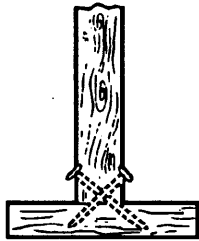
STARTING A NAIL



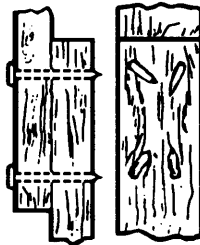
ZIG - ZAG PATTERN



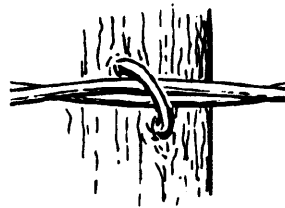
DRIVE NAIL AT ANGLE



TOE NAILING



CLINCHING



DRIVE STAPLES AT ANGLE



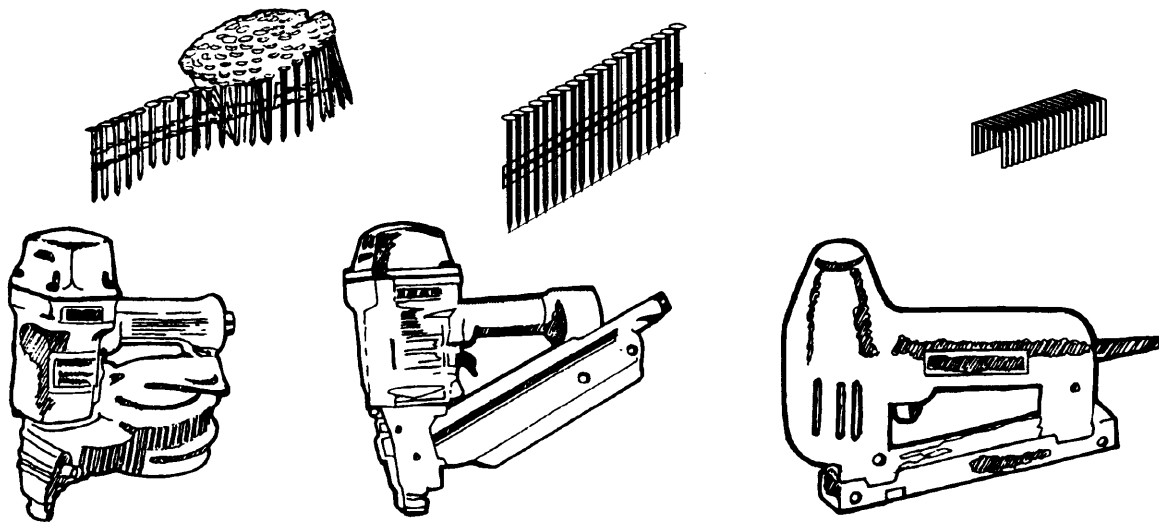
Driving nails at a **slight angle** will increase their holding ability. Nails must be driven at an angle when toe-nailing. **Toe-nailing** is useful when a nail cannot be driven from the backside or directly through a joint. For example, studs can be toe-nailed to the sole and top plates when framing a building.

The points of nails which stick out of the opposite side of the board should be clinched. **Clinching** is accomplished by bending the point of the nail over on the back side of the joint and forcing it into the wood. Not only is the material safer to handle with the points bent over, but clinching can also increase the strength of a joint.

Drive staples with the points at a *vertical angle*. This prevents both points from entering the same grain in the wood. Also, drive the staple at a *slightly upward angle* so the upper prong is deeper than the lower prong. Staples should only be driven up against the wire, avoiding crimping or forcing them into the post.

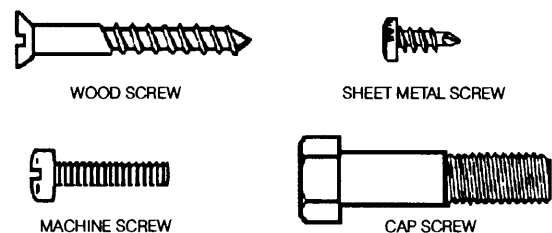
Nail Drivers

In addition to hammers, nails and staples are also driven with nail guns. Common types of nail guns are **pneumatic** and **electric** guns. Pneumatic nail guns use compressed air to drive nails. Electric nail guns use an electro-magnetic powered striker to drive nails. The size of the gun determines the size of nails or staples which can be used in it. Nails and staples are packaged in **coils** or **runs**. Each coil or run contains from 25 to 300 nails or staples. Plastic webbing, resin, or some other adhesives hold them together.



SCREWS

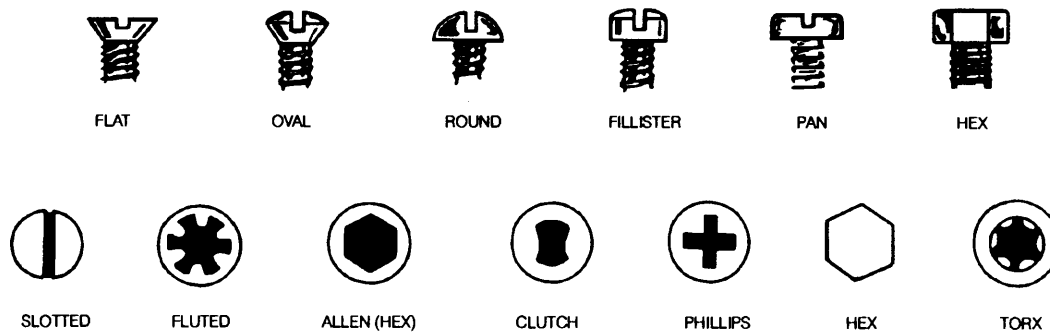
There are many different types of fasteners that may be referred to as screws. Major classifications of screws include: **wood screws**, **metal screws**, **machine screws**, and **cap screws**. Cap screws may also be referred to as **bolts**.



Types of Screws

Screws are also classified by: 1) the size and shape of the head, and 2) the size and shape of tool slot or socket in the head used for installation and removal. Common shapes of screw heads are: flat, oval, round, fillister, pan, and hex.

Most wood, metal and machine screw heads are slotted to accept standard blade or phillips screwdrivers. However, fluted, allen, clutch, hex, and torx headed screws are available and becoming more popular. Common types of cap screws and bolts will be discussed later.

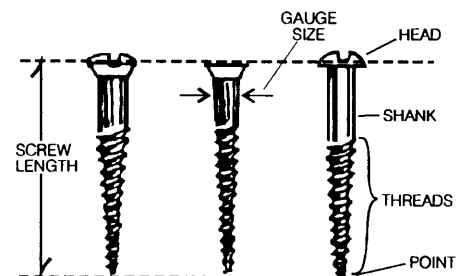


Types of Screw Heads

Most types of screws are made of steel. They may have a thin coating of nickel, zinc, or brass to prevent corrosion. Other screws are made of brass, bronze, copper, and aluminum.

The selection of screws is based upon: 1) type of head, 2) size and length of the shank, 3) material from which the screw is made, 4) type and thickness of material to be attached or held together, 5) appearance, 6) type of threads, 7) type of point, and 8) required strength.

The threads on most screws or bolts are right-handed. That is, the screw or bolt head is turned in a clockwise manner to the right when it is installed. If a nut is used, the nut is screwed on in a clockwise direction (when looking at the screw or bolt from the thread end). Some types of screws and bolts are available with left-handed threads for special purpose applications such as a turnbuckle.



Parts of a Screw

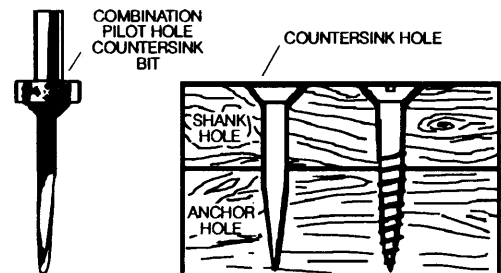
Wood Screws

Most wood screws provide more strength than nails. However, the final selection of the type of wood screw to use is often based on the desired appearance of the work and how hard the wood is.

Wood screws are sized by the diameter of the shank. Screw shank sizes are expressed as **gauge numbers**. Each gauge number size is .013 or approximately 1/64 inch larger or smaller than the next. The larger the gauge number, the larger the diameter of the screw. The length of the screw is measured from the widest part of the head to the point. Gauge numbers range from 0 (1/16") to 24 gauge (just over 5/16"). Wood screw lengths range from 1/4 inch to 6 inches. A typical "1½ x #12 flat" wood screw would have a flat head, be 1½ inches long, and have a shank diameter of .216 or just under 7/32 inch.

Smaller gauge screws are used when there is a danger of splitting. Larger gauge screws provide greater strength and are used in softer woods because there is more thread area. Some types of wood screws will be smooth on the upper one-third of the shank.

Drilling a pilot hole will often prevent wood from splitting. The anchor hole should be slightly smaller than the diameter of the threaded screw shank. It may also be necessary to countersink for the smooth shanks and heads of some screws.



Drilling a Pilot Hole



LAG SCREW WITH EXPANSION SLEEVE

The countersink should be the same diameter as the head of the screw and shank. This will allow the head of the screw to be placed flush or below the surface of the wood and still hold the top object firmly in place. Drill bits are available to drill the pilot hole, and the countersink hole for the smooth shank and head at the same time.

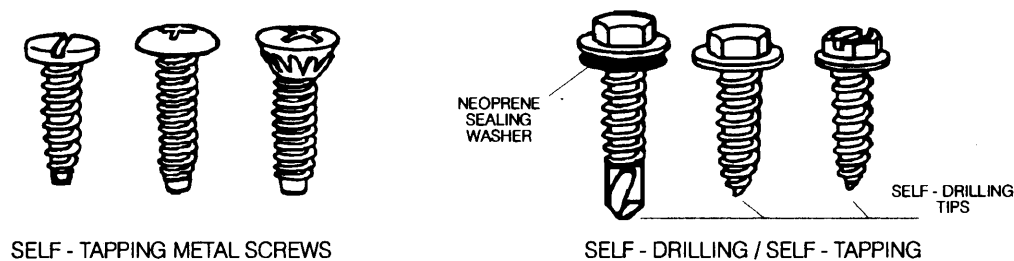
Drywall screws have smaller shanks than normal wood screws. This lessens the need for drilling a pilot hole. Drywall screws were originally designed as self-drilling screws to attach drywall (gypsum wallboard) to light metal or wood framing. The shanks are hardened to resist twisting and bending during installation.

The threads of a drywall screw provide excellent strength against pullout. Drywall screws are available in lengths from 5/8 to 4½ inches in #6 and #8 gauge sizes. Galvanized drywall screws (commonly called deck screws) are used in outdoor wood construction. Drywall screws can be easily installed with power drills and screwdrivers.

Lag screws (also called lag bolts) resemble cap screws except that they have coarse wood screw threads. They have square or hex heads with shank sizes from ¼ to ¾ inch. Lag screws are used when regular wood screws, nails, or spikes cannot provide the desired strength. Lag screws are also used with **lead expansion sleeves** for masonry anchors. The expansion sleeve expands as the lag bolt is screwed into it.

Metal Screws

Metal screws are generally classified as self-tapping and/or self-drilling. **Self-tapping metal screws** require a small pilot hole to first be drilled through the metal and other materials being fastened. The pilot hole should only be slightly larger than the shank size excluding the threads. The hardened threads on the metal screw then "tap" threads into the metal, hard plastics, fiberglass, wood, or other materials as the screw is installed.



Typical Metal Screws

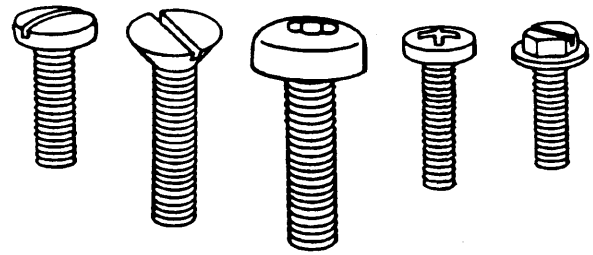
Self-drilling metal screws have special pointed tips which bore their own pilot hole *and* tap their own threads as they are installed. Self-drilling/self-tapping metal screws are commonly used in: building construction to attach sheet metal roofing and siding to metal purlins and girts; and in sheet metal fabrication for heat, cooling, and ventilation ducts.

Metal screws are sized by the same gauge number and length system as used with wood screws. Metal screws do not usually require the use of a nut on the back side of the material being fastened.

Machine Screws

Machine screws are small bolts less than $\frac{3}{8}$ inch in diameter. They are sometimes referred to as "stove bolts." Machine screws usually have threads the entire length of the shank. They may be used with nuts or inserted into threaded holes.

Machine screws below $\frac{1}{4}$ inch shank diameter use the same screw gauge number designation as wood and metal screws. Sizes range from **#2** which is just over $\frac{5}{64}$ inch to **#12** which is approximately $\frac{7}{32}$ inch in diameter. Machine screw sizes of $\frac{1}{4}$ inch shank diameter and larger are expressed in fractions of an inch ($\frac{1}{4}$ ", $\frac{5}{16}$ " and $\frac{3}{8}$ ").



Typical Machine Screws

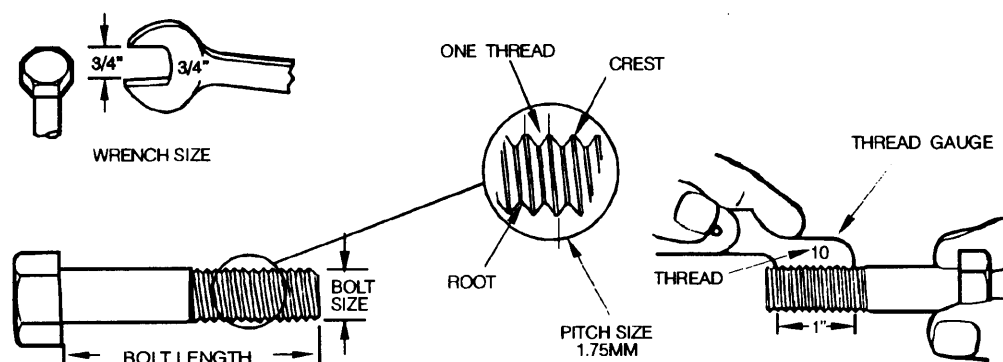
Machine screws are also classified by the number of threads per inch. The number of thread per inch range from 56 for tiny **#2** machine screws, to 16 threads per inch for larger $\frac{3}{8}$ inch machine screws. A typical **#10-24 X $1\frac{1}{2}$ " machine screw** would: be a **#10** screw which is just over $\frac{3}{16}$ inch in diameter, have 24 threads to the inch, and be $1\frac{1}{2}$ inches long. Like wood screws and metals screws, machine screws are available with many different types of screw head designs.

CAP SCREWS AND BOLTS

By definition, a **cap screw** or **bolt** is a length of metal rod with a formed head and a body. The body has external screw threads. The terms cap screw and bolt are used interchangeably in many references. A cap screw is often called a "bolt" when it is used in a plain hole to hold two or more pieces of material together. The bolt is tightened and held in place with a mating **nut**. In contrast, the same size and type of bolt may be referred to as a "cap screw" when it is used in a threaded hole without a mating nut.

Bolt length is normally measured from the bottom of the head to the end of the threads. The bolt head size is determined by measuring across the **flats**. The bolt head size thus determines the **wrench or socket size** needed to hold or turn the bolt. **Bolt size** is determined by the outside diameter of the threads.

The top of a thread is called the **crest**. The bottom of the groove between two crests is called the **root**. The area from one crest to the next is referred to as one **thread** or **pitch**.



Determining Cap Screw or Bolt Sizes

The American National Standards Institute (ANSI) controls the standards for thread sizes and types. **Thread sizes** for standard unified screw thread bolts (bolts measured in inches) are determined by counting the number of threads per inch. Within each unified (inch) bolt size, there are two standard thread sizes. **UNF** indicates **unified fine**, while **UNC** indicates **unified coarse**.

1/2-20 UNF X 6 indicates a 1/2-inch diameter bolt. The bolt will have 20 unified fine threads to the inch and will be 6 inches long. **1/2-13 UNC X 6** also indicates a 1/2-inch diameter bolt that is 6 inches long. However, the bolt will only have 13 unified coarse threads to the inch.

Common bolt sizes and the number of threads per inch are: **1/4"-20 & 28**, **5/16"-18 & 24**, **3/8"-16 & 24**, **7/16"-14 & 20**, **1/2"-13 & 20**, **5/8"-11 & 18**, **3/4"-10 & 16**, **7/8"-9 & 14**, and **1"-8 & 12**.

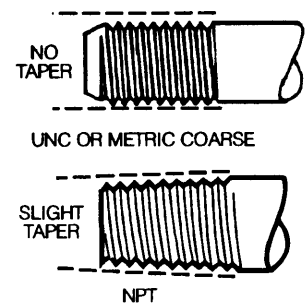
In the past few years, the use of **metric bolts** has become more common. The International Organization of Standardization (ISO) has established standards for metric bolts. Attempts have been made to gradually convert to a metric measurement system for all equipment manufacturing world-wide. Metric bolts serve the same functions as standard unified (inch) bolts. However, metric bolt sizes and lengths are measured in millimeters instead of inches.

Thread sizes for metric bolts are determined by measuring the distance between two threads in millimeters. The distance is referred to as the bolt **pitch**. Like each standard unified screw thread bolt size, each ISO metric bolt size is available in at least two thread pitch sizes. **For example:** A M12 or 12 millimeter metric bolt may have **coarse-1.75 mm**, **fine-1.50 mm**, or **extra fine-1.25mm** pitch threads.

M12 X 1.75 X 160 would indicate a metric bolt that is 12 MM in diameter and 160 MM in length (approximate equivalent to a $\frac{1}{2}$ " bolt - 6" long; $\frac{1}{2}$ " = 12.7 MM, 6" = 152.4 mm). The thread pitch size would be 1.75 mm or ISO coarse.

When installing or replacing nuts and bolts, it is important to determine the *exact* bolt size and thread type needed. **For example:** There is only .0275 inch or .7 mm difference in the diameter between a $\frac{1}{2}$ -inch standard unified bolt and a 12 mm metric bolt. Within these two similar sizes of bolts, there are five possible thread sizes or types: UNF, UNC, ISO coarse, ISO fine, and ISO extra-fine.

It may be difficult for even an experienced service technician to tell all the types and sizes of bolts apart simply by looking at them. Different types and sizes of nuts and bolts may "start" to screw together. However, the threads will strip, cross-thread, and/or gall if tightening continues. **Thread gauges** are available in both inch and metric measurements to quickly determine exact bolt sizes and thread types.



National Pipe Thread (NPT) is a type of coarse thread used on pipes and pipe fittings. Pipe threads are designed with a slight taper. The taper allows the threads to wedge together and seal the connection when the pipe and fitting are screwed tightly together. Although NPT, UNC, ISO-coarse threads are similar in appearance, they *are not* interchangeable.

Bolt Grades and Classes

Bolts and cap screws are also classified based on: 1) the materials they are made from, 2) the treatments they received during manufacturing, and 3) their tensile strength. **Tensile strength** is how much "pull" something will withstand before it stretches and breaks.

The Society of Automotive Engineers (SAE) has established **strength grades** for bolts and screws sized by inch measurements. The ISO has established **strength classes** for metric bolts. Both organizations use a marking system to indicate the grade or class of each bolt and its approximate tensile strength.

The SAE system uses radial slashes on the bolt head to indicate grade. SAE grades range from soft steel, **Grade 1** bolts to hard steel, high strength **Grade L9** bolts. The bolt heads will have two less slash marks than the actual bolt grade. **For example:** A **Grade 5** bolt will have three slash marks on the bolt head.

Exceptions are the grade one and grade two bolts which normally have smooth heads, and the new grade L9 bolt which has nine slash marks. In addition to the nine marks, the new grade L9 bolts will also have "L9" printed in the center of the bolt head. The slash marks and L9 are not to be confused with company logos, stamps, etc.

UNIFIED (INCH) STEEL BOLTS & SCREWS					METRIC STEEL BOLTS & SCREWS			
HEAD MARKING	SAE GRADE	DIAMETER INCHES	TENSILE STRENGTH PSI		TENSILE STRENGTH mPa	DIAMETER mm	150 CLASS	HEAD MARKING
	GRADE 1	1/4 TO 1-1/2	60,000	APPROX. EQUIV.	400	5 TO 36	CLASS 4.6	
NO MARK					420	UP TO 16	CLASS 4.8	
	GRADE 2	1/4 TO 3/4 (LENGTH UP TO 6 IN)	74,000	APPROX. EQUIV.	520	5 TO 24	CLASS 5.8	
	GRADE 5	1/4 TO 1	120,000	APPROX. EQUIV.	800	UP TO 16	CLASS 8.8	
		OVER 1 TO 1-1/2	105,000		830	16 TO 36		
	GRADE 7	1/4 TO 1-1/2	133,000	APPROX. EQUIV.	900	UP TO 16	CLASS 9.8	
	GRADE 8.2	1/4 TO 1	150,000	APPROX. EQUIV.	1040	UP TO 36	CLASS 10.9	
	GRADE 8.	1/4 TO 1-1/2						
	(NONE) SOCKET HEAD	UP TO 1/2	180,000	APPROX. EQUIV.	1220	UP TO 36	CLASS 12.9	
		5/8 AND LARGER	170,000					
	GRADE L9	1/4 TO 1 1/2	180,000 TO 200,000					

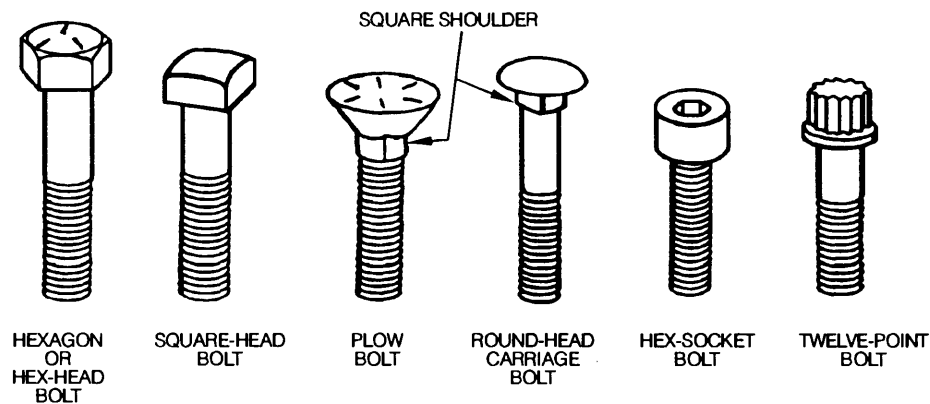
SAE and ISO Bolt Markings and Tensile Strength Specifications

The ISO standards range from **Class 4.6** to **Class 12.9**. A soft-steel Class 4.6 ISO bolt is equivalent to a Grade 1 SAE bolt in strength. A Class 8.8 is equivalent to a medium-strength Grade 5 bolt. ISO metric bolts will normally have the class number printed on the bolt head.

The higher the grade or class of the bolt selected, the stronger the bolt. The stronger the bolt, the less it will stretch. The stronger the bolt and matching nut used, the less likely the threads will strip when tightened.

Types of Bolt Heads

Bolts are also classified by the type or shape of their heads. Each type has a specific application.



Common Types of Bolt Heads

Hexagon or hex-head bolts are commonly used to assemble machines and equipment. Some sizes of lower grade, **square-head bolts** are still available. They are used primarily for assembling wood structures and beams.

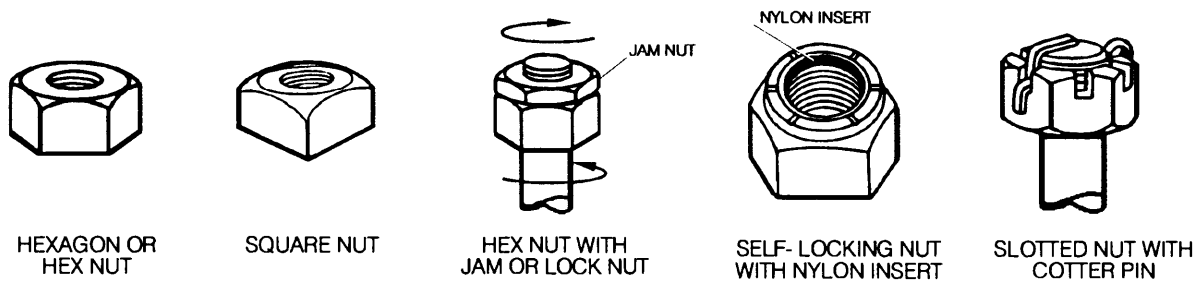
Round-head carriage bolts are often used to attach wood to wood or wood to metal when a smooth head is required. The square shoulder under the head is pulled into the wood. This keeps the bolt from turning while the nut is being tightened. Carriage head bolts are also used to assemble metal parts which have square punched holes.

Plow bolts are made with special tapered heads and square shoulders. The tapered head and square shoulder fit into a countersunk hole. This allows the head to be flush with the surface when the bolt is tightened. Plow bolts are used to attach cutting blades to earth-moving equipment and plow shares to plow standards. **Hex-socket** and **twelve-point bolts** are used when the bolt head must fit into a confined area or recessed hole.

NUTS

Nuts are the fastener devices used to tighten or secure bolts and machine screws. **Hexagon** or **hex-head nuts** made of steel are the most common. **Square nuts** are still used in some applications.

Nuts are sized by the inside diameter, and the size and type of threads (UNC, UNF, and ISO-coarse, fine, or extra fine). The nut size and thread type must match the bolt or machine screw they are used with. Nuts are also manufactured to different strength standards which correspond with the different grades or classes of bolts.



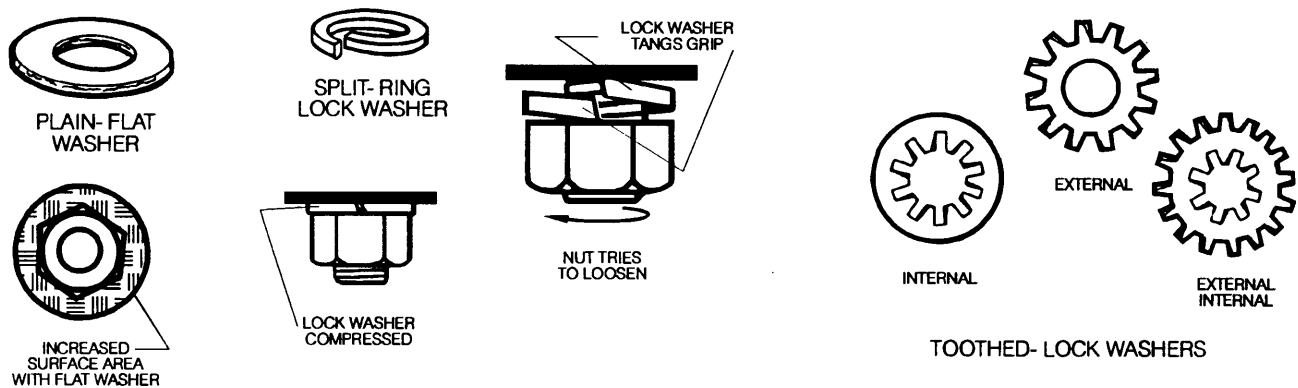
Common Types of Nuts

A **lock nut** or **jam nut** is actually a thin hex nut. A jam nut is tightened in the opposing direction against a regular hex nut to prevent it from vibrating loose. A **self-locking nut** has a special plastic insert. The plastic insert grips the threads of the bolt when tightened to prevent the nut from moving during operation.

A **slotted nut** is similar to a hex nut, but has slots cut into the top. When the slotted nut is tightened to the desired position, a cotter pin is inserted through two of the slots and the hole in the bolt. Slotted nuts and cotter pins are used on adjustment rods and bolts when the nut cannot be tightened securely against another surface. There are literally hundreds of other styles and designs of nuts and bolts for different applications.

WASHERS

Washers may be considered accessories used with other types of fasteners. **Plain flat washers** are used with bolts, nuts, and screws to distribute the stress load at the head over a larger surface area. Plain flat washers are usually sized by the diameter of the bolt they will fit over and not their actual inside diameter. **For example:** The inside diameter of a "nominal $\frac{1}{2}$ -inch plain flat washer" is approximately $\frac{1}{8}$ -inch oversize so it will easily fit over a $\frac{1}{2}$ -inch bolt shank.



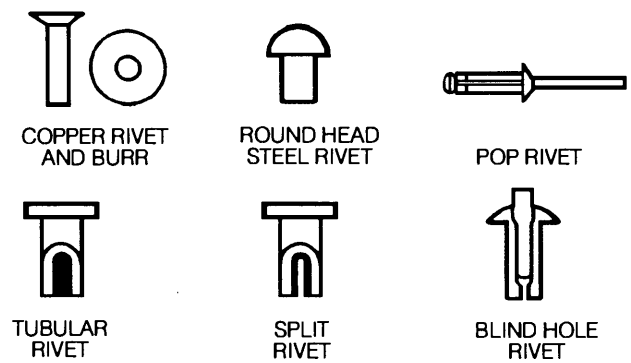
Lock washers keep bolts and nuts from vibrating loose during operation. **Split-ring lock washers** are made of spring steel. They are made with each end bent slightly to form tangs. The spring washer is compressed as the nut or bolt is tightened. The tangs grip into the nut or bolt head and the fastened surface if the nut or bolt tries to vibrate loose.

Other types of lock washers are **toothed-lock washers**. These washers have hardened teeth. The teeth are also bent in such a way that they grip the nut or bolt head, and the surface of the fastened part. Common types are **internal**, **external**, and **internal-external** toothed-lock washers.

Do not reuse lock washers that have been flattened and the tangs or teeth do not spring back into their original shape.

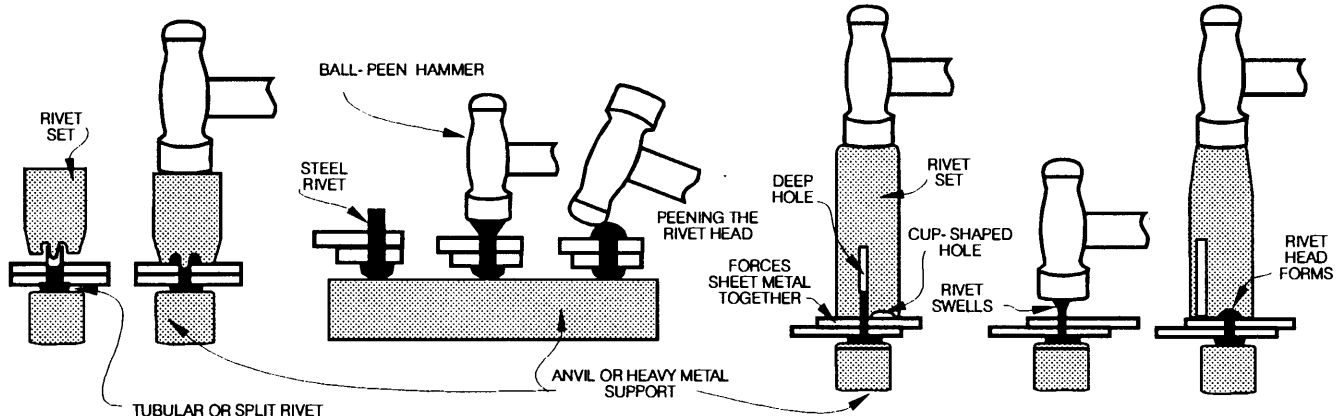
RIVETS

Rivets are fastening devices used to hold materials together by swelling or spreading one or both ends. They are used to fasten everything from steel bridge frames, to sickle mower knife-sections, to thin sheet metal, to pockets on jeans. Rivets may be made of steel, cooper, or aluminum. They are available in solid, hollow-tubular, or split designs with different shapes of heads for various applications.



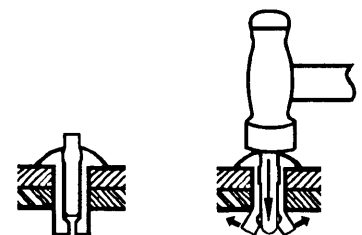
Common Types of Rivets

The rivet selected must fit tightly into the holes through the material. Before the second rivet head is formed, the pieces of material being fastened must first be forced firmly together. The rivet is then swelled or "set" with a **rivet set** and/or a **ball-peen hammer**. The secret to properly setting a rivet is making sure the support behind or under the rivet is heavier than the hammer.



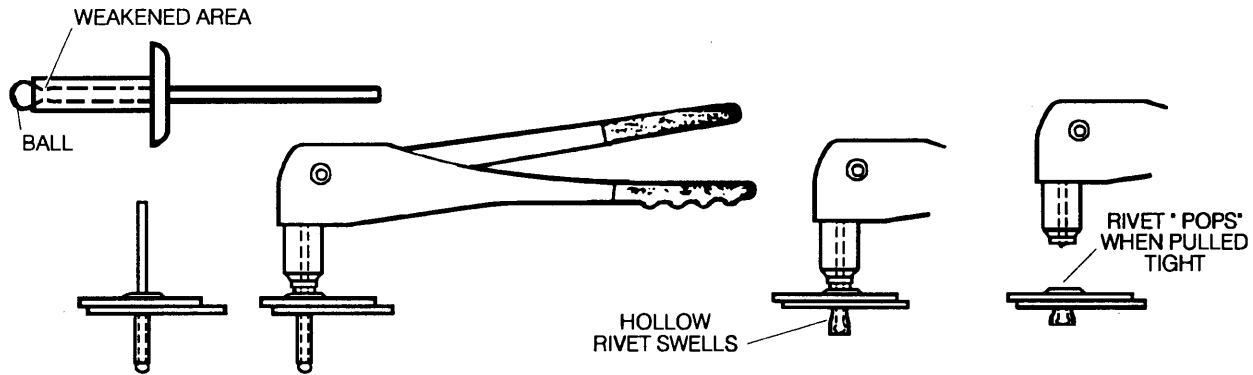
Setting Rivets with Rivet Sets or a Ball-Peen Hammer

Blind hole rivets are used when only one side of the joint is accessible. One type of blind hole rivet is set by driving a pin or stem through a small restricted area in a hollow-tubular rivet. The hollow rivet spreads holding the material together.



Drive-Pin Type Blind Hole Rivet

Another common type of blind hole rivet is called a **pop rivet**. It is set or swelled on the back side by pulling a stem with a small ball on one end through the hollow rivet tube. The ball is slightly larger than the inside diameter of the tube and causes it to swell. When the hollow rivet is pulled tight, the ball breaks or "pops" off at the weakened area.

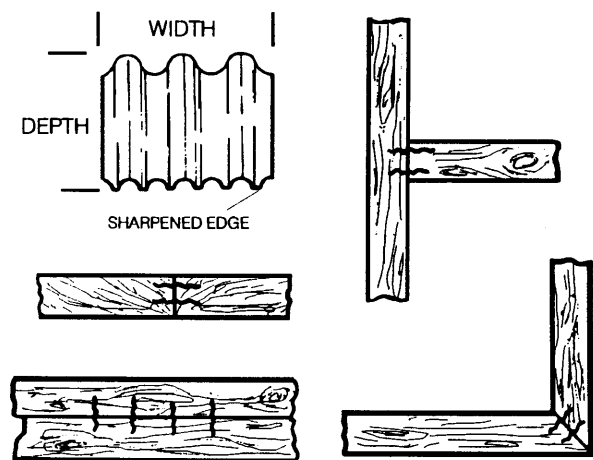


"Pop Rivet" and Pop Rivet Gun

CORRUGATED FASTENERS

Corrugated fasteners are used to connect small boards together when other types of fasteners might split the wood. They are often used on window, door, and picture frames. The bottom edge of the fastener is sharpened so it cuts through the wood fibers as it is installed instead of causing them to split.

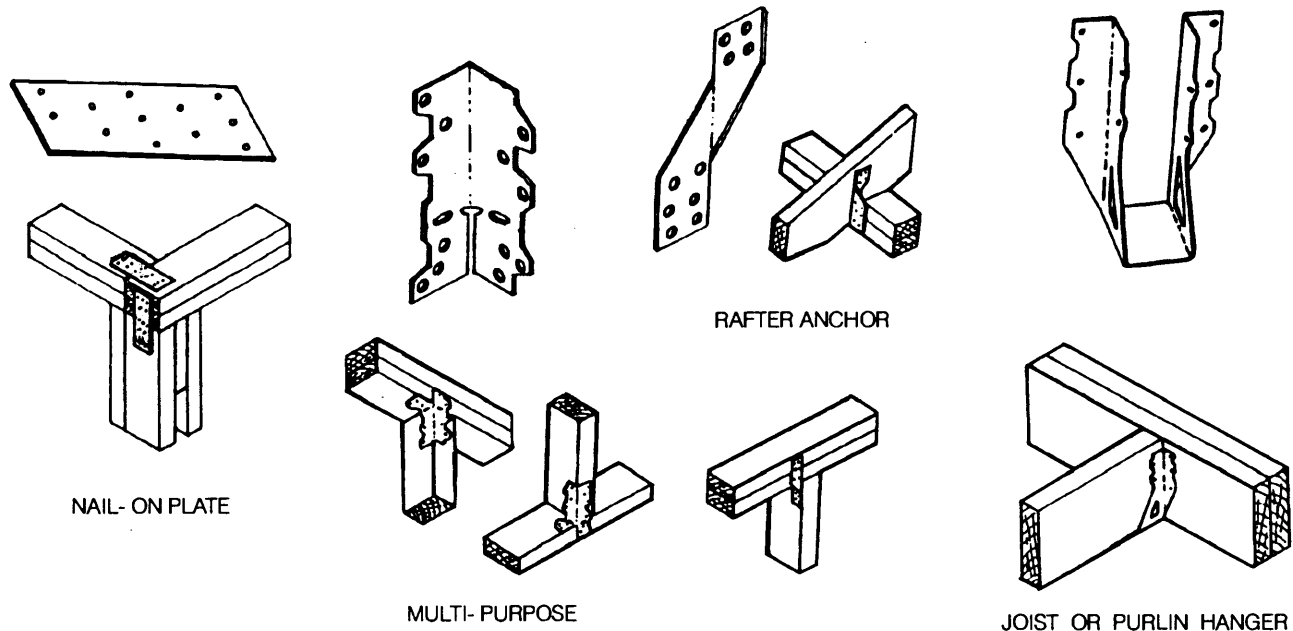
Sizes range in widths from 2 to 7 corrugations and depths from $\frac{1}{4}$ to 1 inch. Always select a corrugated fastener that is at least $\frac{1}{8}$ -inch shorter than the thickness of the wood. The width of a corrugated fastener is evenly spaced between both pieces of wood. The corrugated fastener is slowly driven with a hammer. The fastener must enter the wood straight in order for it to hold properly.



Corrugated Fasteners

FRAMING ANCHORS

In recent years, the use of **framing anchors** has increased in many types of wood construction. When properly installed, framing anchors provide additional strength and bracing to joints. They often eliminate the need for toe-nailing which can cause wood to split.



Framing anchors are available in different pre-formed sizes and shapes for a variety of construction needs. Shapes include: **joist and purlin hangers**, **nail-on plates**, **rafter anchors**, and **multipurpose anchors**. Framing anchors are usually made of galvanized steel. Always follow the manufacturer's recommended installation procedures when using framing anchors.

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Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, and Mr. Bradley Green, Graduate Assistant developed and organized the information in this topic. Mr. Donald Krobot, Intern, Department of Agricultural Education, Texas A&M University developed the student activities.

SUGGESTED STUDENT ACTIVITIES

Fill In The Blank: Complete the following statements by inserting the correct words in the blanks.

- _____ 1. ? are the simplest type of fasteners.
- _____ 2. Lag bolts are fitted into ? ? to fasten wood to concrete, brick, and stone.
- _____ 3. ? ? distribute the stress load over a wider area than bolt heads and nuts.
- _____ 4. ? are devices used to hold materials together by swelling or spreading.
- _____ 5. A ? is a U-shaped wire fastener for securing fencing material to wood posts or frames.
- _____ 6. A nail with a sharp ? is more likely to split wood than a dull one.
- _____ 7. The shanks of some nails are ringed, spiraled, or barbed to ? holding power.
- _____ 8. ? washers are used to keep bolt nuts tight against a metal surface.
- _____ 9. ? is the bending of the point of the nail over on the backside of the joint.
- _____ 10. Nails must be driven at an ? when toenailing.

SHORT ANSWER: Answer the following items in a sentence, phrase or short paragraph. (Use additional paper when needed.)

11. Compare the use of a split-ring lock washer with toothed lock washers.
12. Discuss the procedure for driving fence staples.
13. Discuss the reasons for using fasteners.
14. What are the benefits of using framing anchors?
15. Explain how a standard bolt can be distinguished from a metric bolt by looking at the head.
16. What would happen if a UNC bolt was inserted into an NPT fitting?
17. Discuss the advantages of using drywall screws.

TRUE OR FALSE: Circle "T" if the statement is more true than false. Circle "F" if the statement is more false than true.

- T F 18. A double-headed or duplex nail is commonly used as a fastener for work that is to be disassembled at a later time.
- T F 19. The shank of a box nail is larger in diameter than that of a common nail.
- T F 20. Framing anchors make joints stronger than when using nails or screws.
- T F 21. Metric bolt threads can be UNC coarse, UNC fine, or UNC extra fine.
- T F 22. Grade 1 bolts have a greater tensile strength than Grade 2 bolts.
- T F 23. Nuts are sized by their outside diameter and types of threads.
- T F 24. A 1/4-20 UNF x 1½ would indicate a 1/4 inch bolt 1½ inches long with coarse threads.

ADDITIONAL SKILL AND ENHANCEMENT ACTIVITIES: Perform each of the following as assigned by instructor.

1. Obtain several different sizes of nails and various scrap pieces of wood of various thicknesses. Drive several sharp pointed nails near the ends or edges of materials. Examine splits and cracks. Blunt several nail points on a hard surface. Drive them into the wood pieces near edges and ends. Describe the differences observed.
2. Visit your local hardware supply store and examine the wide variety of fasteners used in different applications. Price a few samples and discuss the proper uses of each.
3. Obtain several different sizes of coarse and fine thread bolts and nuts. Examine the differences. Attempt to start different type threads by hand. Next compare metric (ISO) and standard (ANSI) bolt sizes and thread types. Attempt to start a metric nut on a standard bolt. Observe and discuss results.
4. Mix a large variety of bolts and attempt to identify each by the bolt head markings. Distinguish between different grades and thread designs.
5. If possible, visit several building sites in different stages of construction. Identify as many different types of fasteners as possible, discuss their uses.

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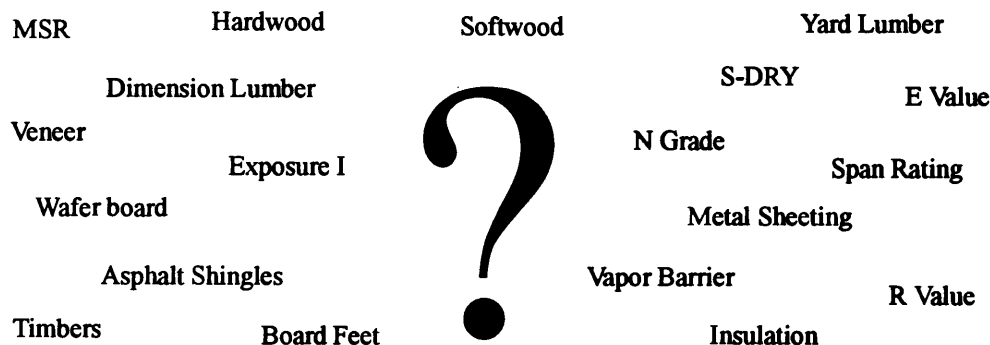
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N1992

IDENTIFYING AND SELECTING WOOD AND OTHER BUILDING MATERIALS



The construction of strong, functional, and long lasting agricultural structures does not end with the proper planning and design of the buildings. The proper building materials, fasteners, and adhesives must also be selected. Factors to consider when selecting materials may include:

alternative costs	availability
ease and cost of installation	durability
life expectancy	personal preference

LUMBER

Lumber is classified as hardwood or softwood. Softwood comes from trees such as pine, cedar, fir, or cypress. Hardwood lumber comes from trees such as oak, walnut, hickory, or ash. Most farm buildings and homes are made of softwood lumber.

Lumber is the general term used to describe wooden products after they have been sawn from the trunk of a tree. It has five major characteristics which will usually determine its use. They include: 1) strength, 2) durability, 3) appearance, 4) paint holding ability, and 5) nail holding ability.

The **strength** of the wood is probably the most important factor when selecting lumber for agricultural structures. Lumber is the main structural support in many types of construction. There are two factors of strength to consider. *Bending strength* is a measure of the horizontal load carrying capacity of a board. *Stiffness* is a measure of the resistance to bending or deflection under load.

For example: Two boards of the same size and length may easily be able to support several thousand pounds of weight in the middle without breaking. However, one board may bend or deflect one inch under the load, while the other may bend or deflect two inches.

The strength of lumber is determined by: 1) the size and type of the grain pattern, 2) size and type of knots, 3) separation of the wood fibers between the growth rings, 4) rot or decay, 5) the orientation of growth rings when the lumber was sawn, and 6) moisture content.

Durability is the lumber's ability to resist wear and deterioration. The summer growth rings and heart wood of certain species of trees are harder and more durable than others.

Appearance is also considered. This is especially true when lumber is used for trim or when large surface areas are exposed.

Nail holding ability refers to how well the lumber grips a fastener. As a rule, the denser and harder the wood, the greater the nail holding ability. Increasing the diameter of the nail will also increase the holding power, provided the wood does not split. Pilot holes and blunt-pointed nails will reduce splitting.

The ability of lumber to bond with paint is its **paint holding ability**. Lumber that is sawn with the edge of the grain exposed rather than the flat side will normally hold paint better. Paint will also stick better to lumber that is free from excessive knots, natural pitch or resins, and surface moisture.

Lumber Grades

Softwood lumber is graded to standards established by the U. S. Department of Commerce. Regional independent inspection agencies such as the Southern Pine Inspection Bureau (SPIB) or the Western Wood Products Association (WWPA) enforce these standards. The terminology and abbreviations used will vary slightly among the different inspection agencies. For purposes of grading, lumber used in most residential and agricultural construction is categorized into two broad classifications: 1) yard lumber and 2) structural lumber.

COMMON LUMBER GRADES

CLASSIFICATION	GRADE	DESCRIPTION OR USE
YARD LUMBER		
<u>Finish or Select</u> up to 2" nominal thickness, 2" or more wide	B or btr C D	Graded for appearance as trim and molding Very clear, only minor defects for natural finish More and larger defects for paint finish Lower quality, still suitable for painting
<u>Boards</u> up to 2" nominal thickness, 2" or more wide	Select or #1 Construction or #2 Standard or #3 Utility or #4 Economy or #5	Graded for appearance and use as general construction lumber Light residential and agricultural construction panels, siding, shelving, etc. Subfloors and roof sheathing Lower in quality than #2 Low cost - light construction Crating, bracing, and low quality sheathing
STRUCTURAL LUMBER		
<u>Dimension</u> 2" to 5" thick, 2" or more wide		
<u>Light Framing</u> 2" to 4" thick, 2" to 4" wide	Construction Standard Utility Economy	Used where only good strength and appearance are required General framing Little lower quality for general framing Lower cost - good strength for blocking, studding, and plates, etc. Crating, some bracing and temporary construction
<u>Structural Light Framing</u> 2" to 4" thick, 2" to 4" wide	Select Structural #1 #2 #3	For engineered use when higher strength is required Where highest strength, stiffness, and good appearance is required such as exposed trusses, structural framing, rafters, joists, etc. Similar to Sel. Str. but a little lower quality Lower strength general structural construction General structural construction where appearance is not a factor
<u>Structural Joists and Planks</u> 2" to 4" thick, 6" and wider	Select Structural #1 #2 #3	Where highest strength, stiffness, and good appearance is required such as exposed trusses, structural framing, rafters, joists, etc. Similar to Sel. Str. but a little lower quality Lower strength general structural construction General structural construction where appearance is not a factor
<u>Stud</u> 2" to 4" thick, 2" to 4" wide less than 10' long	Stud	Only one grade where high compressive strength and stiffness is required, but less concern for appearance
<u>Timbers</u> 5" or more in least dimension	Select Structural #1 #2 #3	Superior strength and appearance for exposed beams, etc. Similar to Sel. Str. but a little lower quality General construction Rough general construction, lower quality and strength

Yard lumber is a general category for lumber *less than* two inches thick. It is graded primarily for visual appearance and finishing ability, with less concern for strength. The two classes of yard lumber are: 1) boards, and 2) finish or select. **Boards** are less than two inches in thickness and more than two inches in width. They are used in general light construction, fencing, sheathing, sub-flooring and some finish work. **Selects and finish** are for interior and exterior trim, molding and finish work.

Structural lumber is the general category of lumber *at least* two inches in thickness. It is primarily graded for its potential use and strength, as well as appearance. Structural lumber is further divided into: 1) dimension lumber and 2) timbers.

Dimension lumber is two to five inches thick and two or more inches wide. Dimension lumber is then sub-divided into four different categories based on size and intended use. **Timbers** are at least five inches thick and used for heavy framing and supports.

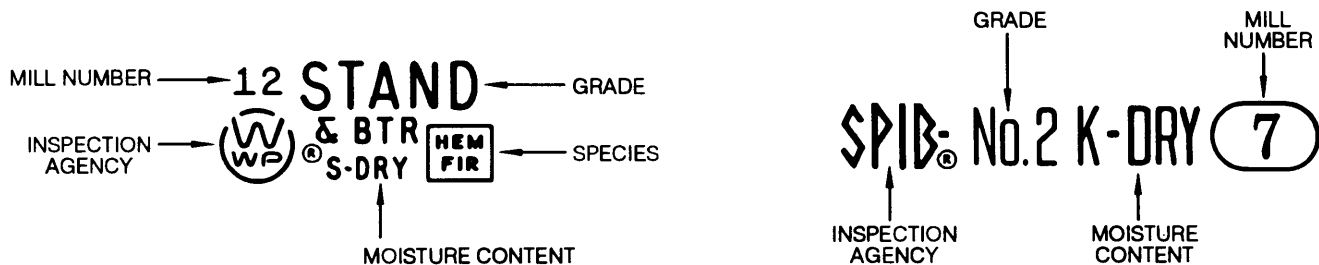
Shown in the chart is a general description of the different sizes and grades of lumber and their common uses. For comparison, a "*select structural grade*" - structural light framing 2" x 4" is approximately twice as strong as a "*construction grade*" - light framing 2" x 4."

Lumber graders visually monitor lumber as it comes off the saw for the number and type of defects. To test lumber for strength, a piece must be pulled from the saw line and put into a press. The deflection and the force needed for the lumber to break is then recorded. Since this test destroys the piece of lumber, only representative samples are periodically tested. Graders then select the appropriate lumber grade for the rest of the bundle or stack. The grade is based on the "average appearance and strength" in comparison to the lumber actually tested.

The moisture content of lumber affects how much it will swell, shrink, or warp, and the strength of the wooden fibers. Standards established by inspection agencies limit the surface moisture level when the lumber is milled and graded. A **S-GRN** stamp indicates the lumber was milled when it was green with surface moisture content higher than 20 percent. This type of lumber is more likely to shrink and warp when used.

S-DRY lumber is dried in large covered stacks in the outdoor air. The final milling and grading is performed when surface moisture level is below 19 percent. **K-DRY** or **KILN-DRY** lumber is dried inside huge heated kilns where the temperature and humidity are carefully controlled. K-dry lumber is milled and graded when the surface moisture level is between 15 and 19 percent.

Normally, a lumber yard will not stock each grade of lumber, but it will have a variety in different price ranges suitable for most needs. Lumber is usually available in lengths from 8 to 24 feet in increments of 2 feet. Lengths over 20 feet will usually cost more per foot and may have to be special ordered. When selecting lumber for strength, inspect and sort pieces that are clear (free from knots) or that have only small knots. Other defects such as warps, cracks, and signs of decay should be avoided if possible.



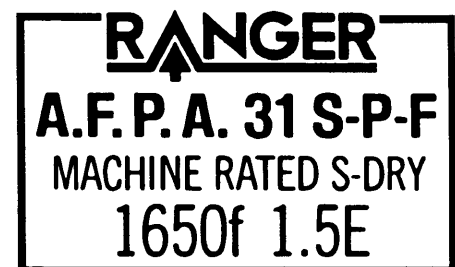
Common Lumber Grade Stamps

MSR Lumber Grades

For many years, lumber was only visually graded as it came from the saw mill. Today, modern technology and new building codes have brought about the use of **Machine Stress Rated (MSR)** dimension lumber. This lumber may be used for structural building frames and trusses.

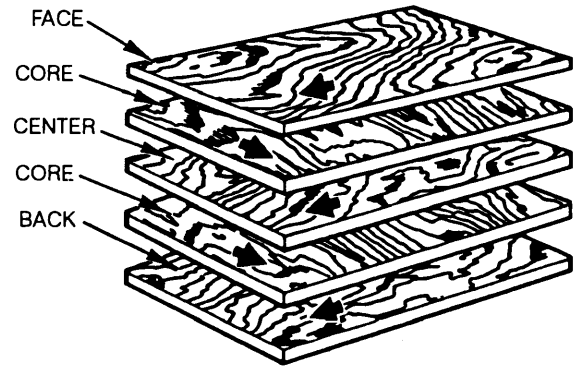
Many modern sawmills have machines that can test each piece of lumber. The test is nondestructive and does not affect the other properties of the lumber. The lumber goes through a machine which electronically calculates an **"E" value** (modulus of elasticity) based on the stiffness of the lumber. The higher the "E" value, the higher the bending strength. The bending strength or fiber stress of wood is expressed as a **"F or Fb" value**. Every piece of lumber which successfully passes the MSR test is then visually graded for the other requirements.

MSR dimension lumber is now available at many lumber yards in common 2"x4" and 2"x6" lengths, or by special order. MSR lumber will cost more, but builders or contractors can be more confident that the structures or trusses they build will meet or exceed strength specifications.



PLYWOOD

Plywood is a versatile building material for many agricultural applications because of its strength and durability. Plywood is made by gluing three, four, or five thin sheets or "plys" of wood called **veneer** in alternating directions. Veneers are "peeled" from many different types and grades of logs. The type and grade of log affects the quality and potential use of the plywood.



Composition And Grain Direction
Of A Sheet Of Plywood

Veneer Grades - As the veneer is peeled from the logs, it is graded on the basis of the type, size, and number of defects. Defects include knots, knot holes, pitch pockets, splits in the grains, and stains. Veneer grades range from N to D.

- N: *N grade* is the highest quality veneer. It has a "natural finish" veneer that is free of defects and has less than six neatly repaired splits. Plywood with a N grade veneer is not used much in agricultural construction.
- A: *A grade* veneer is free of open defects and surfaces are smooth for natural or painted finishes. Up to 18 repairs to the grain can be made.
- B: *B grade* veneer provides a solid surface with circular repairs and tight knots up to 1" diameter. Some minor splits are allowed.
- C: *C grade-plugged* veneer is repaired and limits splits to 1/8" wide. Knot and insect borer holes up to 1/4" x 1/2" are allowed.
C grade veneer allows tight knots up to 1-1/2" and knot holes up to 1 inch. Synthetic and wood patches are permitted with limited grain splits. Stitching of split grains is also allowed.
- D: *D grade* veneer is the lowest quality allowed and is limited to use on Exposure I and Interior plywood. Knots and knotholes up to 2-1/2" wide across the grain are allowed. Limited splits and stitching are permitted.

Plywood is manufactured to standards established by the U.S. Department of Commerce and the American Plywood Association (APA). Plywood is divided into different categories by: 1) front, middle, and back veneer grades; 2) type of glue used; 3) types of trees the logs are cut from; and 4) potential use grades.

Glue Types - Interior plywood is bonded together with a glue that is water-resistant, but not water proof. It is not recommended for outdoor use or wet indoor areas. Some plywood designed for sub-floors and roof sheathing is stamped with **Exposure I** or **Exposure II**. This means it is designed for interior use, but can be exposed to wet weather for short periods. Exposure I will withstand longer periods of moisture than Exposure II. All **exterior plywood** is manufactured with veneer grades and waterproof glue which can be exposed to outdoor weather or high moisture areas. Some special purpose interior plywoods may also be made with waterproof exterior glue and will be marked for "Interior use - Exterior glue."

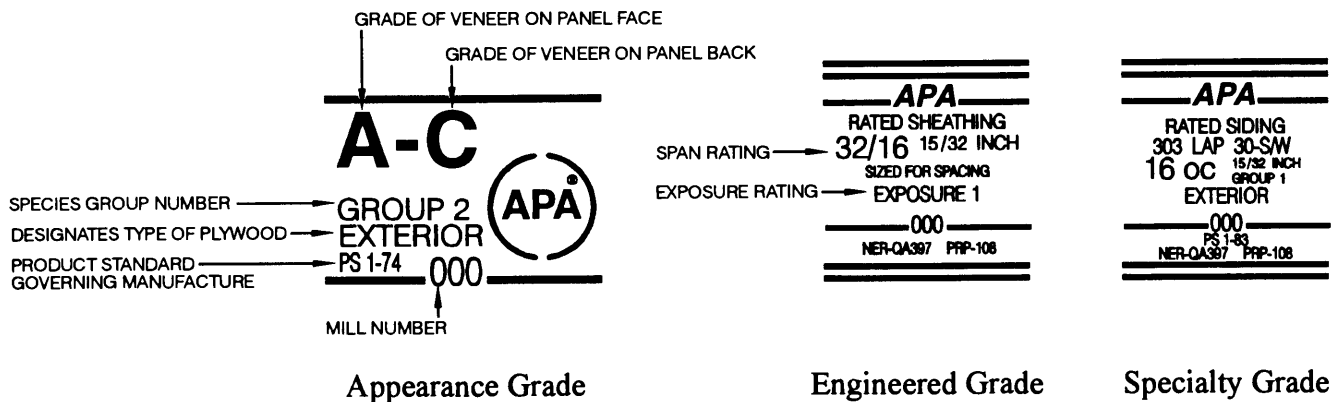
Tree Group Classification - Logs for plywood can be cut from over 70 different species of trees. The wood fibers of some species are stronger, stiffer, and more durable than others. For grading purposes, these 70 species are divided into 5 groups (Group 1 to Group 5). The lower the group number, the higher the strength of the plywood.

Use Grades - Plywood is also classified into three groups or use grades based on a combination of the other characteristics, qualities, and the designed use. They include: 1) appearance, 2) engineered, and 3) speciality grades.

Appearance grade plywood has a sanded surface designed and graded primarily for the finished appearance. Plywood with an appearance grade of **BC** would have "B" grade veneer on the face side and "C" grade veneer on the back side.

Engineered grade plywood is usually unsanded and is graded based on the engineered strength, veneer grade, group number, and glue type. Engineered plywood stamps will also show the **span rating**, which is an indication of the plywood strength. The span rating appears as two numbers separated by a slash such as 32/16. The left hand number indicates the maximum recommended spacing of supports when the plywood is used for roof sheathing. The right hand number is the recommended spacing when the plywood is used for sub-flooring.

For Example: One-half inch plywood with a span rating of 32/16 could be used as roof sheathing if rafters are placed on 32-inch centers or closer. The same plywood could be used as sub-flooring if floor joists were placed on 16-inch centers or closer.



Typical Plywood Grade Stamps

Speciality grades are classified based on strength, glue type, and special surface textures or finishes for siding, etc. Speciality grades may also be span rated.

Several other types of four-by-eight feet sheets of wood panels are gaining popularity in many types of agricultural building construction because of their lower cost. **Particle board** is made of fine wood flakes, chips and shavings bonded together with water resistant resin glues. Particle board is not as strong as other types of wood panels and plywood. Also, the wood fibers in particle board will swell and the glue will deteriorate when it becomes wet.

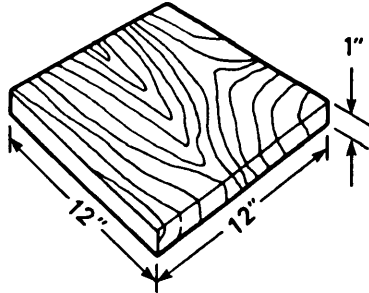
Waferboard is made of higher quality, higher strength flakes of wood up to one and one-half inches square. The flakes are bonded together in a random pattern under heat and pressure with a water proof resin glue.

Oriented strand board is similar to waferboard in appearance, but is made of narrower strands or strips of wood fibers. The fibers are laid in layers arranged at approximate right angles to each other. They are then heated, pressed, and bonded with a water proof glue. Some grades of waferboard and oriented strand board may be span rated and treated for use as roof sheathing, sub-flooring, walls, and dividers.

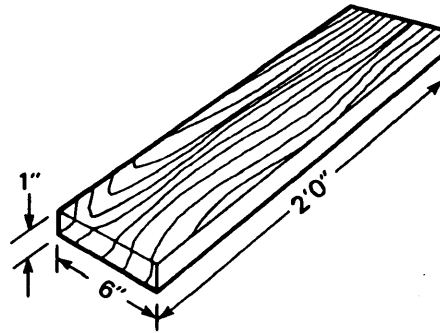
CALCULATING BOARD AND SQUARE FEET

Large quantities of lumber are often priced by the board foot. A board foot is 1-inch thick, 1-foot wide, and 1-foot long. The number of board feet is calculated by using the **board foot formula**.

1 BOARD FOOT = 1" X 12" X 1' 0" LONG



OR



1 BOARD FOOT = 1" X 6" X 2' 0" LONG

To use the board foot formula, lumber must be grouped by width, thickness, and length. The length of the boards may be measured in feet or inches. If the length is in feet: multiply the number of boards by the thickness, times the width, times the length, and divide by 12. For example, to find the board feet in 5 - 2"x4" - 12' 0" long, proceed as follows:

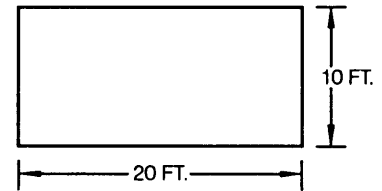
$$\begin{array}{r} 5 \times 2 \times 4 \times 12 \\ \hline 12 \end{array} = 40 \text{ board feet}$$

If the length is in inches, follow the same procedure, but divide by 144 instead of 12. For example, to find the board feet in 6 - 2"x4" - 120" long, proceed as follows:

$$\begin{array}{r} 6 \times 2 \times 4 \times 120 \\ \hline 144 \end{array} = 40 \text{ board feet}$$

A **square foot** is one-foot long and one-foot wide, regardless of thickness. It is often abbreviated as sq. ft. Many types of wall and floor coverings are sold by the square foot. The formula to calculate the total square feet of an area is the total length times the total width. For example, the total square feet for a flat roof that is 10-feet wide and 20-feet long is calculated as follows:

$$10' \times 20' = 200 \text{ sq. ft.}$$

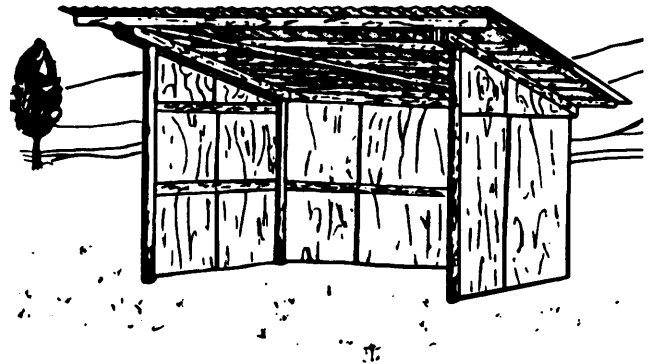


ROOFING AND SIDING MATERIALS

The most common types of roofing materials for agricultural structures are metal sheeting and asphalt shingles. Common siding materials include metal sheeting and plywood.

Advantages of metal sheeting include:

1) lower initial building cost, 2) ease of installation, 3) fire-resistance, 4) wind-resistance when properly installed, 5) hail-resistance, and 6) a long useful life. Metal sheeting may be: 1) corrugated, galvanized steel, 2) corrugated painted steel, or 3) corrugated aluminum.



Metal sheeting is available in 26, 28, 29, or 31 gauges with 26 being the thickest. **Standard corrugated, galvanized steel** is 29 gauge. It is often selected for siding while the heavier 26 gauge is used for roofing because of its strength. The corrugated sheets are zinc coated for rust protection. The zinc coating is measured in ounces per square foot of metal sheeting. Galvanized metal is manufactured to ASTM standards.

Current coatings designations used for agricultural roofing and siding are: G90 and G60. **G90** is called **commercial** coating and has .90 ounces of zinc per square foot (total for both sides). It replaces the previous 1.25 coating class. When used in general agricultural applications, **G90** has an expected life of 10 to 15 years life before rust begins to show.

G60 is called **light commercial** and has .60 ounces of zinc per square foot. It will have an expected life of 7 to 10 years in normal conditions before beginning to rust. Heavier coating designations are also available in some areas. The small differences in the weight of the zinc coatings means a great difference in the length of time before the galvanized metal will begin to show rust.

Corrugated painted steel roofing or siding is gaining popularity because of a longer life expectancy and neater appearance. However, it is more expensive. Different color enamel paints are baked on top of the galvanized steel during the manufacturing process. This can extend the useful life to over 40 years.

Metal sheeting is available in widths from 24 to 48 inches wide and common lengths up to 24 feet. Special order lengths up to 40 feet are available to help eliminate seams and joints on larger buildings. Different corrugation heights and patterns are available from different manufacturers.

The height and pattern of the corrugation helps determine the strength of the roofing or siding and the recommended spacing between purlins or girts. The larger and the higher the corrugation or crimp pattern, the further apart the support spacing can be. Always follow manufacturers' recommended procedures when attaching metal siding or roofing materials.

Corrugated aluminum can last 40 to 50 years, however wind or hail can easily damage it. It is used in some areas to re-cover existing wooden or asphalt shingle roofs and also as siding where strength is not a factor. Aluminum sheeting may be used in some new construction as a covering over solid wall, roof sheathing, or decking.

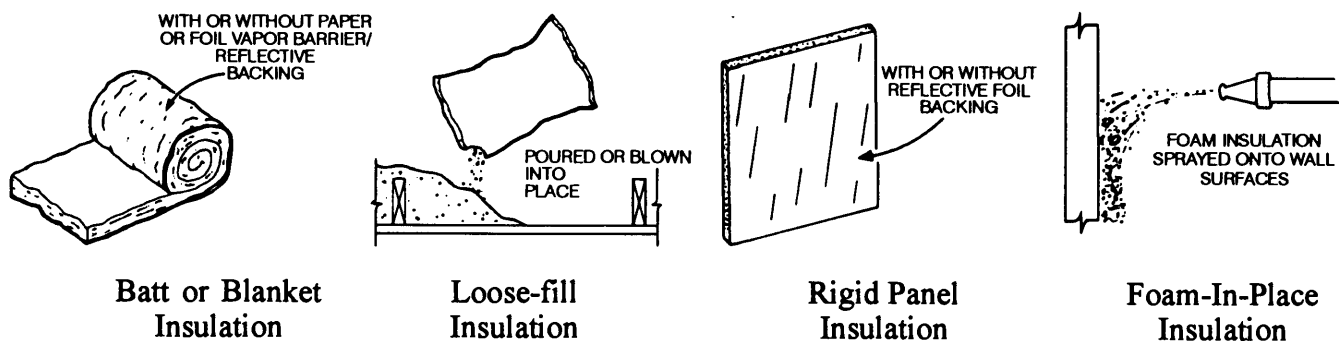
Asphalt cellulose or fiberglass reinforced shingles have a life expectancy of 7 to 25 years. Asphalt shingles must be laid on a solid decking or sheathing. They are not as resistant to hail, sun, high winds, or fire. Shingles need a roof with a slope of five inches to the foot or greater. The cost of solid sheathing and extra roof support can increase the cost of asphalt shingles.

INSULATION

Insulation is any material that reduces the heat transferred from one area to another. Most common building materials such as wood and concrete have some insulation value. However, the term "insulation", as related to building construction, refers to materials especially made with a high resistance to heat transfer. Insulation is usually lightweight and contains large numbers of tiny trapped air spaces. The **R-value** of a material indicates its resistance to heat transfer. The higher the R-value, the higher the resistance to heat transfer.

With increasing fuel cost, insulation can often pay for itself in savings over a period of two to four years. Insulation can: 1) conserve energy by preventing heat loss from the inside out, during the winter, 2) reduce heat gain from the outside in, during the summer, and 3) prevent or help control formation of condensation as temperatures change.

A **vapor barrier** is often installed on the warm side of the walls and ceiling to help stop the outward flow of moisture. Common vapor barriers are aluminum foil, polyethylene plastic film, and asphalt building paper (tar paper). Some types of insulation have a built-in vapor barrier backing that is inserted as the insulation is installed.



There are five general types of insulation used in building construction. **Batt or blanket insulation** is made of mineral wool, fiberglass, or cellulose fibers. It is available in 1 to 8-inch thick layers, 16 to 48-inch widths, and in various length rolls. Batt or blanket insulation may have some type of paper, plastic or aluminum backing on one side.

Loose-fill insulation is packaged in bags. It is made of such materials as mineral wool, cellulose fibers, ground cork, corn cobs, or polystyrene. It is usually poured or blown into place. Some types of loose-fill insulation have a tendency to settle over time leaving an unprotected area when used in vertical walls.

Rigid insulation is made of cellulose fibers, fiberglass, polystyrene, and polyurethane. It comes in sheets 1/2 to 4 inches thick, up to 4-feet wide and lengths from 8 to 12-feet long. Rigid insulation may also provide some structural strength.

Foam or foam-in-place is a relatively new type of insulation. It is made by mixing organic chemicals with air or inert gases causing the chemicals to foam. As they dry, small air cavities are formed. This process is used to make certain types of rigid insulation, or it can be sprayed on surfaces or into larger cavities. Some types of foam insulations are highly flammable and give off toxic fumes when they burn.

Reflective insulation is made of aluminum foil or similar materials to reflect radiant heat. Reflective insulation may be combined with vapor barriers and other types of insulation.

Factors to consider when selecting the type of insulation to use include: 1) R-value per inch of material; 2) ease of installation; 3) compatibility with the type of building design and location in the structure where insulation will be installed; 4) fire-resistance; 5) possible damage from exposure to livestock, rodents, birds and weather; and 6) cost.

Many types of building material are not considered "insulation" even though they have some R-value. However, their insulation value is included when totaling the R-value of a complete wall or roof section. Shown in the table are the R-values for common types of insulation and different types of building materials.

Agricultural structures are classified into three types: **cold buildings, modified environment or cool buildings, and supplementally heated or warm buildings.** Cold buildings are usually not insulated. Small amounts of insulation are used in the walls and ceiling of cool buildings. Warm buildings require larger amounts of insulation to reduce energy heating costs.

R-VALUE OF COMMON TYPES OF INSULATION AND BUILDING MATERIALS

MATERIALS	APPROXIMATE R-VALUE	
	PER INCH	FOR THICKNESS LISTED
Batt & Blanket		
Mineral wool or Fiberglass	3.00 - 3.80	
Loose-fill		
Cellulose	3.13 - 3.70	
Fiber glass or		
Mineral wool	2.50 - 3.00	
Vermiculite	2.20	
Shavings or sawdust	2.22	
Rigid Insulation		
Extruded polystyrene	5.00	
Molded polystyrene	4.20	
Expanded polystyrene	6.25	
Glass fiber	4.00	
Wood or can fiberboard	2.50	
Polyisocyanurate	7.04	
Foam or Foam-In-Place		
Polyurethane	6.00	
Building Materials		
Concrete, solid	0.08	
Concrete block		
8" standard weight		1.11
8" lightweight aggregate		2.00
Metal siding		0.00
Softwoods		
Fir and pine	1.25	
Hardwoods		
Maple and oak	0.92	
Plywood, 1/2"	1.25	0.62
Hardboard, tempered, 1/4"	1.00	0.25
Insulating, sheathing, 25/32"		2.06
Asphalt shingles		0.44
Wood shingles		0.94
Windows		
Single glazed		0.91
With storm windows		2.00
Double pane, 1/4" air space		1.69
Air space (3/4" to 4")		0.90

Acknowledgements

Mr. Bradley J. Green, Graduate Assistant, Department of Agricultural Education, Texas A&M University and Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the material in this topic.

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Ranger Machine Stress Rated Lumber, Simpson Timber Company, Shelton, WA.

APA Design/Construction Guide, American Plywood Association, Tacoma, WA.

Quality Control Department, Granite City Steel Division, Granite City, IL.

SUGGESTED STUDENT ACTIVITIES

LISTING: Respond to the following items in the spaces provided.

1. List five major characteristics of lumber which determines its use.

(a) _____	(b) _____
(c) _____	(d) _____
(e) _____	

2. List five of the six factors discussed that determine the strength of lumber.

- (a) _____ (b) _____
(c) _____ (d) _____
(e) _____

3. List three types of common sheet metal roofing.

- (a) _____ (b) _____
(c) _____

**TRUE OR FALSE: Circle "T" if the statement is more true than false:
Circle "F" if the statement is more false than true.**

- T F 4. When lumber splitting is a problem, sharp-pointed nails should be used.
- T F 5. Paint will adhere better to lumber that has rough knots and natural pitch than a smooth surface.
- T F 6. Standard or utility grade light framing 2"x4"s are the recommended grades to use for rafters and joists.
- T F 7. When selecting MSR graded lumber for constructing trusses, the higher the "E" and "F" values, the stronger the lumber.
- T F 8. Corrugated galvanized steel that is 26 gauge with a G90 zinc rating is better quality than standard 28 gauge-G60 galvanized steel.
- T F 9. Corrugated galvanized steel siding or roofing materials will normally last longer than corrugated painted steel siding or paneling.

MATCHING: Match the letter of the option in the right-hand column with the term in the left-hand column it best matches.

_____ 10. Rigid insulation	A. material used to stop flow of moisture through air.
_____ 11. Vapor barrier	B. best veneer with only six or less neatly made repairs.
_____ 12. R-value	C. building materials especially made with a high resistance to heat transfer.
_____ 13. C grade	D. veneer with tight knots up to 1-1/2", holes up to 1" and grain splits.
_____ 14. Insulation	E. resistance of a material to heat transfer.
_____ 15. N grade	F. sheets made of cellulose fibers, fiberglass, polystyrene or polyurethane.
_____ 16. Batt insulation	G. made of mineral wool, fiber glass or cellulose fibers in various thicknesses and various length rolls.

FILL-IN-THE-BLANKS: Place the correct word(s) in the space provided.

_____	17. <u> ? </u> is a lumber's ability to resist wear and deterioration.
_____	18. <u> ? </u> lumber is milled and graded at surface moisture levels over 20 percent.
_____	19. <u> ? </u> lumber is stack dried in large covered stacks until the surface moisture is below 19 percent.
_____	20. <u> ? </u> lumber is dried inside large heated kilns to a surface moisture level between 15 and 19 percent.

SHORT ANSWER: Answer the following items in a sentence, phrase or short paragraph.

21. Briefly explain the MSR lumber grading system and explain why it is important.

22. Describe several advantages of metal sheeting.

23. Briefly explain "loose fill" insulation. List one disadvantage of using it.
24. Explain the difference between CD exterior grade plywood and BC interior grade plywood.
25. Discuss the factors to consider when selecting the type of insulation to use.

ADDITIONAL SKILLS & ENHANCEMENT ACTIVITIES: Perform the following activities or skills as assigned by your instructor.

1. Drive sharp and blunt-pointed nails near the end of samples of different size and grades of lumber to demonstrate the effect of splitting.
2. Interview a person in your community who has recently constructed an agricultural structure. Determine the factors used in selecting the type and grade of materials selected in addition to total cost.
3. Obtain building plans and planning handbooks for an agricultural structure you or someone you know may be planning. Determine the type and grade of lumber and other building materials recommended.
4. Call toll-free or write to different building material trade associations and suppliers for the latest literature on new types, grades, or specifications of building materials.

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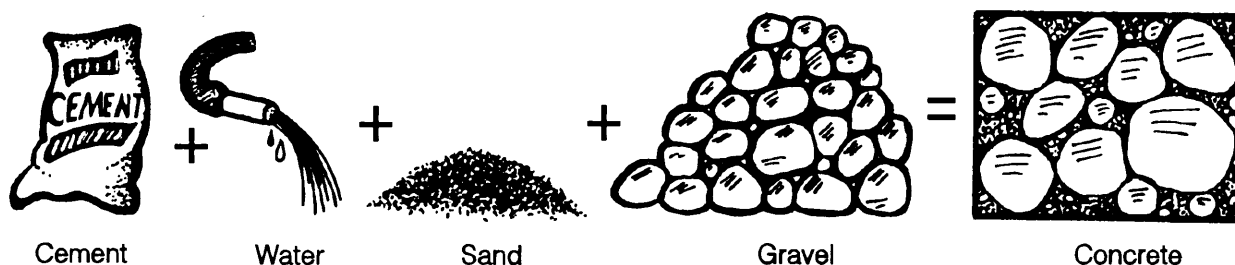
IDENTIFYING AND SELECTING CONCRETE AND MASONRY BUILDING MATERIALS

Do you know the difference between concrete and cement? What makes quality concrete? What is masonry construction?

QUALITY CONCRETE

Concrete and masonry are becoming popular building materials in many types of agricultural structures and projects. There are several advantages for using concrete and masonry construction. Concrete and masonry can be **cheaper** and **stronger** than some other types of building materials. Concrete and masonry structures are **durable** because they will not burn and can be rodent proof. Concrete and masonry **will not rot or wear away** rapidly. When allowed to properly cure, concrete becomes **watertight**. Concrete can be **molded** into many different shapes by using forms or molds.

Cement is made by mixing limestone, shale, clay, iron ore, and gypsum together. The mixture is heated and ground into a very fine dry powder. Small 94 pound sacks of dry cement are sold to lumber yards and other stores for resale to individual customers. Cement is also sold in bulk form to ready-mix concrete plants.



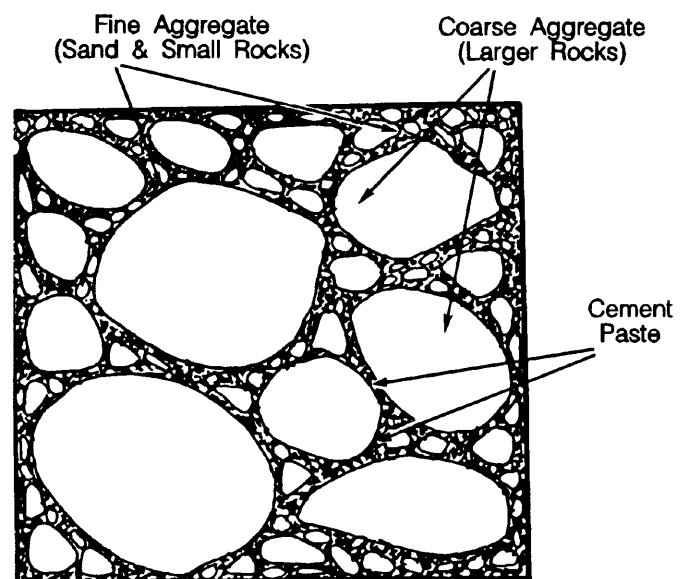
Concrete is a mixture of the dry powdered cement, aggregate, and water. **Aggregate** is another name for the sand and small rocks or gravel. Fine aggregate is the sand and small rocks less than $\frac{1}{4}$ inch in diameter. Coarse aggregate refers to rocks between $\frac{1}{4}$ and 2 inches in diameter.

When mixed, the cement powder and water make a **cement paste**. Cement paste forms the glue-like gel that holds each small rock and sand particle together when it hardens. An individual can mix concrete in a wheelbarrow or small portable mixer for some projects. In addition to the cement, clean water, sand, and rock must be obtained, measured, and mixed. For some small projects, "*Sack-crete*" is available. Sack-crete is a pre-measured mixture of dry cement, sand, and small gravel in a sack. All you do is add the correct amount of water and then mix. It is like a pre-measured cake mix in a box. Sack-crete is known by many different brand names.

Concrete for large projects is usually ordered from ready-mix concrete suppliers. Large quantities of water, bulk cement, sand, and rock are weighed. They are then mixed and delivered to the job site in large mixer trucks.

The cement and water used in concrete or sack-crete goes through a chemical process as it dries and hardens called **hydration**. The cement paste bonds or "glues" the sand particles, gravel or rock, and any reinforcement steel together as it goes through the hydration process.

Quality concrete is made with minimum voids and the correct amount of cement and water. A **void** is an empty space or opening. There must be enough cement paste to coat each small grain of sand and each rock. The mixture must be properly mixed and placed in the forms. The cement paste, sand, and smaller pieces of rock will then fill in all the voids between the larger rocks. If all the voids are not filled, the concrete will be weak. This is because the tiny voids will only contain air and the sand and rocks will not be bonded together.



AFFECT OF WATER-CEMENT RATIO ON STRENGTH OF CONCRETE

Even if there is enough cement, sand, and small rocks, the water and cement must be in the proper ratio. When too much water is used, the cement paste or "glue" will be diluted. The mixture will be too "soupy." Part of the extra water will evaporate as hydration occurs. When the extra water evaporates, it will leave many more tiny voids or air spaces. This will weaken the concrete. If too little water is used, there will not be enough for the complete chemical reaction. This will also weaken the concrete.

As discussed, the amount of cement and water in a concrete mixture affects its strength. The more cement added to a mixture, the stronger the concrete will be. Cement is also the expensive ingredient in concrete. The more cement used, the more expensive the concrete.

Water-cement ratio is one way of expressing the amount of water and cement used in the concrete. **For example:** one small concrete mixture uses 94 pounds of cement (one sack = 1 cu ft and weighs 94 lbs), 5 gallons of water, and the proper amount of sand and gravel. Water weighs 8.3 pounds per gallon.

$5 \text{ gal} \times 8.3 \text{ lbs/gal} = 41.5 \text{ lbs water}$ $41.5 \text{ lbs} \div 94 \text{ lbs} = .44$ **water-cement ratio**

When mixed with the proper amount of sand and gravel, this type of mixture would be "stiff." It would be more difficult to place in the forms, smooth, and finish. However, when properly cured, it would have a compressive strength of approximately 4,500 psi. This is considered a strong concrete.

Suppose another mixture used the same amount of cement, sand, and rocks. Instead of 5 gallons of water, 8 gallons is used. The mixture would be very "soupy."

$8 \text{ gal} \times 8.3 \text{ lbs/gal} = 66.4 \text{ lbs water}$ $66.4 \div 94 \text{ lbs} = .71$ **water-cement ratio**

This type of mixture is easier to place in the forms. But, when properly cured, it would only have a compressive strength of less than 3,000 psi. This type of concrete could crumble, break, and wear away much easier. (**Note:** The amount of sand and gravel used in a mixture will be discussed in other topics.)

Some projects require the strongest concrete available that will not wear away. Others do not require maximum strength or durability and can be mixed as cheap as possible.

One can control the strength of the concrete and its expense by controlling: 1) the amount of cement, 2) the amount of water, 3) size of the aggregate, and 4) the type of the aggregate. Aggregate is not used as just a filler. If the aggregate is weak and crumbly, the concrete will also be weak and crumbly. The size and type of aggregate to use are discussed in other student topics.

Shown in the table are examples of different types of agricultural structures. Also shown are: 1) the recommended strength of the concrete needed; 2) the amount of cement used for each cubic yard of concrete; 3) the amount of water added for each sack of cement; and 4) the approximate water-cement ratio for each type of mixture.

Type Structure or Conditions	Approx. Compression Strength(PSI)	Sacks of Cement/ 1 cu. yd. Concrete	Gallons of Water/ 1 Sack of Cement	Water-Cement Ratio (lbs. Water/ 94lbs. Cement)
Severe Abrasion and Wear- Higher Strength Confinement Livestock Slats, Feed Bunks, Above Ground Silos, Dairy Barns	4,500 & Above	6.5 to 7.0	5.0	.44 & Less
Manure Pits, Parking Lots, In-Ground Silos	4,000	6.0	5.5	.49
Feedlots, Shop-floors, Driveways, Slabs, Re-inforcement Walls, Support Beams and Columns, Sidewalks	3,500	5.5	6.0	.53
Larger Foundation Walls, Footings, Massive Structures, Etc. Less Severe, Lower Strength	3,000 & Below	4.5 to 5.0	6.5 to 7.0	.58 to .66

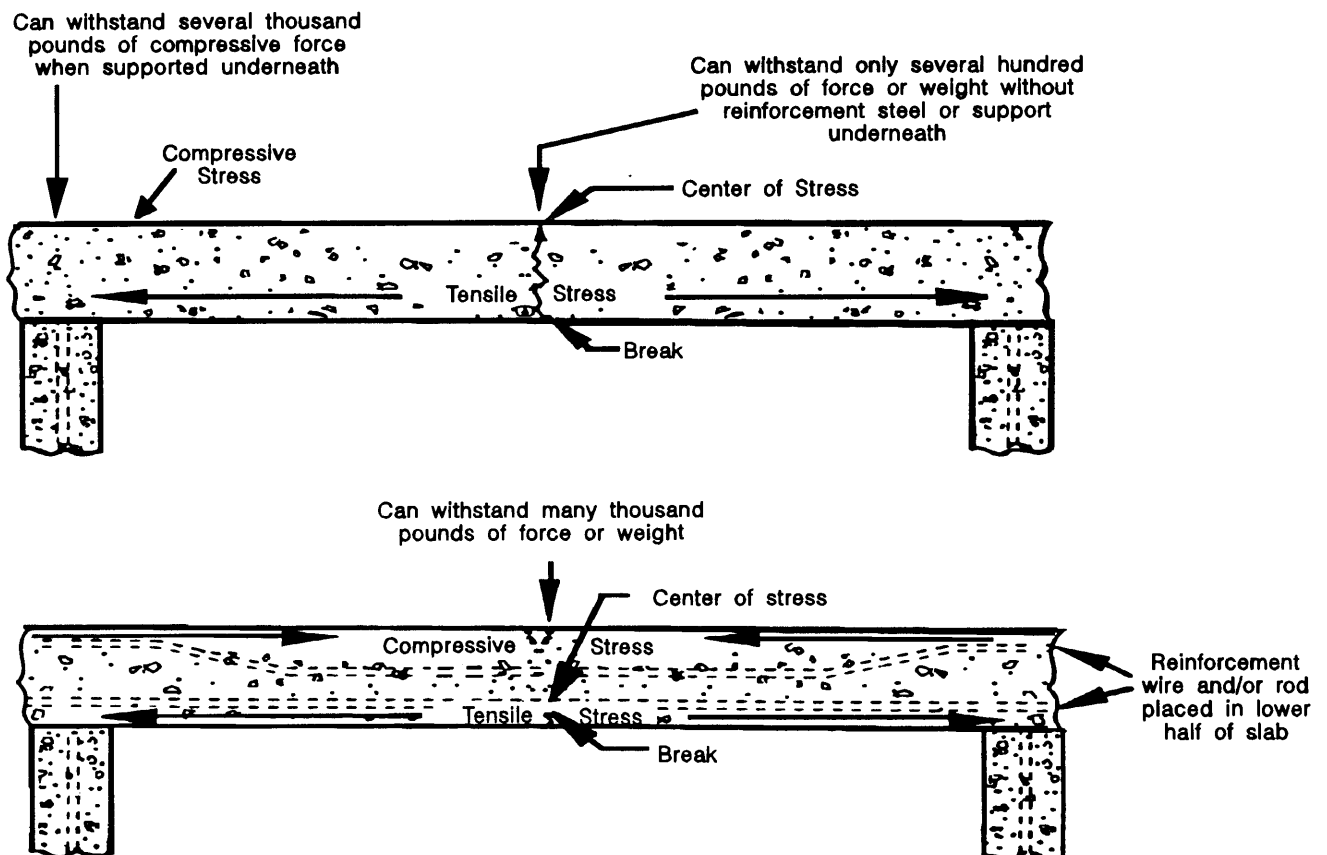
A common ready-mix concrete mixture ordered for general agricultural use is called a "6 sack - 6 gallon mix." This ready-mix concrete has 6 sacks (6 cu ft) of cement per cubic yard and 6 gallons of water for each sack. The mixture would have an average compressive strength, average price, with approximately a .50 to .53 water-cement ratio. This would be the same basic mixture of concrete as the "1:2:3: 6" formula used when mixing an average strength concrete in small portable mixers (see topic # 8153-A).

COMPRESSIVE AND TENSILE STRENGTH OF CONCRETE

Compressive strength is the maximum pressure, force, or weight something will support before it becomes crushed. **Tensile strength** is the pulling force or stress required to pull something apart. The compressive strength of unreinforced concrete ranges from approximately 2,500 to over 5,000 psi based upon the water-cement ratio and the type of aggregate used.

The tensile strength of unreinforced concrete is usually about 10 times less than the compressive strength. Thus, only several hundred psi of stress may be required to break or pull apart an unreinforced piece of concrete.

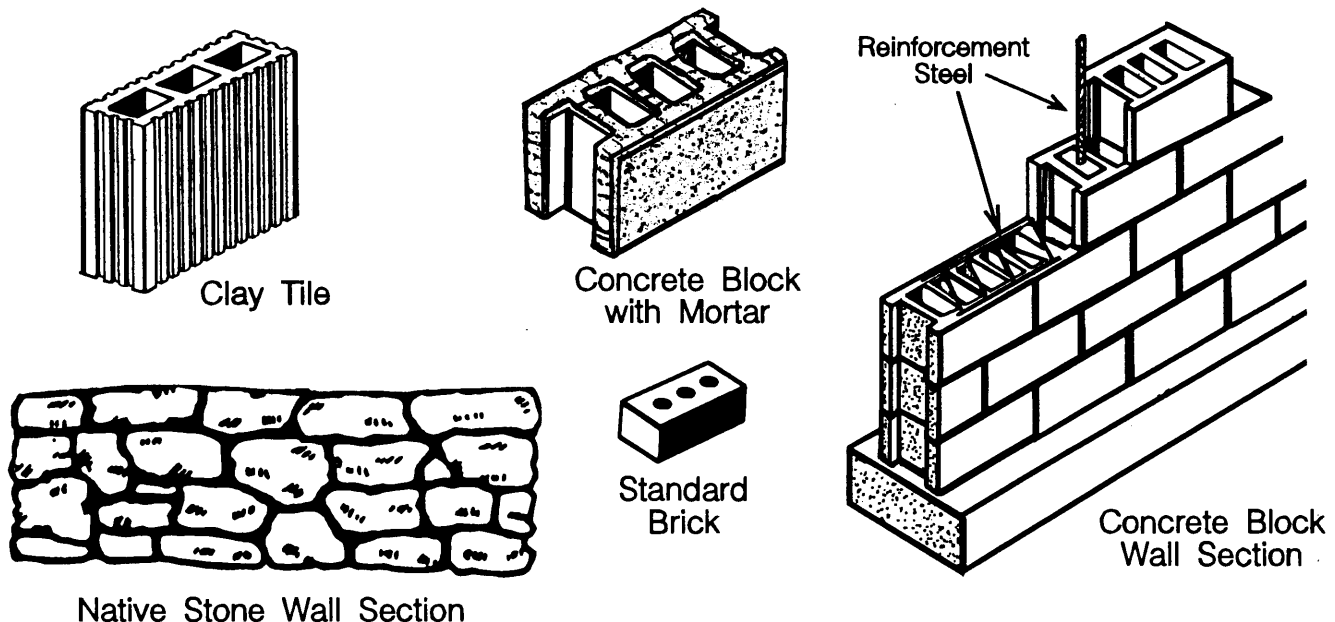
Steel has a much higher tensile strength than concrete. **Steel reinforcement rods and wire** are added to concrete structures to increase the tensile strength and help prevent cracking. The cement bonds or glues to the steel reinforcement just as it does to the rocks. The tensile stress will then try to pull the steel apart in addition to trying to pull the rocks apart. Reinforcement steel is positioned in the structure or beam where the tensile stress will be the greatest.



CONCRETE MASONRY CONSTRUCTION

Light weight **concrete blocks** for masonry construction are made of a special concrete mixture of cement, water, sand and very small pebbles, crushed rock or cinders. **Bricks** and **clay tiles** are made by grinding clay or shale and other ingredients into a fine powder. Water is added to the mixture to make a stiff mud. The mud is molded into various sizes and shapes of bricks and tiles. The molded clay bricks or tiles are then baked in a large kiln until dry.

Concrete blocks, bricks, clay tiles or large native stones, are stacked together to form walls or other structures. As they are stacked, **mortar** is placed between them, but not completely around them. Mortar is also a mixture of cement and water plus hydrated lime and sand. The mortar used in masonry construction goes through a similar hydration process as the cement and water in concrete.



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- Cement Masons' Guide To Building Concrete Walks, Drives, Patios, and Steps*, Portland Cement Association, Skokie, IL.

Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

TRUE OR FALSE: Circle "T" if the statement is true; circle "F" if the statement is false.

- T F 1. Cement and concrete are the same thing.
- T F 2. Cement paste goes through a chemical reaction called hydration as it dries and hardens.
- T F 3. Aggregate is another name for the glue that holds concrete together.
- T F 4. If properly mixed and cured, concrete can be watertight.
- T F 5. A .44 water-cement ratio mix of concrete will normally be weaker than a .71 water-cement ratio mix.

FILL IN THE BLANK: Place the correct word in the space provided.

- _____ 6. The more water added to a given amount of cement, the _____ the water-cement ratio.
- _____ 7. Normally, the higher the water-cement ratio, the _____ the concrete will be.
- _____ 8. _____ is the maximum pressure, force, or weight something will support before it becomes crushed.
- _____ 9. _____ is the pulling force or stress required to pull something apart.
- _____ 10. _____ is a mixture of cement, water, hydrated lime, and sand used in masonry construction to bond concrete blocks, bricks, clay tiles, and/or native stones together.

SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph. (Use additional paper when needed.)

11. Describe where the reinforcement steel should be located in a concrete structure or beam.
12. Discuss the advantages of using concrete and masonry in agricultural construction.
13. Describe the difference between fine aggregate and coarse aggregate.
14. Explain why quality concrete must have only a minimum amount of tiny voids.

ADDITIONAL SKILLS AND ENHANCEMENT ACTIVITIES: Perform the following activities or skills as assigned by your instructor.

1. Contact a local ready-mix concrete supplier. Obtain price quotes for different water-cement ratio mixes used in your community for common types of agricultural structures. Compare the amount of water, cement, sand, and gravel used per cubic yard in each type of mix.
2. Observe several old concrete structures that have cracked or broken. See if you can determine if any reinforcement steel was used and where it was located. Use a magnifying glass to see if you can tell if there are any small voids in the concrete.

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PLANNING BUILDINGS AND SELECTING EQUIPMENT

There are several questions which must be answered before building a new agricultural structure. Why, where, and what type of building or structure to build must be determined before construction can begin.



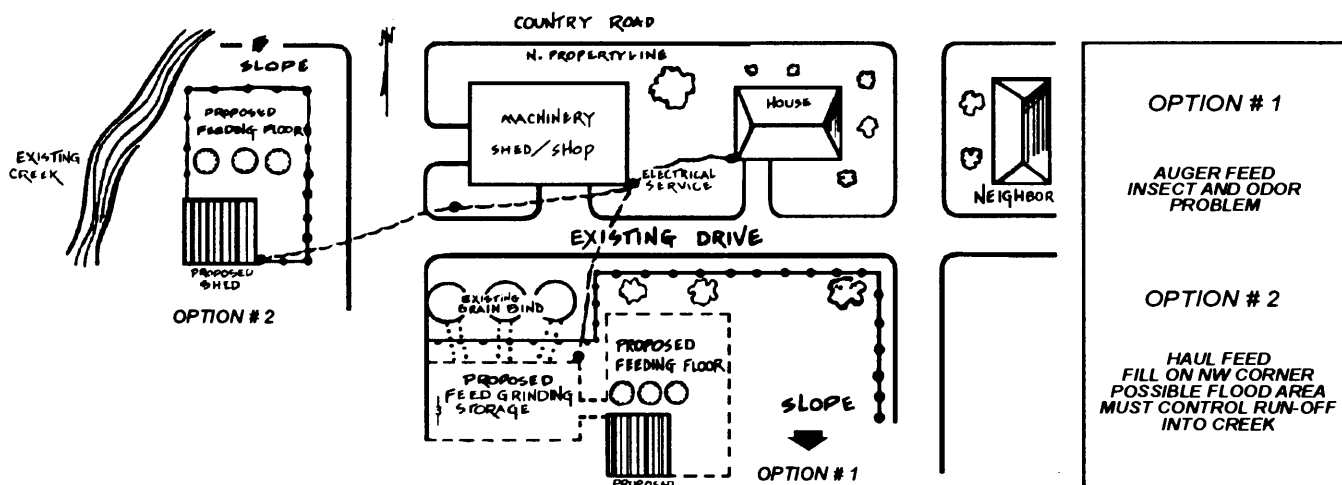
Answers to "why build" may involve considerations such as: providing increased shelter or storage capacity, reducing costs, improving safety, and protecting the environment. Answers to the question "where to build" may include: legal interpretations of a new law or building code, locations of other buildings, and soil conditions. The answers to "what type of structure to build" are determined by considering all the other factors, plus geographic location, total construction costs, and personal preference.

PLANNING BUILDING SITES AND STRUCTURES

The term **building** may refer to just the building. The term **structure** is broader. It includes the building plus the building site, and the equipment and facilities in and around them. The climate of the area and the anticipated use of the buildings must also be considered when planning a structure. There are many questions and factors to consider when planning a building or structure. They may include:

- *...special or multi-purpose building?
- *...type and shape of the surrounding land?
- *...site preparation required?
- *...location of other buildings for convenience and safety?
- *...availability and location of utilities?
- *...type of environment?
- *...useful life expectancy of structure?
- *...direction and distance from other business or residential areas?
- *...building codes and ordinances?

An **overhead view plan**, drawn to scale, will be helpful in the decision-making process. The plan should show all planned and existing buildings, fences, drives, roads, utilities, etc. In addition to the overhead plan, a worksheet of each option should be developed. The **worksheet** includes all the advantages and disadvantages of each option. It may also include an estimate of all construction expenses. Structures need to be located as close as possible to each other for convenience and utilities. However, they need to be far enough away to prevent such problems as odors, insect infestations, fire, chemical exposure, noise, dust, etc.



Overhead View Plan and Worksheet

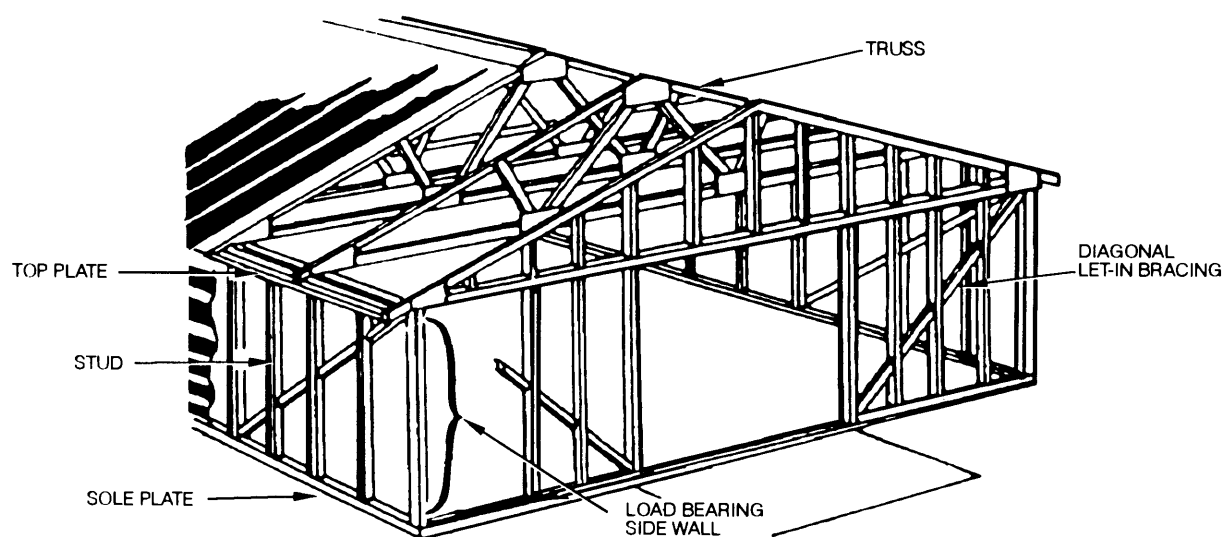
In addition to the costs of building a new structure, the agricultural business owner must also consider future expenses. Some of these costs are repairs, maintenance, depreciation, taxes, and insurance. Expansion or new construction in one area may require expansion or new construction in another area for maximum efficiency. **For Example:** A new or larger laying-hen house may require a new or expanded egg processing and packaging facility.

BASIC TYPES OF AGRICULTURAL STRUCTURES

The general purpose of an agricultural structure is to provide a barrier between two different environments: the inside and outside. Structure design and the materials used will vary with elements of the environment and what the person is trying to keep "in or out."

Agricultural structures are built using six basic types of construction techniques. They include: 1) stud frame, 2) pole frame, 3) rigid frame, 4) concrete masonry, 5) tilt-up concrete, and 6) shotcrete/welded-wire sandwich panel construction.

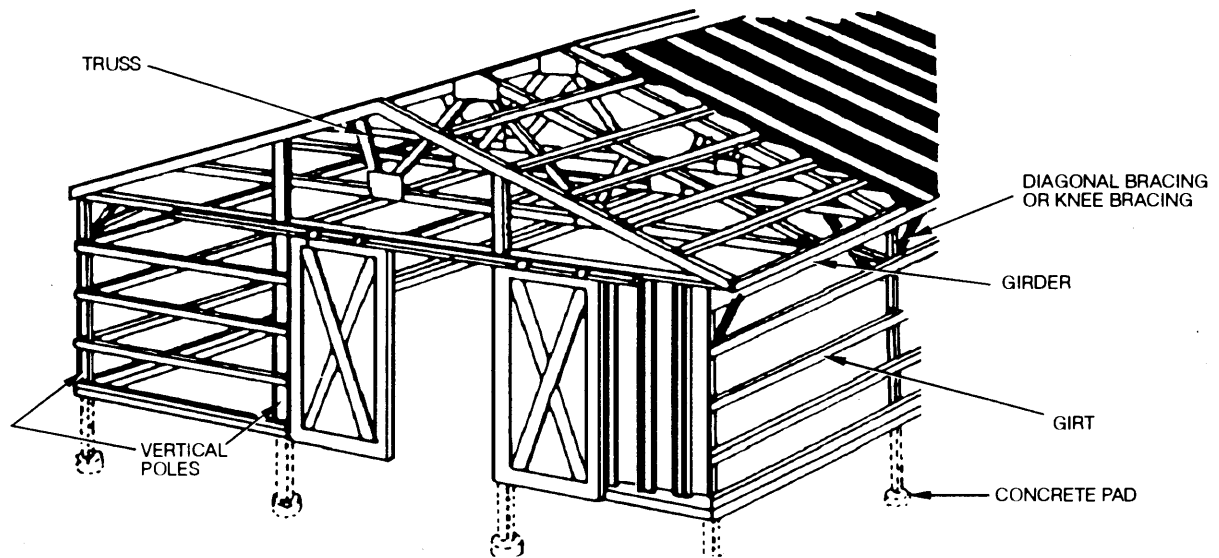
Stud frame construction is commonly used in residential homes. However, some types of agricultural buildings are also built using this design. Vertical members called **studs** provide the main vertical structural support for the walls and roof. The bottom of the studs attach to **sole plates**. The sole plates attach to the foundation or subfloor. The top of the studs connect to **top plates**. The top plates also provide a surface to attach and support the roof. **Load bearing walls** are internal partition walls or external sidewalls that provide vertical support for the roof.



Stud Frame Construction

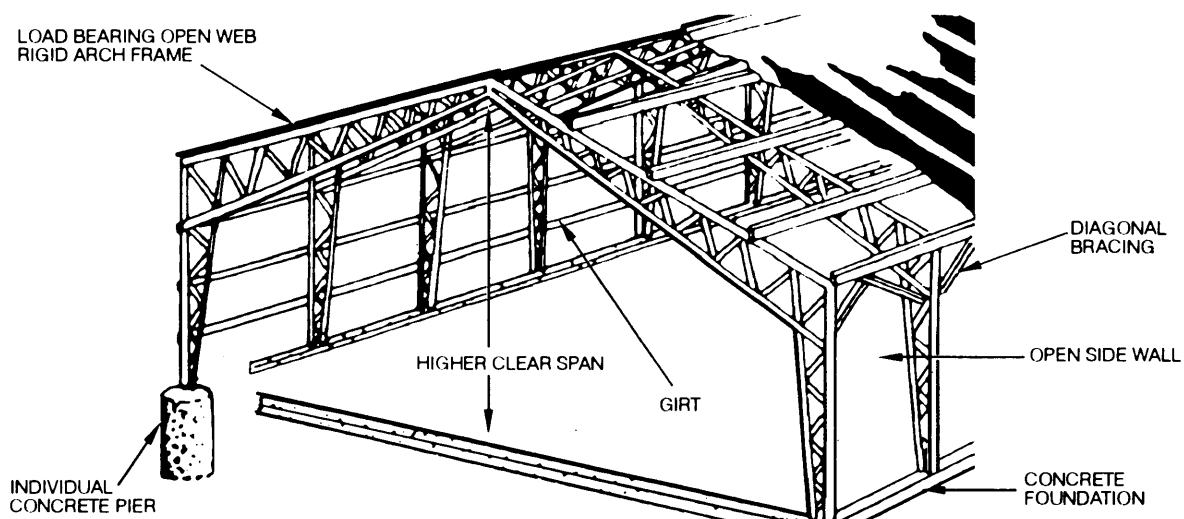
Pole frame construction is probably the most common type used in agricultural structures. Pole frame buildings are economical, easily modified, quickly erected, and easy to build. **Concrete pads** anchor **vertical poles** into the ground to provide both the foundation and the vertical roof support. "Poles" may be wooden posts or structural steel pipes. Horizontal members called **girders** are placed across the top of poles. They tie the poles together and support any roof framework that does not rest on top of a pole. Pole frame buildings may be open on the sidewalls. **Girts** are horizontal members sometimes placed between the poles. They provide a surface to attach sheet metal or other siding materials to close in sidewalls if desired. **Diagonal or knee bracing** provides support and bracing between the poles and girders, and the poles and roof framework.

Open-sidewall pole frame buildings, constructed in areas subject to high wind loads, often need extra diagonal bracing.

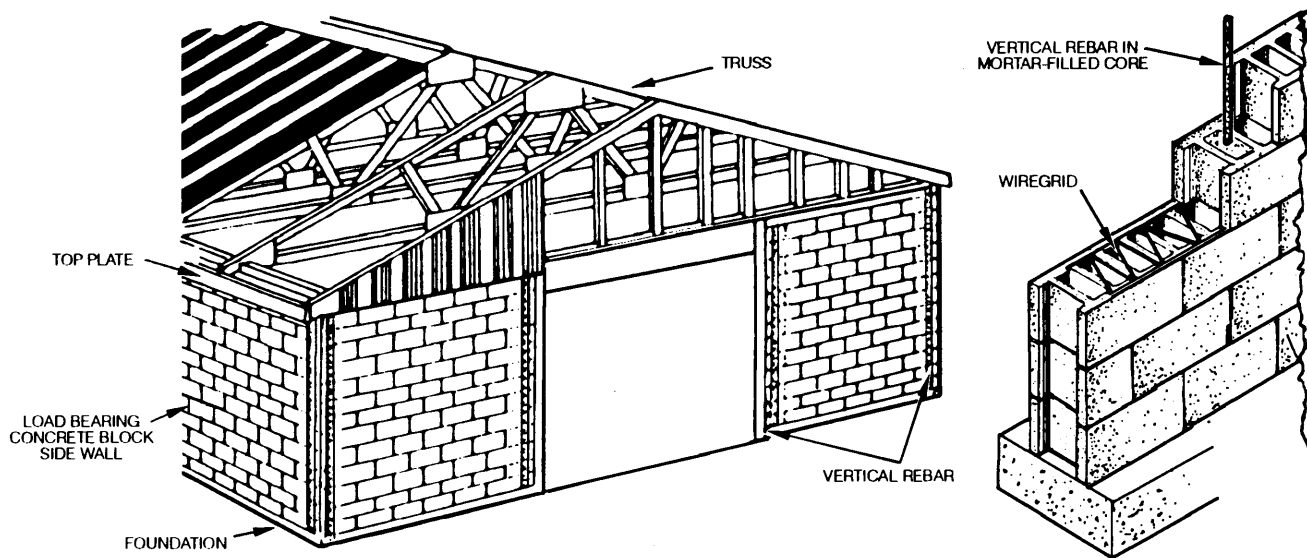


Pole Frame Construction

Rigid arch frame construction is similar to pole frame construction. A rigid arch frame supports the roof. The rigid frame is normally constructed of wooden or steel arches. They allow for clear span widths up to approximately 60 feet. Because of the rigid arch frame design, a higher inside clear span working area is possible. The bottom end of each rigid frame arch anchors to the **concrete foundation** or to individual **concrete piers** around the perimeter of the building. Horizontal **girts** between the rigid arches provide a surface to attach sidewall coverings. The use of adequate **diagonal bracing** allows rigid arch buildings to be open on sidewalls if desired.



Rigid Arch Frame Construction



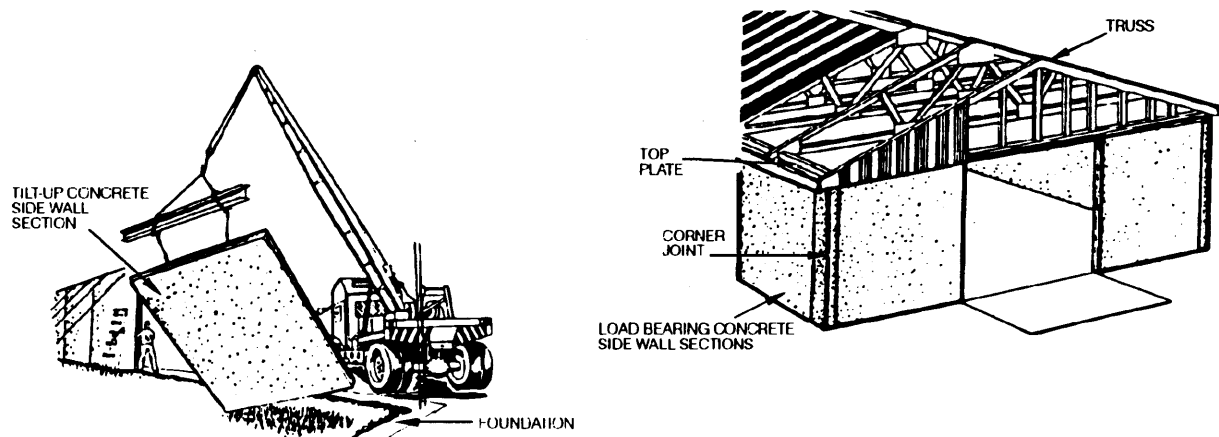
Concrete Masonry Construction

Concrete masonry construction continues to be used in many types of agricultural structures. "**Concrete blocks**" are stacked on top of a **foundation**. A cement-based mortar bonds the individual concrete blocks together. The concrete blocks create the sidewalls, plus provide part or all of the vertical support for the roof.

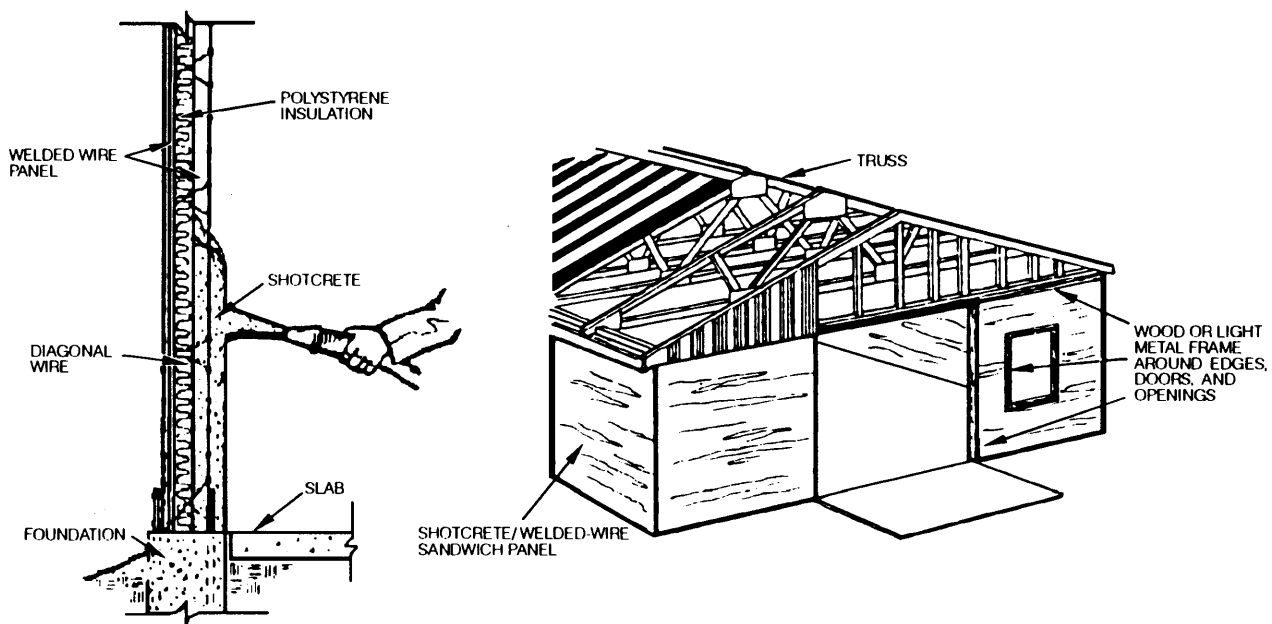
Vertical steel rebars are placed in the cores of concrete blocks near doors, at corners, and at 8 to 12-foot spacings in long walls. The core spaces containing the rebars are then filled with concrete or mortar to provide additional vertical and horizontal support. **Wire grids** are placed in the horizontal mortar joints to provide horizontal support. A **top plate** is anchored to the top of the concrete masonry walls with bolts embedded in cement mortar. The top plate then provides a surface to which the roof framework can be attached.

Tilt-up concrete construction is a building technique that is increasing in popularity for many agricultural structures. **Concrete sidewall sections** are poured, finished, and cured on a flat surface. The sidewall sections are reinforced with **rebar** and/or **welded-wire mesh**. Some may have a layer of **insulation** in the middle. The wall sections are then tilted or lifted into a vertical position and placed on top of a **foundation**. The wall sections and corner joints are anchored together and sealed with a cement mortar or caulking compound.

The tilt-up sections provide both the sidewalls and the vertical support for the roof. A wood or metal **top plate** across to the top of the sidewall sections provides a surface to attach the roof framework.



Tilt-up Concrete Construction

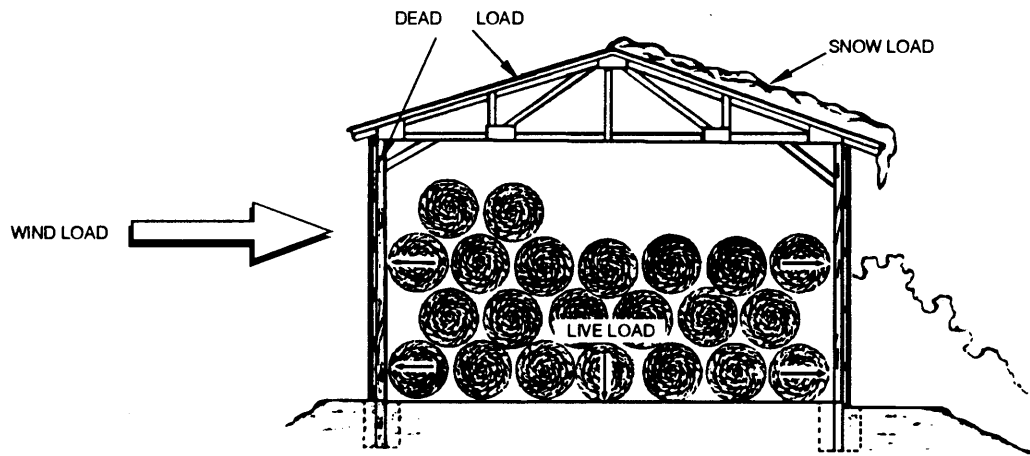


Shotcrete/Welded-Wire Sandwich Panel Construction

One of the newest construction techniques in constructing agricultural structures uses **shotcrete** and **welded-wire sandwich panels**. **Prefabricated sidewall panels**, made of two layers of welded-wire mesh with insulation sandwiched in between, are erected on top of a foundation. **Wooden or metal frames** are placed around openings and across the top of the wall sections. A 1½ to 2-inch layer of cement plaster or mortar is "shot" or sprayed on each side of the panels. The resulting panel is strong enough to be a load bearing exterior sidewall for most buildings.

FORCES WHICH EFFECT AGRICULTURAL STRUCTURE DESIGN

There are four types of loads or forces which act on agricultural structures. They must be taken into consideration when deciding which type of building to construct. They are: 1) dead loads, 2) live loads, 3) snow loads, and 4) wind loads.



Dead load is the weight of all the *permanent* parts and equipment of the structure. This is the weight of the roof, walls, and framework, plus the weight of permanent equipment and lights attached to the framework. After the structure is built, the dead load will not change unless the building is modified.

Live load is the weight or force applied by the contents of the structure and/or any *temporary* equipment such as an overhead chain hoist attached to the framework. The live loads *will change* as the content or usage of the structure changes. **For example:** Round bales stacked in a pole barn push down on the floor and foundation. Depending upon how they were stacked, they can also push out against the walls with great force. As the amount of hay stored increases, the horizontal and vertical live load forces increase.

Snow load is the weight of snow and/or ice that may accumulate on a structure. It is based on the weight of approximately 60 percent of the highest snow or ice accumulation on the ground at any one time. **Wind loads** are the pushing and suction forces caused by blowing winds against the sides and roof of a structure. Agricultural structures should withstand wind loads based on the maximum wind velocity recorded during the previous 25 years. The United States Weather Bureau records determine average snow and wind loads.

Agricultural engineers or building contractors calculate the highest expected **combined force** of all four types of loads when they design a structure. They then determine the type of building design and the strength of the building materials needed. Agricultural structure's handbooks and planning guides are available to help choose the type of building and building materials to use. IMS topics #8148-B and #8148-C contain additional information on the selection of building materials.

New governmental regulations may specify where and how certain types of agricultural structures can be built, and what they can be used for. There are two general types of regulations: 1) zoning ordinances, and 2) building codes. **Zoning ordinances** are designed by local or county governments to help plan the future growth and development of the community. Land may be classified, or zoned, for use as: agricultural, industrial, residential, or commercial businesses. County-wide planning committees are being established to protect both rural and urban interests.

Building codes specify certain building construction standards which help assure the health and safety of animals and humans in and around the structure. They also protect the environment, as well as maintain or improve the aesthetic appearance of the area. The construction of new agricultural buildings, manure handling, waste and chemical storage facilities, etc., may fall under building codes governed by local health departments and/or the U.S. Environmental Protection Agency.

Some agricultural businesses and industries may produce noise and odors that may be offensive, or a "nuisance" to other people; although they may not be a threat to health and safety. Some communities have **nuisance laws** which help agricultural business owners determine the type and location of certain types of agricultural structures. Most nuisance laws state: "All persons have the basic right to use and enjoy their property, unreasonable interference with enjoyment is legally a nuisance."

Contact the county clerk's office, the county extension office, and/or the county health department concerning specific building codes and ordinances in your community. Construction permits, prior plan approval, and periodic inspections may be required before construction can begin.

PRIVATE AND PUBLIC SOURCES OF PLANNING AND DESIGN ASSISTANCE

There are three main sources of assistance available to help plan and design agricultural structures. Many **agricultural building contractors** and/or **building material suppliers** provide a "free" basic planning and design service. More detailed assistance is then available once the customer agrees to purchase the company's goods or services.

Assistance is also available through the county office of the **USDA Cooperative Extension Service**. Assistance may range from self-help bulletins, plans, or fact sheets, to an on-site visit by an agricultural engineering specialist from the state university extension program.

Private professional consultants and **agricultural engineers** can also be hired. Services may range from a legal opinion of a new law to a detailed blueprint, plus on-site construction supervision and inspections.

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Acknowledgements

Mr. Bradley J. Green, Graduate Assistant, Department of Agricultural Education, Texas A&M University and Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

LISTING: Respond to the following items in the spaces provided.

1. List the six basic types of construction used to build agricultural structures.
 - a. _____
 - b. _____
 - c. _____
 - d. _____
 - e. _____
 - f. _____
2. List five future costs or expenses in addition to actual site preparation, and construction costs an owner or manager must consider when planning and designing a structure.
 - a. _____
 - b. _____
 - c. _____
 - d. _____
 - e. _____
3. What are the four types of loads which must be considered when planning a structure?
 - a. _____
 - b. _____
 - c. _____
 - d. _____

FILL-IN-THE-BLANKS: Place the correct word(s) in the space provided.

- _____ 4. A ? includes all of the advantages and disadvantages of each proposed option.
- _____ 5. ? is the type of frame construction most commonly used in agricultural structures and is usually the most economical.
- _____ 6. Agricultural engineers calculate the ? force or weight of loads when designing a structure.

SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph.

7. Which of the four loads or forces that act against buildings is/are subject to change as building usage and weather changes?
8. Explain the basic differences between planning and designing a building and planning and designing a structure.
9. Explain what is meant by a "nuisance law."
10. What should an overhead plan include?
11. What is a zoning ordinance?
12. What is a building code?
13. Who could be contacted to help interpret a new building code or zoning ordinance?

ADDITIONAL SKILLS & ENHANCEMENT ACTIVITIES: Perform the following activities or skills as assigned by your instructor.

1. Contact local agricultural building contractors in your community or those advertising in an agricultural magazine and determine the types of planning and design assistance they provide. If possible, obtain the average per square foot cost of several types of building construction. Prepare a report for the class.
2. Contact the local county health department, county cooperative extension office, and/or the county clerk's office. Determine if there are any local building codes or zoning ordinances that govern the construction of agricultural structures in your community.
3. Obtain basic building plans and information for an agricultural structure you or someone you know may be planning from the county cooperative extension office.
4. Using overhead drawings, worksheets, and the information you obtained in the first three activities, complete a planning and design process for a building site and structure you or someone you know may be planning.

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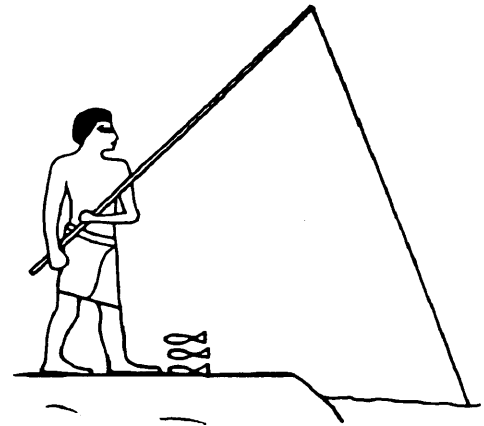
College Station, Texas 77843-2588

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DRAWING AND READING BUILDING PLANS

IMPORTANCE OF BUILDING PLANS

Sketches and drawings have been used as methods of communicating visual images for many centuries. People often say, "A picture or drawing is worth a thousand words," when they are trying to describe something. A sketch or drawing uses lines, shapes, textures, symbols, and/or colors to communicate or describe an idea or image. Straight lines represent edges, corners, or flat surfaces. Curved lines and circles represent irregular or round shapes or surfaces.



Early Egyptian Drawings

Building plans are more than just the sketches or mechanical drawings of an object. They are the "link" between the design and construction of a project. Some type of building plan is needed for even the simplest construction projects. Building plans allow a project that was designed by one group to be built by others. Building plans also allow a project to be constructed at a later time without the worry of having to remember all the specifications.

It is important for persons pursuing careers in many different areas of agriculture to be able to draw, read, and/or understand building plans and communicate with visual images. **For example:** Complete building plans are often required by agricultural lending agencies before they will consider loaning money for any major construction project. No longer can a person just say, "I want to borrow \$??,???.?? to build a barn, greenhouse, trailer, etc."

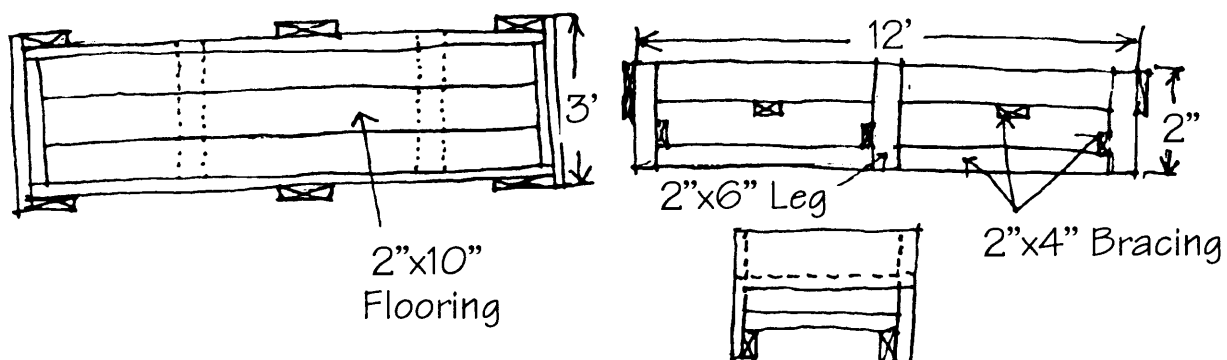


An agricultural engineer, business owner, and/or construction worker must be able to design the project and draw necessary building plans to match. The agricultural business owner or manager must be able to present and explain the building plans. The agricultural loan officers at the lending agencies must be able to read the building plans and visualize where, how, and what type of structure is to be built. They must determine how it will fit into the total enterprise before they make their final decision. The person working in agricultural production, construction, or service must be able to read the building plans to construct the project.

Building plans, also called **working drawings** or **shop drawings**, include 1) **sketches or mechanical drawings** of an object. Enough different views of the project must be included to show all the necessary details for planning and construction purposes. In addition, building plans should include 2) **all necessary dimensions**, 3) **the types of building materials to be used**, and 4) **the location of all parts and other equipment within the project**.

Building plans are the appropriate place to 5) **record any modifications or revisions** made to the original idea or design. The building plans may also include 6) **a plan of procedures section**. This is a sequence of steps necessary to complete the project. It is included especially if certain procedures or steps are not obvious and must specifically precede or follow others.

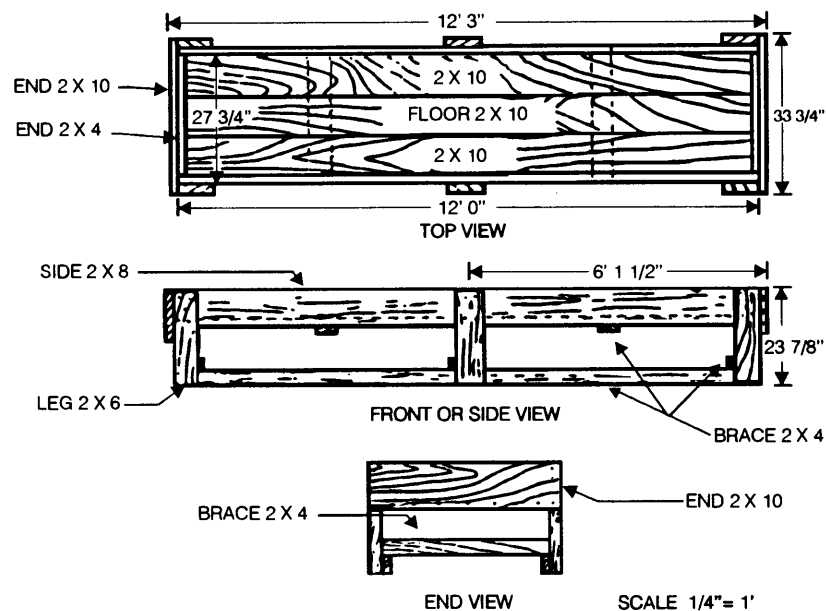
The illustrations or visual images included in building plans may range from simple, **handmade sketches** to detailed **mechanical drawings**. A sketch is a simple rough outline of an object. Sketches may be drawn freehand or with the aid of a straightedge or ruler. Sketches are not usually drawn to an exact scale.



A Rough Freehand Sketch of a Feed Trough

In some types of design and construction, simple hand sketches are far more practical than time-consuming, expensive mechanical drawings. A person will often use simple hand sketches to record visual images or ideas while "brainstorming" or designing an object. The hand sketches are then used as guides for more complex mechanical drawings completed later.

Mechanical drawings are made with precision drawing and measuring instruments, or computer assisted design (CAD) programs. Their lines show the actual or to-scale dimensions of the object. Generally, the more complex the construction procedures, the more complex the mechanical or CAD drawings will be.



Mechanical Drawing of a 12' Wooden Feed Trough

Very seldom does one use the original drawings during actual construction. This is especially true with building plans drawn by an agricultural engineer or architect for a major construction project. Rather, copies or prints of the drawings are made and used. The originals are saved for future reference. Copies of these mechanical drawings are sometimes referred to as "**blueprints**." This is because a common reproduction process used to duplicate the building plans prints the image as white lines on a blue-tint paper. Thus, the name, blueprint.

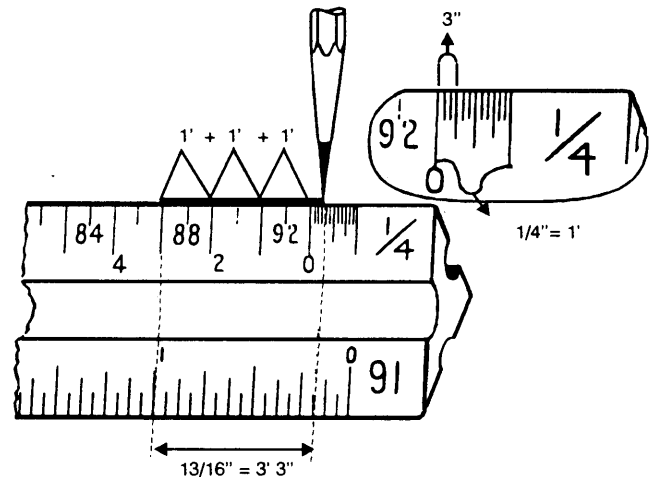
DRAWING SCALES

A sketch or drawing of an object should be drawn as close to the actual size as possible to show maximum detail. If the object is too large to fit on the drawing paper, it can be drawn "**to-scale**." **Scale** is the relationship between the size of the drawing and the actual size of the object it represents. This is usually an inch or some fraction of an inch used to represent another unit of measure on the object.

Common scales are $\frac{1}{8}$ inch = 1 foot, $\frac{1}{4}$ inch = 1 foot, $\frac{1}{2}$ inch = 1 foot, and 1 inch = 1 foot. An **architect's scale** is a triangular-shaped ruler that has three different sides. Each side has different scales included. Engineer's scales are similar, except that inches are divided into decimal parts in units of 10.

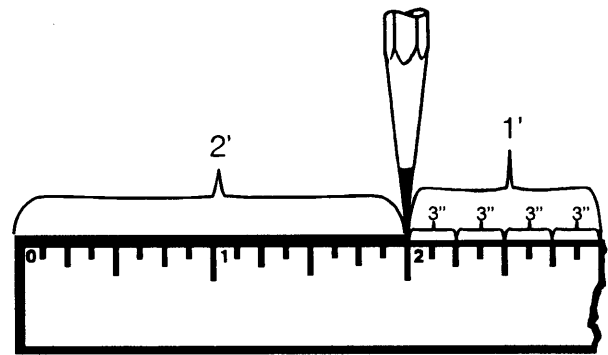
Using the $\frac{1}{4}$ inch = 1-foot scale on an architect's scale, a line that is $\frac{1}{4}$ inch long on the drawing would represent a dimension of 1' 0" in length on the actual object. Therefore, a 40-foot long building would only be 10 inches long on a drawing.

On most architect's scales, one section on each scale is further divided into equal parts. These sections can be easily converted to inches when precise lengths or detail must be shown. **For example**, using the same $\frac{1}{4}$ inch = 1-foot scale, a $\frac{1}{4}$ inch line equals 1 foot or 12 inches. A section of the $\frac{1}{4}$ inch scale is further marked into equal parts that can be divided by 12. In this case it is actually 48th's of an inch. Thus, using the $\frac{1}{4}$ inch = 1-foot scale, a $\frac{1}{16}$ or " $\frac{3}{48}$ " inch line would equal 3 inches of the actual object. Using this scale, a line on a drawing that is $\frac{13}{16}$ inches long would equal an actual object that is 3' 3" long [$(\frac{1}{4}" = 1') + (\frac{1}{4}" = 1') + (\frac{1}{16}" = 3") = 3' 3"$].



An Architect's Scale Using a $\frac{1}{4}" = 1'$ Scale

If an architect's scale is not available, a common ruler can also be used. However, it is often more difficult to show exact inches on the drawing when precise measurements are needed. **For example**, using the one inch = 1-foot scale, an actual object 2-feet long could be easily shown with a two-inch line on the drawing. However, if the actual object is 2' 2" long, it is difficult to accurately divide the 1-inch scale on the ruler into 12 equal parts. On most rulers, the inches are only subdivided into halves, fourths, eighths, and sixteenths of an inch. Using this 1 inch = 1-foot scale, the 1/4 inch marks could only be used to accurately show even increments of 3 inches.

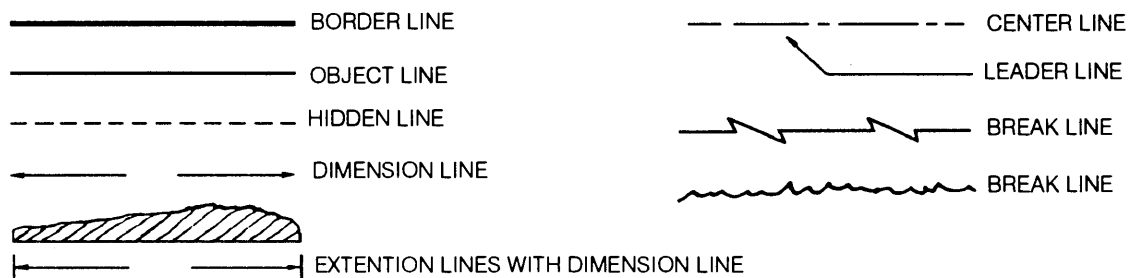


Using a 1" = 1' Scale with a Ruler

LINES, SYMBOLS, AND ABBREVIATIONS

Symbols and abbreviations are used to conserve space on sketches and drawings. They identify units of measure, specify types of building materials, and provide detailed instructions, eliminating the need for lengthy notes and explanations. Plans for wood and metal projects use many of the same basic types of symbols and abbreviations.

Several different types of lines are used in sketches and drawings. Each has a specific meaning. There are three basic types of lines: 1) solid, 2) broken, and 3) dashed. The lines also vary from thick dark lines (also called *heavy lines*) to narrow light lines (also called *thin lines*).



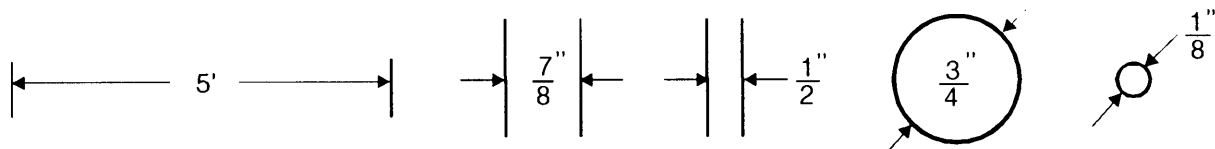
Border lines are extra-thick solid lines drawn parallel to the edges of the drawing paper. They are used to frame or enclose the entire drawing. **Object lines** are thick solid lines used to show the visible edges of the main object. **Hidden lines** are drawn with a series of evenly-spaced, short thin lines or dashes to illustrate a line or edge that is hidden behind another part of the object.

Center lines of round objects or holes are shown by alternating, evenly-spaced thin long-short-long lines. A typical center line is made with a long dash, a short blank, a $\frac{5}{8}$ " line, a short blank, a $\frac{1}{16}$ " dash, a short blank, a $\frac{5}{8}$ " line, a short blank, followed by a long dash on the other end. **Leader lines** are thin solid lines used to indicate the part or area to which a number, note, or detail applies. Most leader lines also include an arrowhead, which points to the specific point.

Break lines are used to show that the drawing or sketch stops but the object does not. Short breaks are shown by heavy lines with short, irregular-shaped zigzags. Long breaks are shown by long thin lines with evenly-spaced and shaped zigzags.

Dimension lines are thin, solid lines with arrowheads at each end. They are used to indicate the length, width, or height of an object or part. Dimension lines often have a break in the middle to insert the measurement and any abbreviation(s) and/or symbol(s). The tips of the arrowheads on dimension lines usually just touch the extension lines.

Extension lines are thin solid lines used with the dimension lines to indicate from what point the exact dimensions are measured. They should be drawn approximately $\frac{1}{16}$ " away from the point on the object and extend approximately $\frac{1}{8}$ " past the tip to the arrowhead on the dimension lines.



Dimensioning Techniques

Circles and ellipses are used to represent holes or round objects. The arrowheads of the dimension lines normally touch the edge of the circle and point towards the center. Numbers inside or next to the circle indicate the size of the hole or object. The inside or outside dimension of a circle or object is normally given as the diameter rather than the radius. Dimensions between holes or round objects are usually given as the distance from center line to center line.

Other common symbols and abbreviations used to conserve space are:

' - Feet

C/L - Center Line

± - Plus or Minus

ID - Inside Diameter

Ga - Gauge

Vert - Vertical

LG - Length

LH - Left-Hand

" - Inches

° - Degrees

∠ - Angle

OD - Outside Diameter

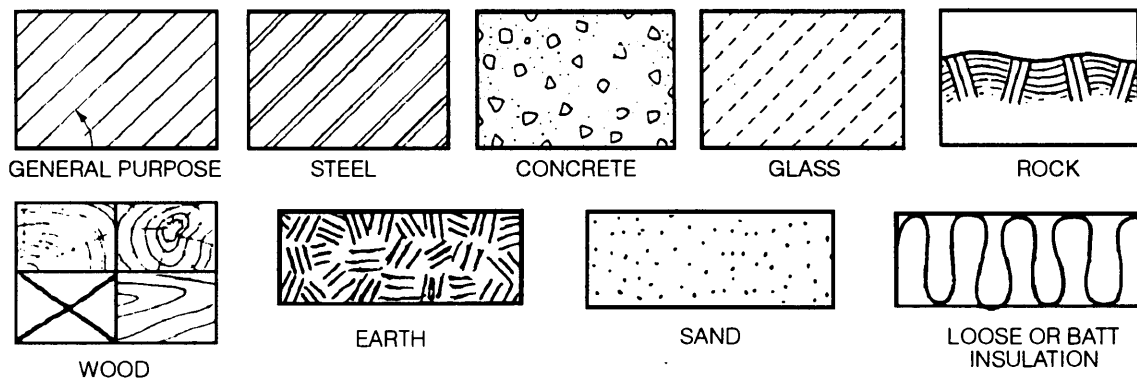
R - Radius

W - Width

Horz - Horizontal

RH - Right-Hand

On some sketches or drawings, it may be necessary to use shading to provide additional detail or to show separate parts. Other symbols or representations are sometimes used to identify various types of common building materials and to show contrast. This is particularly true for cross-sectional views.



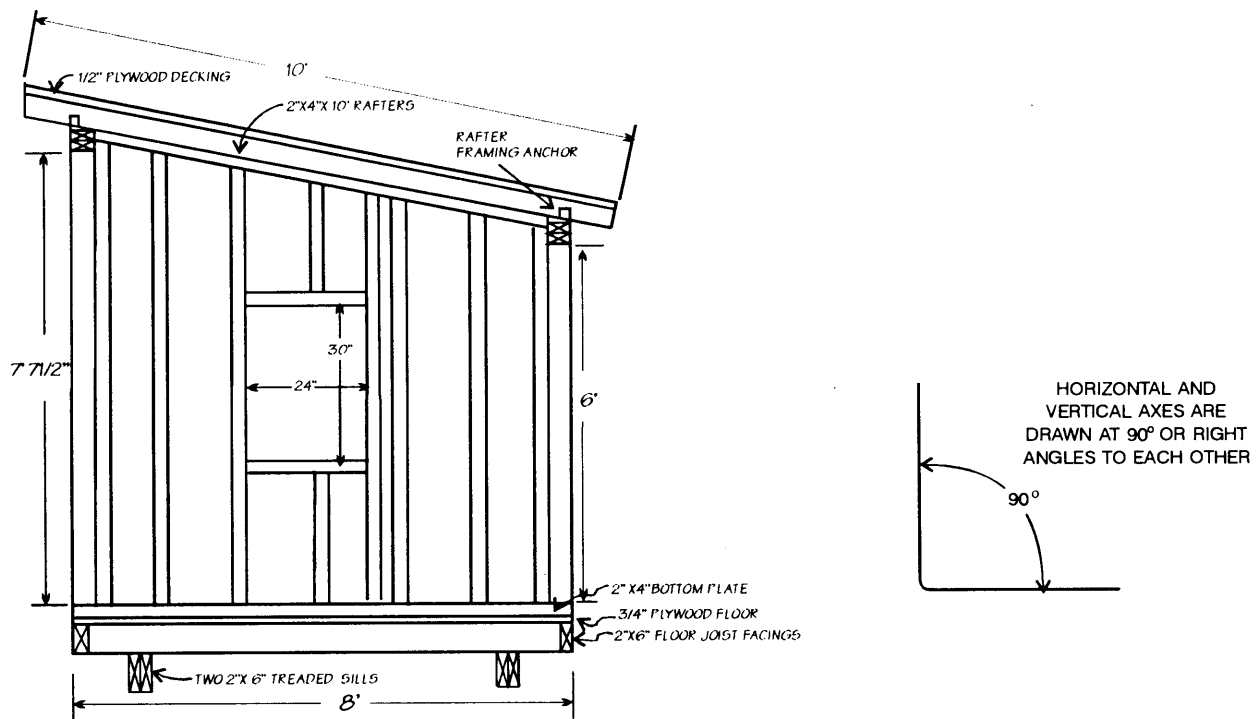
Symbols or Representations of Common Building Materials

TYPES OF VIEWS

The different views of sketches or drawings are often divided into two classifications: 1) two-dimensional views and 2) three-dimensional views. **Two-dimensional views** show two axes, or only one side of an object at a time. **Three-dimensional views** show three axes, the height, width, and depth.

Two-Dimensional Views

An **orthographic view** is a common type of a two-dimensional view. Each view will show a vertical and a horizontal axis of an object using actual or to-scale measurements. *Ortho* or *orthogonal* means "right angle." Thus, the vertical and horizontal axes are drawn at right angles to each other.



Orthographic End View of a Small Portable Building

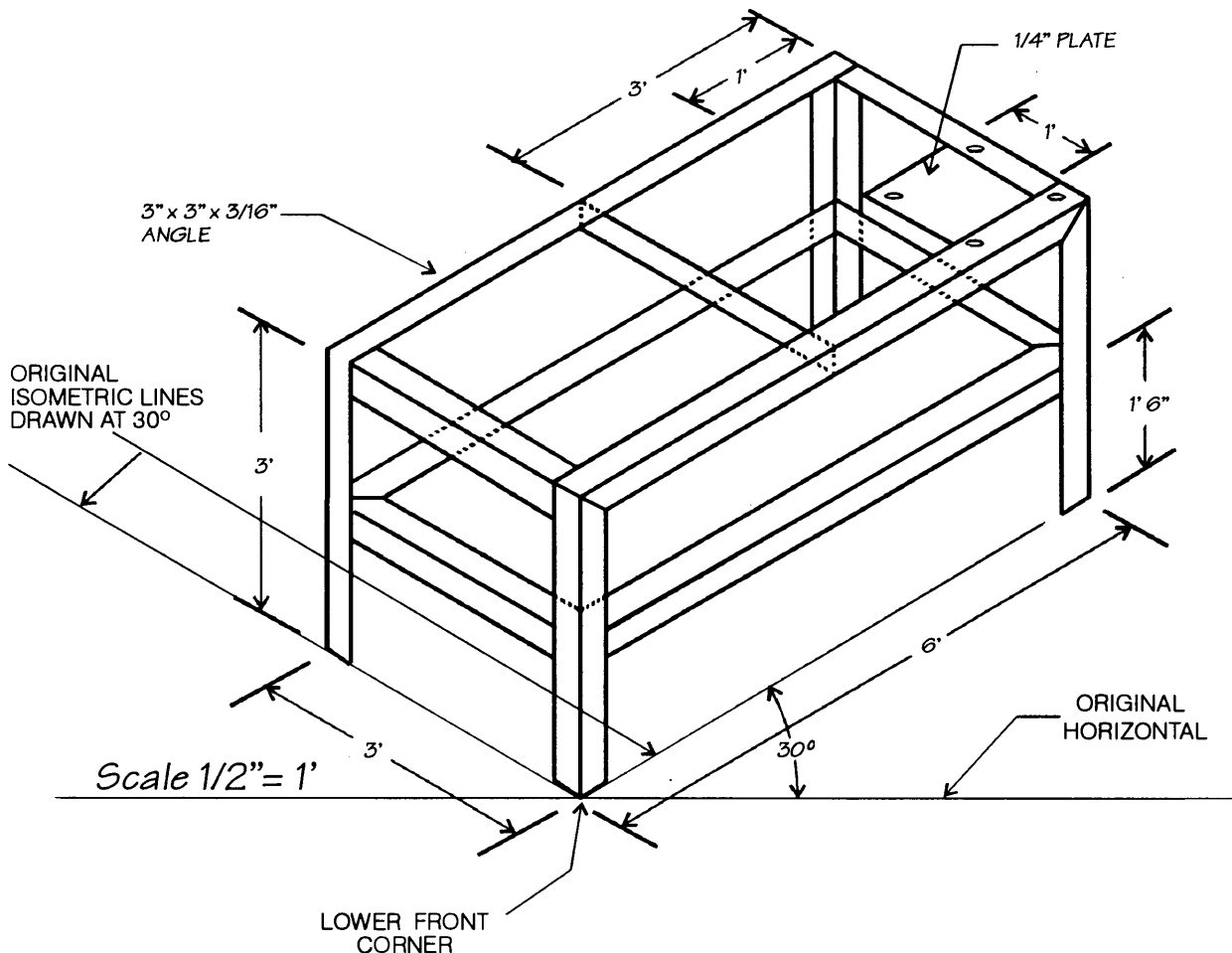
Three different orthographic views are often drawn of each object. A **front orthographic view** is drawn to show the object as it appears from one side or the front. The front view is usually considered the side which is showing the most detail. A **top orthographic view** shows the object as it appears from the top looking down from overhead. A top or overhead view may also be called a floor plan view. An **end orthographic view** shows the object as it appears from the right end. If the opposite end, back, and/or bottom are significantly different, additional orthographic views can then be drawn to show the detail.

Three-Dimensional Views

Three-dimensional views are also called **pictorial views**. This is because an object appears similar to the way it would in a *picture* or photograph. Pictorial views are very useful in showing the details of an object. However, it takes additional training and experience to draw them accurately. There are three main types of three-dimensional views commonly used: 1) isometric views, 2) oblique views, and 3) perspective views.

Isometric views show three axis or dimensions of an object. An isometric view presents an object as it would be seen looking down slightly at one corner. The corner axis is vertical. All other vertical lines on the object are drawn vertically on the sketch or drawing.

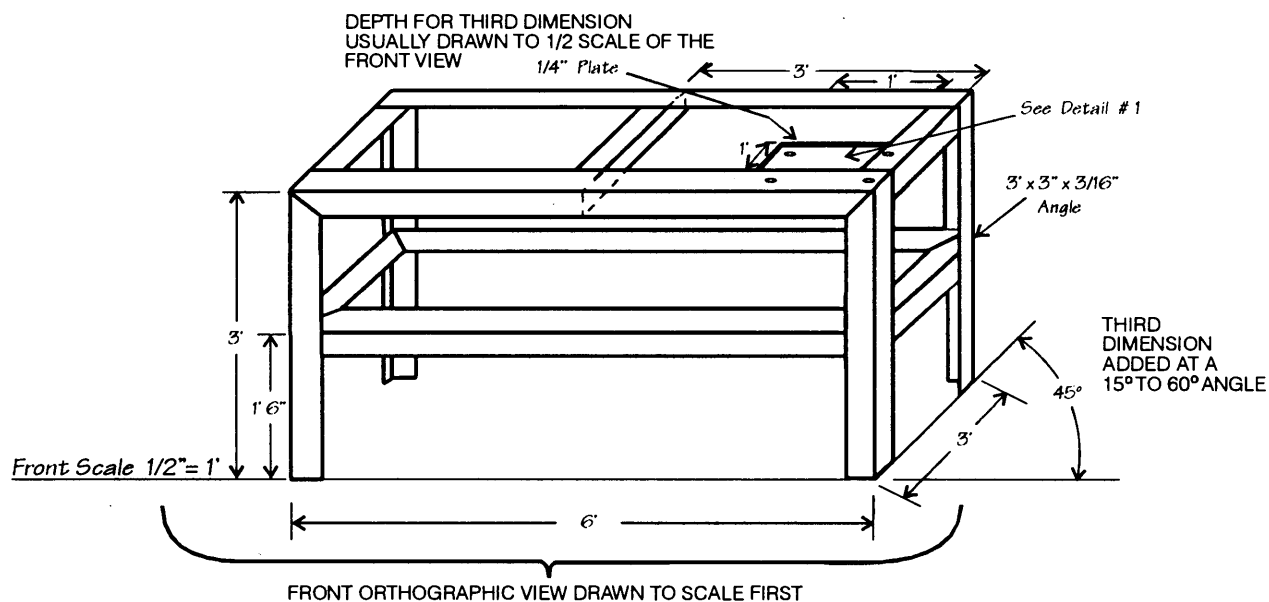
Isometric means same or equal. The other two axis are drawn at "equal" 30° angles from horizontal. All horizontal lines of the object are shown in actual or to-scale lengths at 30° angles from horizontal. An isometric view thus shows the top, side, and one end of an object all at the same time.



An Isometric View of a 6' Shop Table

To draw or sketch an isometric view, first make a horizontal line across the lower part of the page. Next, draw a light vertical line that crosses the horizontal line in the middle of the page. At the intersection of the horizontal line and vertical line, draw two lines at 30° angles. The intersection of these lines forms the lower front corner of the object to be drawn. Actual or to-scale lengths are used for the remaining vertical lines. All the horizontal lines of the object are drawn parallel to the 30° angle lines. When the final sketch or drawing is completed, the unnecessary lines can be erased.

An **oblique view** also shows three-dimensions, or axis, of an object. An oblique view usually starts as a two-dimensional orthographic view of an object. The horizontal axis of the base is drawn first. Vertical lines indicating the outline of the sides are then added. Actual or to-scale height and weight measurements of the object are used. Important features of the front view are then added.

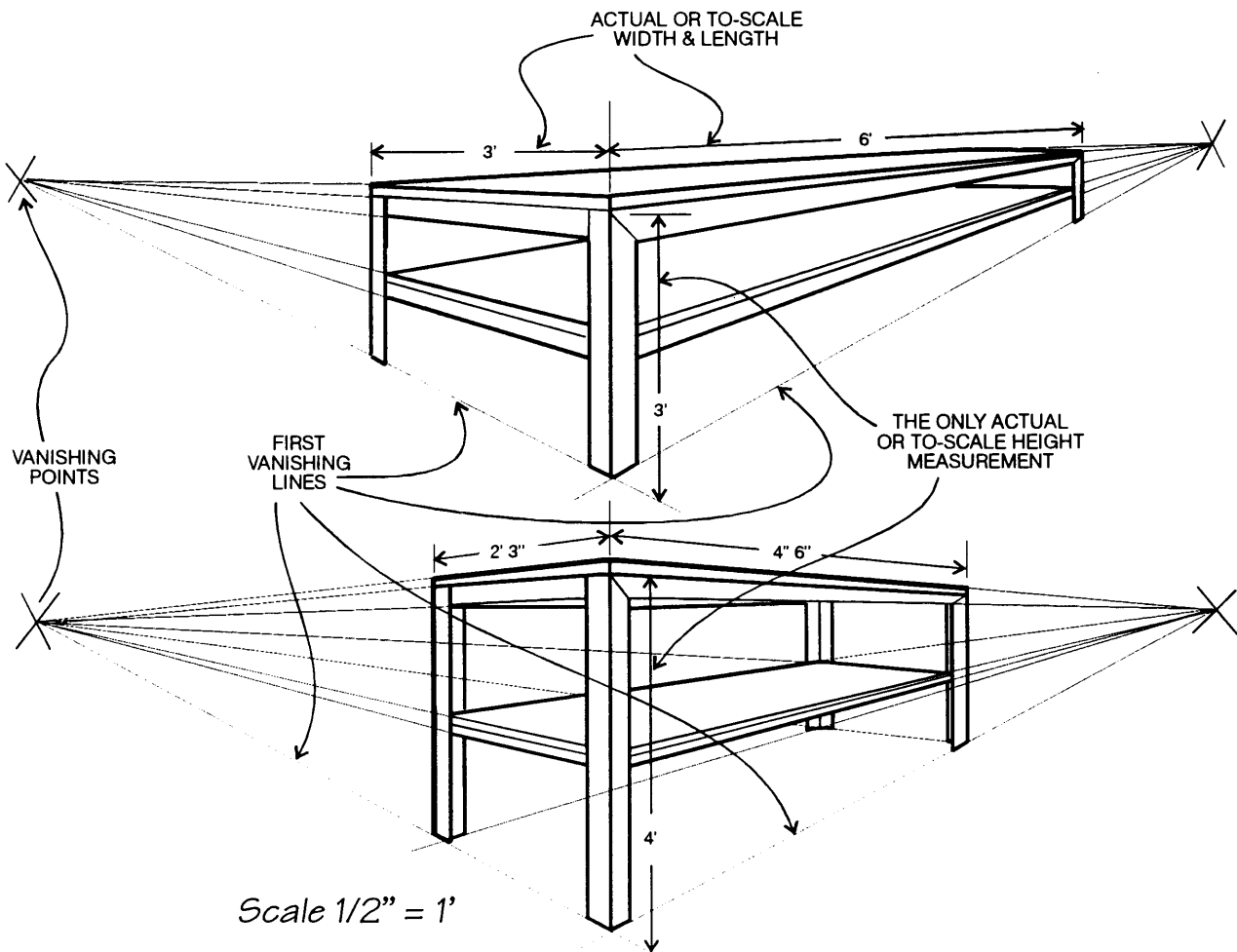


An Oblique View of a 6' Shop Table

Oblique means slanting or sloping; not parallel or perpendicular. The third axis, or dimension lines, are thus drawn on a slant or any convenient angle to show the depth of the object. This angle is usually 15°, 30°, 45°, or 60° because each can be easily drawn with a triangle. Depth lines are often only drawn to one-half of their actual or to-scale lengths.

A **perspective view** represents a "true view" as to how an object would appear to the eye. That is, the further away parts of the objects are, the smaller they appear. Perspective views are difficult to sketch or draw without the aid of **vanishing points** and **vanishing lines**. Vanishing points are arbitrary points to each side of the perspective view to which all horizontal lines lead or come together.

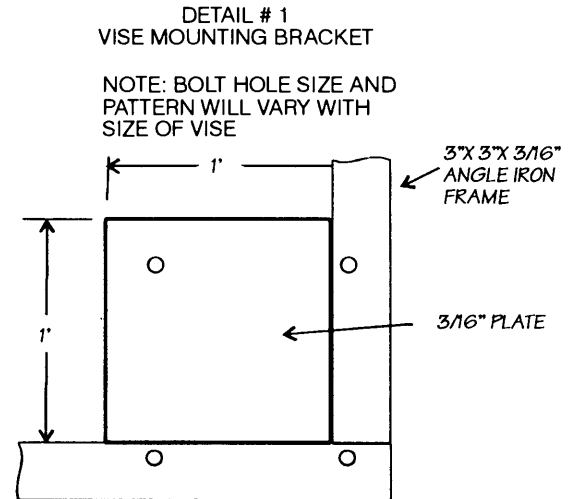
To draw a perspective view, first identify vanishing points on each side of the paper. Draw very light lines from these vanishing points to the middle of the page. The angle of these lines will determine the "perspective" of the view. At the intersection of these lines, draw a very light vertical line. On this vertical line, measure and mark the actual or to-scale height of the front corner of the object to be drawn. This is the only vertical line in the drawing with an actual or to-scale measurement. From the mark on the first vertical line, additional light-colored vanishing lines are drawn back to the vanishing points. Measuring from the height mark on the vertical line, the width and length of the object on the top two vanishing lines are marked.



Perspective Views of Two Different Shop Tables

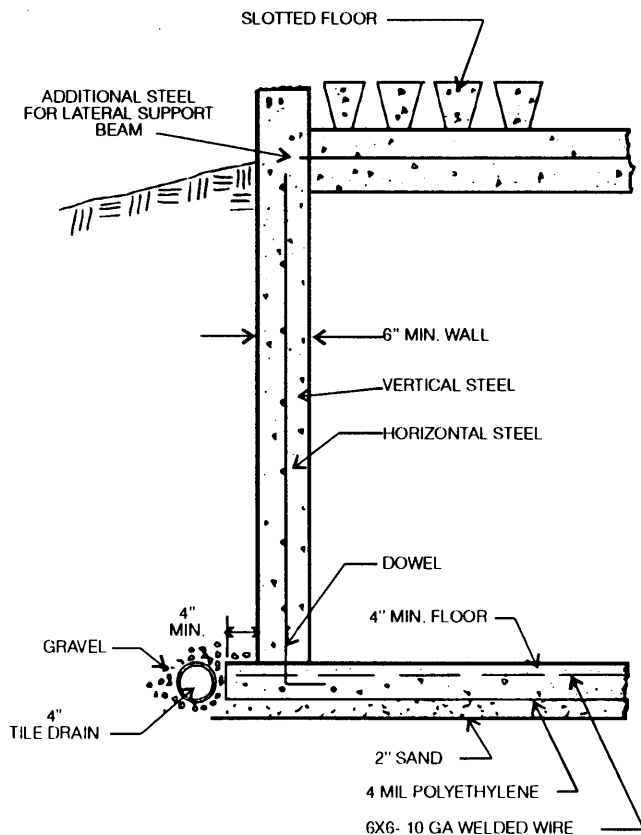
Only the vertical lines are parallel to each other on a perspective view drawing or sketch. Remember, the further away from the "front corner" a part of the object is, the smaller it will appear. Vertical lines that are equally spaced on the actual object, get proportionally closer together as they approach the vanishing points. The size of the object and its parts can only be estimated.

Parallel vertical lines and vanishing lines are added to complete the drawing. The vanishing lines are used to draw the additional horizontal lines for the object and to keep it in "perspective." As needed, sections of the vanishing lines that become a part of the actual drawing are darkened. Others are erased. Refer to the examples of the perspective drawings. As the size and shape of the object to be drawn changes, 1) the location of the vanishing points; 2) the angles at which the first two vanishing lines are drawn; and/or 3) the scale used may need to be changed to give the appropriate "perspective" view.



SCALE 1"=1"

A Detail View Used to Provide Additional Explanation



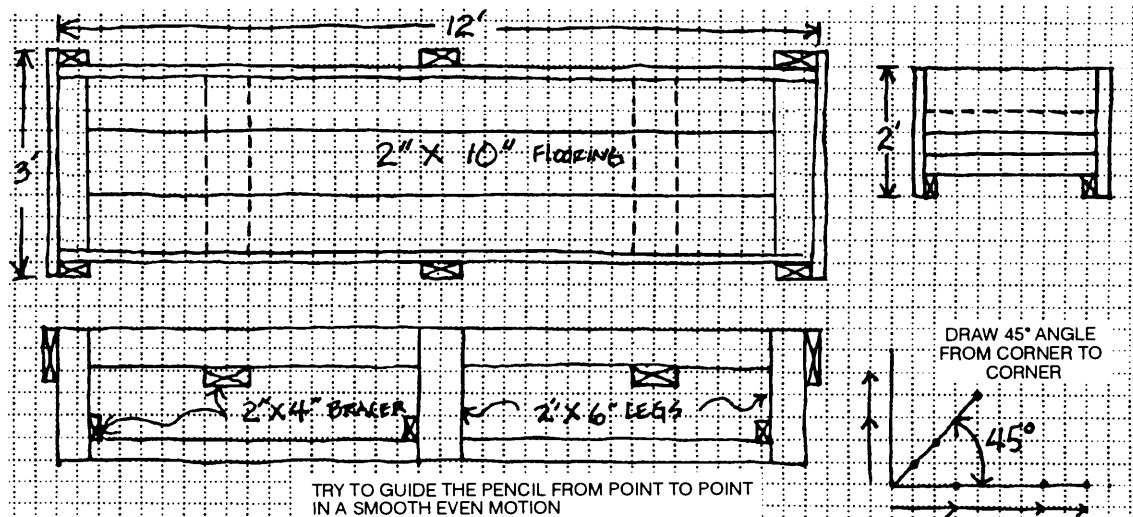
A Cross-Sectional/Detail View of a Manure Pit Wall Included with Building Plans for a Swine Feeding Floor

Detail drawings are used as "helper" drawings. Individual components and joints that require further explanation are often drawn separately. A larger scale and/or a different view may be used to show the additional detail. Notes are often included to describe special features or procedures.

Detail views may be drawn on the same page as the main drawing, or they may be included on a separate page. Detail views are often coded using a lettering and/or numbering system. **For example**, a note on the main drawing might indicate; "SEE **DETAIL #3, PAGE #5.**" The note included with detail view #3 on page #5 would then refer back to the main drawing on the appropriate page.

A **cross-sectional view** shows an object as if it were cut away or cut in half. Such a view is helpful in cases of irregular ends or shapes, and to show inside detail. With practice, a cross-sectional sketch or mechanical drawing can be drawn in either a two- or three-dimensional view.

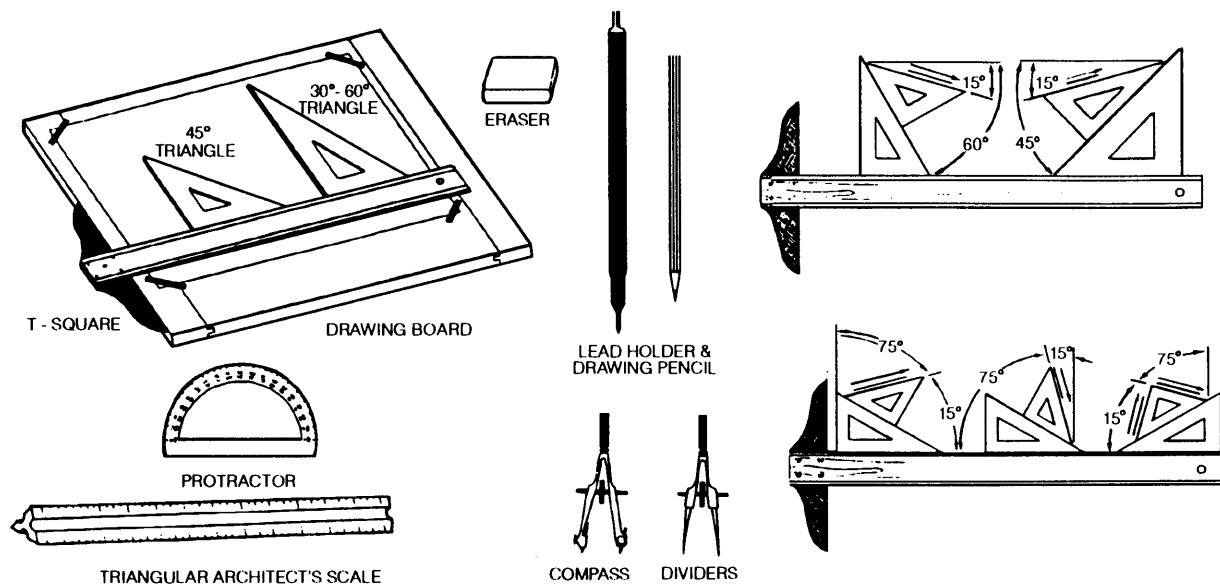
Graph or grid paper can be very helpful for making a basic drawing or sketching. The line or dot spacings can often be used as the scale. Horizontal, vertical, and diagonal lines are the most commonly used marks in sketches and drawings. Even without the use of a straightedge, long lines can be drawn. Instead of one long line motion, short line segments are drawn. With practice, the pencil can be guided from starting or stopping points similar to "dot to dot" drawings in smooth even motions. Forty-five degree diagonal lines can also be easily drawn by using the corners of the squares as references.



Using Graph or Grid Paper to Make Simple Hand Sketches

BASIC MECHANICAL DRAWING EQUIPMENT

A **drawing board** provides a flat rectangular surface for drawing. The surface and edges of the drawing board should be straight and smooth. Some drawing boards have a metal edge inlaid on one end to provide a "true end" surface for the **T-square** to ride against.



Basic Mechanical Drawing Equipment

The *head* of the T-square can be moved up and down the true end as needed to position the blade. When in position, the head is held firmly against the true end of the drawing board. The *blade* of the T-square is thus always horizontal across the drafting board. Using the T-square, drawing paper can be placed squarely on the drafting board and the corners taped into position.

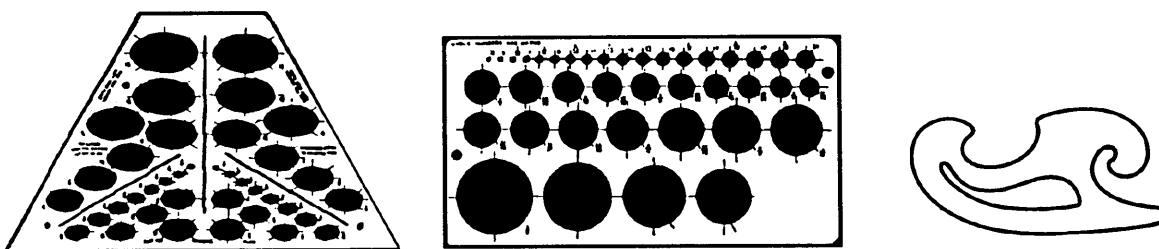
A right-handed person normally positions the drafting board so the true end and head of the T-square are to the left. This helps to prevent interference with the drawing hand arm movement. A left-handed person places the true end and head to the right.

A **triangle** is used to draw lines that are not horizontal by placing it against the horizontal blade of the T-square. Different triangles are classified by their three angles. The most common triangles used have 30°-60°-90° and 45°-45°-90° angles. By using a combination of these two triangles, any angle divisible by 15° can be drawn. A **protractor** can also be used for measuring angles and for drawing those that cannot be divided by 15°.

Compasses are used for marking circles and arcs, and for transferring distances. **Dividers** are somewhat like compasses. They have two steel points instead of one steel and one lead. They are used to transfer distances without making marks on the paper.

Mechanical lead holders and **drawing pencils** are used to draw lines, and to make notes and labels on the drawings. The thickness of the lines is determined by the diameter of the lead used and how it is sharpened. The "**lead**" (actually graphite) used in mechanical holders or drawing pencils comes in varying degrees of hardness. The harder the lead, the lighter the lines. A medium-hard lead is often used for object lines while a slightly softer lead is used for the darker border lines and for labeling. **Rubber erasers** are used to remove pencil lines. **Art gum erasers** are used to clean smudges from the drawing paper.

Different **templates** made of transparent plastic are available for drawing common shapes, circles, curves, symbols, lettering, ellipses, etc. An **ellipse** is oval-shaped and is used to represent a circle or round object as viewed at an angle.



Use Templates for Speed and Accuracy

REFERENCES

- Cooper, Elmer L., *Agricultural Mechanics: Fundamentals and Applications*, Delmar Publishers, Inc., Albany, NY
- Wakeman, T.J., *Modern Agricultural Mechanics*, The Interstate Printers & Publishers, Inc., Danville, IL.
- Umstattd, W.D., *Modern Cabinetmaking*, Goodheart-Willcox, Inc., South Holland, IL.
- Agricultural Structures, Volume 2, Instructional Materials Laboratory, University of Missouri - Columbia, Columbia, MO.
- Structures and Environment Handbook*, Midwest Plan Service, Iowa State University, Ames, IA.

Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, and Mr. Bradley J. Green, Graduate Assistant, Department of Agricultural Education, Texas A&M University, developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

Fill-In-The-Blank: Complete the following statements by inserting the correct word(s) in the blanks.

- _____ 1. Complete building plans are a _____ between the design and construction of an object.
- _____ 2. Drawings are usually more complex than _____.
- _____ 3. _____ views most nearly present what the eye actually sees, but are more difficult to draw.
- _____ 4. A _____ drawing is drawn to an exact scale using special drawing tools.
- _____ 5. Sketches and drawings have been a method of _____ for centuries.
- _____ 6. Symbols and abbreviations conserve _____ on plans.
- _____ 7. Three-dimensional views are also called _____ views.

LISTING: Respond to the following items in the spaces provided.

8. List the items or information which should be included in a complete set of building plans.

(a) _____	(b) _____
(c) _____	(d) _____
(e) _____	(f) _____

9. What three views are usually shown when sketches or drawings are presented in two-dimensional orthographic form?

(a) _____ (b) _____

(c) _____

10. List and briefly describe four types of lines used to create a sketch or drawing. Draw an example of each.

(a) _____

(b) _____

(c) _____

(d) _____

11. What are the three main types of three-dimensional views?

(a) _____ (b) _____

(c) _____

SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph. (Use additional paper when needed.)

12. Discuss different purposes for using complete building plans when designing and constructing a building.
13. If a line on a mechanical drawing is three inches long, and it represents an actual length of six feet on the object, what is the scale of the plan?
14. What do circles on a sketch or mechanical drawing included in building plans usually represent?
15. What visual images does a sketch or drawing use to communicate or describe an idea or image?
16. Why are complete building plans now often required by agricultural lending agencies before considering a loan for any construction project?
17. Why should an agricultural loan officer be able to read building plans?
18. What does isometric means in regards to building blueprints and plans?
What sides are shown in an isometric view?
19. Which view is difficult to sketch or draw without the aid of vanishing points and vanishing lines?

MATCHING: Match the letter of the option in the right-hand column with the term in the left-hand column it best matches.

___ 20. ID	A. Inches
___ 21. C/L	B. Radius
___ 22. °	C. Degrees
___ 23. RH	D. Plus or Minus
___ 24. ±	E. Inside Diameter
___ 25. OD	F. Right-Hand
___ 26. "	G. Outside Diameter
___ 27. R	H. Center Line
___ 28. '	I. Feet

ADDITIONAL SKILLS AND ENHANCEMENT ACTIVITIES: Perform the following activities as assigned by your instructor.

1. Obtain a set of building plans for an agricultural construction project. Study the plans and determine the different views, instructions, specifications, details, notes of explanation, etc., that have been included. Assume you are knowledgeable in construction procedures and you have access to the tools and equipment. Do you feel there is adequate information provided to allow you to construct the project without having to ask questions? What other information do you feel should be provided?
2. Draw freehand sketches of a small project you or someone you know is planning to build. Try drawing the sketches in several different views on clean white paper without the use of lines, a straightedge, or ruler. Now try to draw the freehand sketches on graph or grid paper.

3. Using the basic mechanical drawing equipment, draw mechanical drawings for a small project you or someone you know is planning to build. Add the other necessary information, dimensions, etc., to convert the drawings into "complete building plans." When finished, ask yourself this question, "Have I included all the necessary information and specifications that will allow me or someone else to construct the project one year from now, without having to ask questions or remember how it is to be built?"

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Instructional Materials Service

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N1993

COMPUTING A BILL OF MATERIALS

The cost of a structure or project is partially determined by the types and amounts of materials used. A **bill of materials** is a broad name for the list of all the materials needed to construct a structure or project. It lists the amounts, sizes, and types of materials for a specific construction project. In some cases, it also tells the person constructing the project where each piece of material is to be used. A bill of materials should be developed for each individual project to help: 1) save time, 2) reduce waste, and 3) ensure that the materials are used in the correct place.

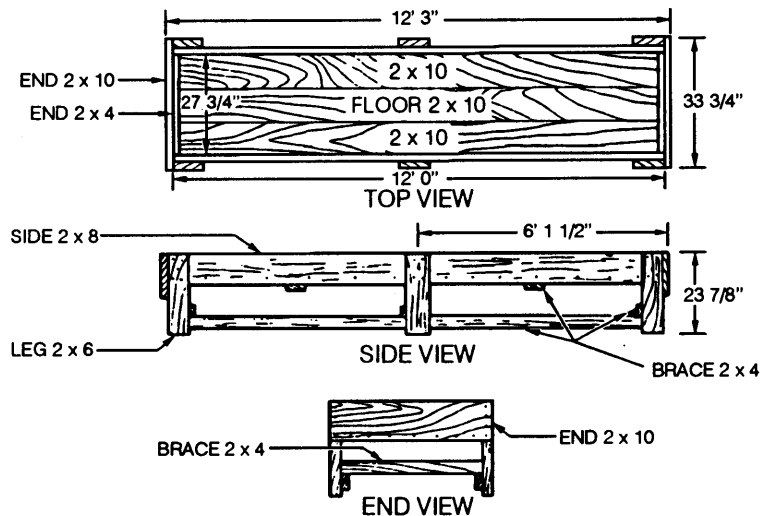
The bill of materials can be a "*shopping list*" from which price quotes can be obtained and materials purchased. This type of list will contain the *total* quantity of each type of material needed to construct the project or structure. It allows for waste from odd lengths, angles, and saw kerfs, etc. Building materials are commercially available in various standard lengths, sizes, packages, etc. It may be necessary to purchase the next longer length of board because the amount needed is only slightly more than the standard available length. A bill of materials may also be a "*saw and cut list*." This type of bill of materials lists the *actual* quantity, description, and actual size or length of the individual pieces needed to construct the project or structure.

DEVELOPING A BILL OF MATERIALS

A bill of materials is developed from a sketch, drawing, or blueprint. All of the various sizes and types of materials needed for the project are listed in it. The materials should be arranged in a logical order. Often the materials are listed in the order they will be needed in the construction process. The bill of materials may include the following information:

* item name or common name	* description
* type or grade needed	* size needed
* amount or number needed	* cost of each piece
* total cost	* allowance for waste
* location each item is used within the structure or project	

WORKING SKETCH - 12 Foot Feed Trough



"Shopping list" Bill of Materials

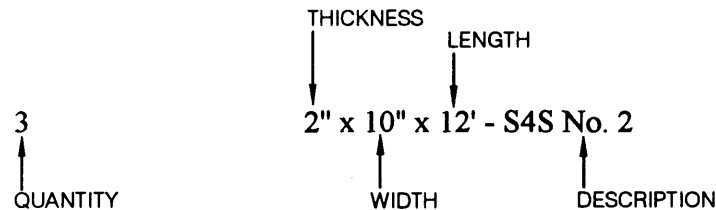
<u>Quantity</u>	<u>Material</u>	<u>Unit Cost</u>
3	2" x 10" x 12' - S4S No. 2	\$ 7.85
2	2" x 8" x 12' - S4S No. 2	\$ 4.85
1	2" x 10" x 6' - S4S No. 2	\$ 4.10
1	2" x 6" x 12' - Treated	\$ 4.55
1	2" x 4" x 8' - S4S No. 2	\$ 1.45
1	2" x 4" x 12' - S4S No. 2	\$ 2.45
2	2" x 4" x 12' - Treated	\$ 2.85
3 lbs.	16 d gal ring-shank nails	\$.48/lb.
1. Gal.	Paint - Latex Barn Red	\$ 12.83/gal.

"Saw & Cut List" Bill of Material

<u>Part</u>	<u>Material Used</u>	<u>Number</u>	<u>Cut Length</u>
Floor	2" x 10" x 12' - S4S No. 2	3	2" x 10" x 12'
Sides	2" x 8" x 12' - S4S No. 2	2	2" x 8" x 12'
Ends	2" x 10" x 6' - S4S No. 2	2	2" x 10" x 33 3/4"
	2" x 4" x 8' - S4S No. 2	2 **	2" x 4" x 27 3/4"
Legs	2" x 6" x 12' - Treated	6	2" x 6" x 23 7/8" (allowance for saw kerf)
Braces	2" x 4" x 12' - S4S No. 2	2	2" x 4" x 30 3/4"
	2" x 4" x 12' - S4S No. 2	3	2" x 4" x 33 3/4"
	2" x 4" x 12' - Treated	2	2" x 4" x 12'

** Note: Approximately 40 inches of the 2" x 4" x 8' will be left after the end pieces have been cut. It will be used to make the fifth brace.

The quantity, size, and description of the materials are often listed together. The quantity is the first number listed. The sizes of the materials are usually listed next. It is listed by the thickness, width, and length of the material. The description of the material follows the size.



Units of Measure

The size and quantity of different types of building materials may be indicated by a different unit of measure.

Board Foot - A board foot is a standard volume of lumber that equals 1-foot long, 1-foot wide, and 1-inch thick. To find the number of board feet in a piece of lumber, multiply the **nominal thickness** in inches times the **nominal width** in inches times the length in feet and divide by 12. Nominal means "name." **For example:** A 2" x 4" board *by name* is 2" thick and 4" wide. The actual measurement is 1 ½ " thick and 3 ½ " wide. A 2" x 4" - 12' long would contain 8 board feet.

$$\frac{2" \times 4" \times 12'}{12} = 8 \text{ board feet}$$

For many years, framing and structural lumber sold at retail lumber yards was priced by the board foot. It was necessary to convert the lumber on the bill of materials to board feet to determine the cost. For convenience, most retail lumber is now priced and sold by the "piece or stick." However, large quantities of lumber sold wholesale or to contractors may still be priced by the board foot.

Running Foot - A running foot is a piece of material 1-foot long, regardless of width and thickness. Narrow lumber, pipe, electrical wire, fencing materials, some types of metal roofing, and certain types of reinforcement steel are sold by the running foot.

Square Foot - A square foot is 1-foot long and 1-foot wide, regardless of thickness. Floor coverings, plywood and paneling, and some types of roofing are sold by the square foot.

Cubic Foot - A cubic foot is 1-foot wide, 1-foot long, and 1-foot thick. Cement and other masonry materials are sold by the cubic foot.

Cubic Yard - A cubic yard equals 27 cubic feet. It is 1-yard wide, 1-yard long, and 1-yard thick. Fill material and larger amounts of concrete are purchased by the cubic yard.

Gallon - A gallon is a liquid measure that equals four quarts. Two pints are equivalent to one quart. Most painting materials and other liquids are sold by the gallon.

Roll - A roll is a cylinder or spool of material. The thickness of the material determines the amount of the material in one roll. Wire fencing, roofing paper, and certain types of roofing can be purchased by the roll.

Square - A square is a term which refers to the amount of material needed to cover an area 10' wide and 10' long, or 100 square feet. **For example:** three bundles of asphalt shingles equal one square, or 5 sheets of 26" wide X 10' long metal roofing, equal a square. (2-inch per sheet allowance for lapping).

Pound - Nails and other types of fasteners are usually sold by the pound. One pound is equal to 16 ounces.

IMS student topic # 8148-A, 8148-B, 8148-C, and 8150-A provide additional information on the description for other types of building materials and units of measure.

		UNIT PRICE
		↓
3 lbs.	16 d gal ring-shank nails	\$.48/lb.
1 Gal.	Paint - Latex Barn Red	\$ 12.83/gal.
↑	↑	
QUANTITY	MATERIAL DESCRIPTION	

These procedures may be followed in preparing a bill of materials:

- (1) Study the sketch, drawing, or blueprint of the structure or project.
- (2) List all of the materials needed. Then make a detailed list for the job. The list should include the size and number of the materials needed.
- (3) Revise the list by listing the materials in a logical order. Give a description or use for each item.

After completing the bill of materials, check it against the plans to be sure that all of the materials and the information needed have been included. The bill of materials should be attached to the sketch or plan for future reference.

Part of the cost of the project or structure can be calculated from the bill of materials. The total cost of materials can be calculated by multiplying the quantity of each material by its unit cost. The total cost of materials for the project is then determined by totaling the cost of each type of material.

"Shopping list" Bill of Materials

Quantity	Material	Unit Cost	Total Cost
3	2" x 10" x 12' - S4S No. 2	\$ 7.85	\$ 23.55
2	2" x 8" x 12' - S4S No. 2	\$ 4.85	\$ 9.70
1	2" x 10" x 6' - S4S No. 2	\$ 4.10	\$ 4.10
1	2" x 6" x 12' - Treated	\$ 4.55	\$ 4.55
1	2" x 4" x 8' - S4S No. 2	\$ 1.45	\$ 1.45
1	2" x 4" x 12' - S4S No. 2	\$ 2.45	\$ 2.45
2	2" x 4" x 12' - Treated	\$ 2.85	\$ 5.70
3 lbs.	16 d gal ring-shank nails	\$.48/lb.	\$ 1.44
1. Gal.	Paint - Latex Barn Red	\$ 12.83/gal.	<u>\$ 12.83</u>
			\$ 65.77

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- Boyd, James, *Practical Farm Buildings*, Interstate Printers and Publishers Inc., Danville, IL.
- Cooper, Elmer L., *Agricultural Mechanics: Fundamentals and Applications*, Delmar Publishers Inc., Albany, New York.
- Phillips, Richard, *Farm Buildings: From Planning to Completion*, Doane and Western Inc., St. Louis, MO.
- Wakeman, T. J., *Modern Agricultural Mechanics*, Interstate Printers and Publishers Inc., Danville, IL.

Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, Mr. Bradley J. Green, Graduate Assistant, and Mr. Donald Krobot, Intern, Department of Agricultural Education, Texas A&M University, developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

MATCHING: Match the description in the left-hand column to the correct term in the right-hand column.

_____ 1. Board Foot	A. 27 square feet
_____ 2. Square Foot	B. 100 square feet
_____ 3. Cubic Foot	C. 1" x 1' x 1' lumber
_____ 4. Square	D. 1' x 1'
_____ 5. Cubic Yard	E. 1' x 1' x 1'

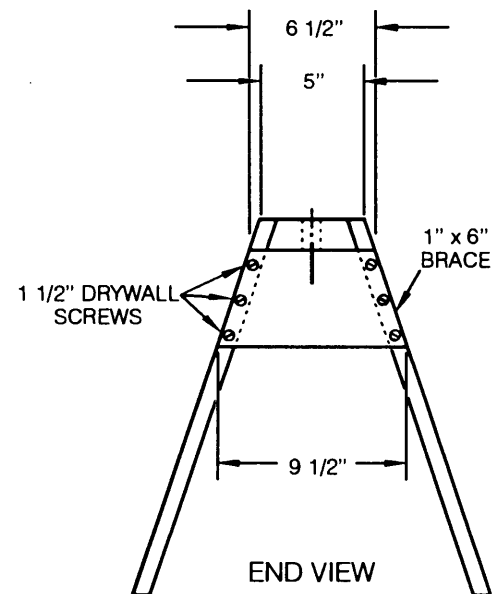
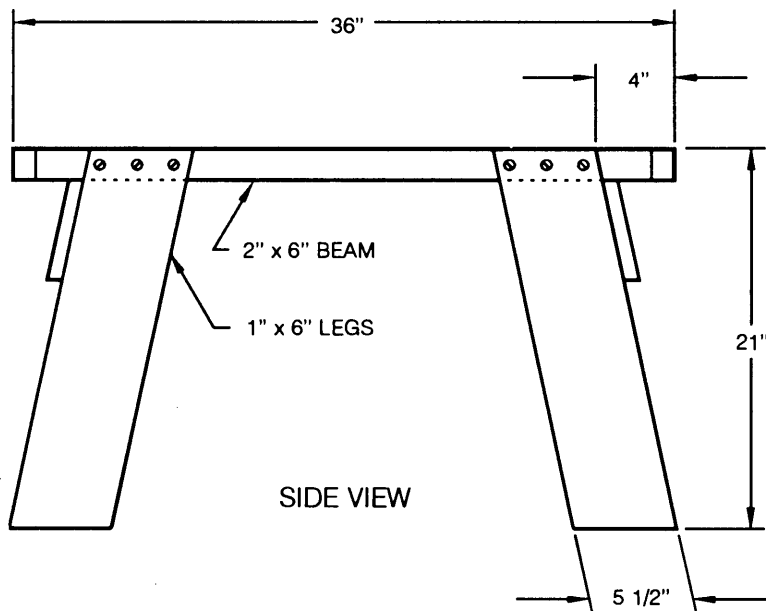
SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph. (Use additional paper when needed.)

6. Describe the information which should be included in a bill of materials.

7. What are some of the advantages of developing a bill of materials?
8. What is the difference between a square foot and a running foot?
9. What are the two uses of a bill of materials? How are these lists different?
10. Describe the procedure to use in making a bill of materials.

ADDITIONAL SKILLS AND ENHANCEMENT ACTIVITY: Perform the following activity as assigned by your instructor.

1. Use the following plan or one supplied by your instructor to make a bill of materials "shopping list."



2. Visit a local building materials supplier for current prices.

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Instructional Materials Service

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N1992

SELECTING PAINTS AND PRESERVATIVES

Paints and other preservatives protect, as well as improve the appearance of agricultural structures and equipment. Paint is a mixture of various chemicals and compounds that protect metal, masonry, plastic, wood, and other surfaces. Paint may protect against rust, corrosion, decay, and in some cases wear. In addition to protection, other compounds can be added to give a desired color. Paint increases the dollar value of the structure or equipment by increasing its life expectancy and improving its appearance.

SELECTING PAINTS OR PRESERVATIVES

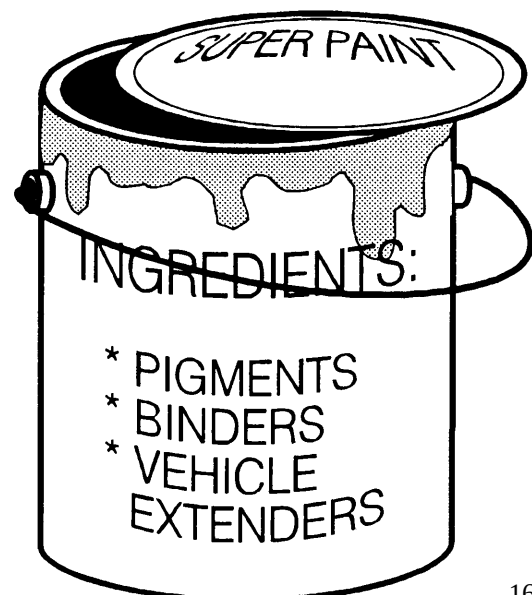
Factors to consider when selecting paints, preservatives, and application methods may include:

- 1) Size, shape, texture, and composition of the surface to be painted
- 2) Desired finish
- 3) Location of surface and conditions that area will be exposed to
- 4) Productive life of the paint film
- 5) Presence of other paints on the surface
- 6) Cost of application equipment
- 7) Ingredients of the paint and how they are mixed
- 8) Toxicity of the paint

Primary Ingredients

For general discussion purposes in this topic, we will refer to all paints, preservatives, stains, etc., as "paints." The primary paint ingredients are divided into three main categories: 1) pigments, 2) binders, and 3) vehicles.

Pigments are those ingredients added to paint for color, covering power, texture, and to some degree protection. At one time, lead and lead oxides were the most common pigments.



Today, they are used less frequently due to the toxic nature of lead. However, many older surfaces that were painted with paints that contained large amounts of lead may still be a potential health hazard. When old paint is removed, dust or small particles can be inhaled or ingested. Care should be taken to insure that animals and people are not exposed to lead paints during the sanding, scraping, or painting process.

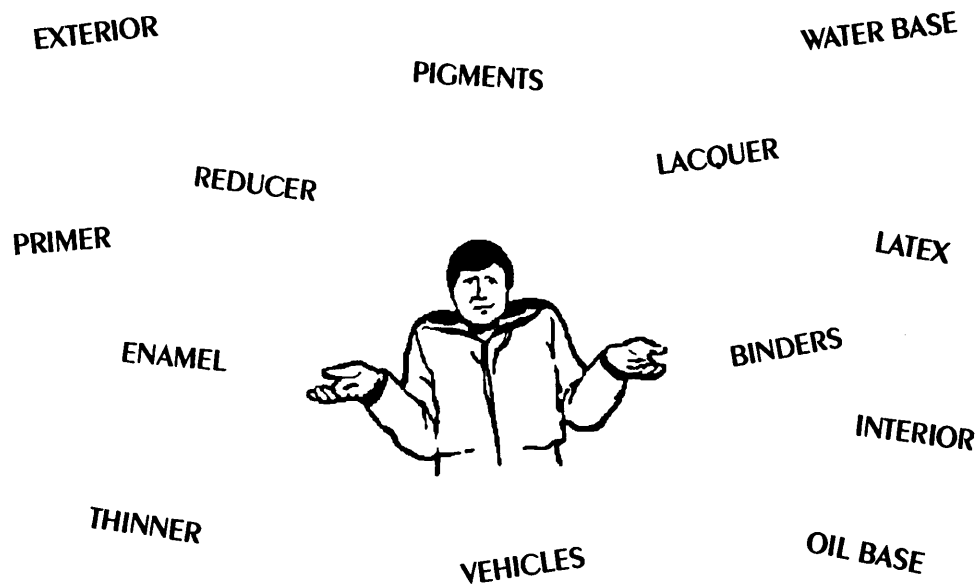
Modern, high quality pigments include titanium dioxide, iron, zinc, and aluminum compounds. As a rule of thumb, the higher the percentage of these pigments in a paint, the better its quality. If possible, avoid lower quality pigments such as calcium, magnesium, and silicon compounds.

Binders are the ingredients that bond the pigments together, and to the surface to be painted. Binders also provide part of the protective and sealing characteristics of the paint. Without binders, the paint film would dry to a powdery dust and would not adhere to the surface. As the binder dries, it produces an exterior film which may either be airtight or porous. The paint film may crack as the surface flexes, expands, or contracts. Paints with high quality binders are more elastic and help prevent the paint film from cracking or peeling.

The **vehicle** is the liquid part of the paint. It serves as a carrier for ingredients and reacts with the binders and pigments. The vehicle aids in the mixing of ingredients and the application of the paint. The vehicle evaporates after the paint is applied, leaving the binder and pigments. The type of vehicle is normally considered the first main classification of the different types of paints. The three main types are: 1) **water based**, 2) **oil based**, and 3) **resin-solvent based**.

Water based paints use water as the vehicle. The water quickly evaporates into the air. These leaves the binders to dry, bind the pigments, and form the paint film. **Oil based paints** contain an oil as the vehicle. Oxygen from the air causes the oils in the vehicle to change their chemical composition and slowly dry.

A third type of paint vehicle is a resin-solvent. **Resin-solvent based paints** use natural plant or synthetic resins in a petroleum solvent as a vehicle. Drying takes place through the evaporation of the solvent and a reaction between the resins and other ingredients. Resin-solvent based paints have excellent sealing and surface protection properties. They will also resist higher temperatures. Resin-solvent based paints may be highly flammable. Their fumes and vapors are usually more toxic than other types of paints. Resin-solvent based paints are relatively new. Therefore, they may sometimes be referred to as a type of oil based paint.



Secondary Ingredients

Additional secondary ingredients provide specific characteristics for special uses and applications. The intended use of the paint determines which secondary ingredients are added to the paint.

Extenders give bulk to the pigment and/or cheapen the manufacturing process. Some common types of extenders are chalk, pulverized limestone, silica, talc, or soapstone. In some paints, a *chalking* or *weathering effect* causes the paint film to slowly wash away and maintain a bright appearance. The color pigments and chalk that slowly washes off can streak and discolor the material or surface below it. Special "trim paints" have better quality binders, extenders, and pigments. They are less likely to chalk and bleed, especially when two different colored paints are applied adjacent to each other.

Wood may be damaged by decay and insects if not protected. The growth of mildew, fungi, and bacteria on painted surfaces can become very unsightly. **Bactericides, fungicides, insecticides** and other **preservatives** are now added with certain paints to help control the growth of these organisms and the damaging effects of insects and decay. Special purpose metal paints contain **rust inhibitors** to help control corrosion. Masonry paints may use **cement** as a sealer and/or surface protector.

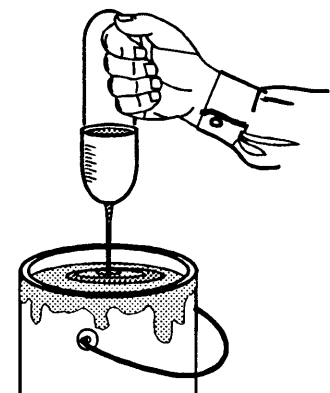
When paint is purchased, it usually contains only a small amount of the liquid vehicle. It is very thick and has a high viscosity rating. **Viscosity** is a measure of the resistance to flow. The higher the viscosity rating, the more resistant to flow. The small amount of vehicle helps prevent the pigments or binders from settling during storage. Before these paints can be applied, they must be thinned and mixed. **Thinning** is done by mixing paint with additional "vehicle."

Each type of paint must be thinned with the proper type of vehicle or "thinner." Water based paints are thinned with **water**. Oil and resin-solvent based paints are thinned with compounds called **paint thinners and reducers**. They are made with oil, alcohol, or petroleum products.

Paint thinners only thin the vehicle of a paint. **Reducers** thin the vehicle and also reduce or dissolve part of the binder. In certain types of oil and resin-solvent based paints, the vehicle must be thinned *and* the binder reduced to begin the drying process. However, if a reducer is added to a paint that only needs the vehicle thinned, the paint will not dry and adhere to the surface properly.

Each paint manufacturer uses different names to describe their particular brand name or type of oil or resin-solvent based paint thinners and/or reducers. Always follow recommendations listed on the paint label for specific mixing procedures. It is important to use the correct thinner and/or reducer and in the proper amounts. Improper mixing of the thinner/reducers can cause the paint surface to "flash dry." This will result in a checked or alligator skin appearing finish.

When thinning paints, regardless of type, always follow recommendations listed on the paint label and use exact measurements. The viscosity of the paint can be checked by the use of a **viscosimeter**. A viscosimeter is a small calibrated tube with a small hole in the bottom. It is filled with a specific volume of paint. The time needed for the paint to drain out is then measured. The more thinner or reducer added, the lower the viscosity and the faster the paint will drain from the tube.



Viscosimeter



The word **solvent** is also sometimes used interchangeably with thinner or reducer. This can be very misleading. A solvent is a liquid that is volatile and will dissolve other compounds. By this definition, gasoline is a solvent and will dissolve some paints. However, gasoline should *never* be used as a thinner, reducer, or cleaner because it is highly explosive and flammable. "Paint solvents, thinners, and reducers" are designed and tested for specific purposes and safety.

Some paint solvents are used primarily for pre-cleaning surfaces to be painted, dissolving the binders of old paint films, or for cleaning paint equipment. It is *essential* that the paint, solvent, and thinner/reducer be compatible and *all* safety precautions be followed. A person *must* follow the paint manufacturers' recommendations listed on the paint, thinner/reducer, and solvent labels.

CLASSIFICATION OF PAINTS AND PRESERVATIVES

Paints are classified in many different categories or types based upon their characteristics, intended uses, and composition. One particular can of paint may or may not be limited to one type, classification, or specialized use. Competition among paint manufacturers has forced the development of new and improved ingredients and additives. This may allow one type of paint to meet the requirements for several different applications.

Type of Paint Vehicle - As previously discussed, one of the main classifications of paints is by the type of vehicle used. The three main types are: 1) **water based**, 2) **oil based**, and 3) **resin-solvent based**. At one time, all metal paints were oil based. With modern technology and synthetic compounds, water based paints are now used on many metal surfaces.



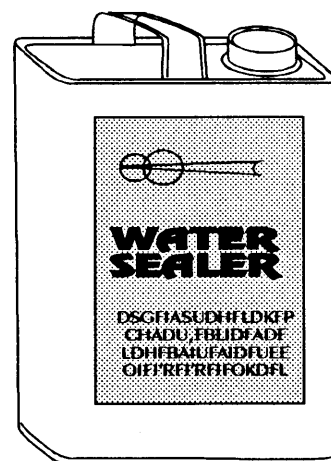
Interior or Exterior Paints - Paints are also classified for either **interior** or **exterior** use or both. Exterior paints can better withstand the damaging effects of the outdoor weather and ultraviolet rays. Both interior and exterior paints can have any of the different types of vehicle bases. The old belief that interior paints were all water based and that exterior paints were all oil based is no longer true. Many exterior paints are now water based, and special types of interior paints are oil based.

Wood, Metal, Plastic, or Masonry Paints - Paints may be further classified according to the type(s) of surface(s) they adhere to and protect. Speciality paints may have special binders and extenders mixed into them for certain surface applications or adverse condition requirements.

Primers and Undercoats - Primers and undercoats are special purpose paints designed to serve as a first coat. They are usually more expensive and contain additional binders to improve adhesion and sealing. They may also contain rust or decay prevention additives. Primers and undercoats may be designed specifically for metal, wood, masonry, synthetics, or a combination of all. Prior planning is required to match the final topcoats with the primer/undercoat.

Type of Finish - An additional classification of paints is by the type of shine or luster of the finish. **Flat paints** will produce a dull finish without a shine. **Semigloss paints** will produce a slight shine while **gloss or high gloss** paints produce a very shiny, glassy finish. The higher the gloss, the more surface imperfections or roughness will show through.

Water-Repellent Preservatives - Special purpose water-repellent preservatives (WRP) are "paints" that are applied to wood to repel rain and moisture. WRPs soak into the outer surface of the wood, but do not completely seal it. WRPs may or may not contain color or texture pigments that change the appearance of the wood. They usually have transparent vehicles and binders that are mixed with fungicides, insecticides, and the wood preservatives. Some WRPs can be topcoated with other types of paint at a later time if desired.



Other Types or Classifications of Paints and Common Paint Terminology

As a general rule, **enamel** paints dry by evaporation of the vehicle *and* oxidation of the pigments and binders. This will produce a harder, more durable finish. However, it may take longer for the paint to completely cure and the surface will usually stay "tacky" longer. This may allow enough time for dust and other small particles to settle on the tacky surface and cause imperfections. Enamel paints can be water, oil, or resin-solvent based.

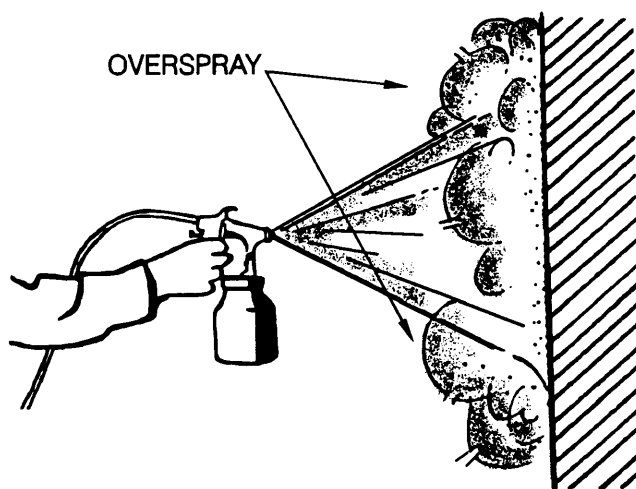
With **lacquer** paints, the paint film forms as the paint vehicle evaporates. Lacquer paints thus dry quicker on the surface, but may not produce as hard or as durable a finish.

Latex is a general term used to describe a rubbery compound used in paints. Latex paint is a popular interior and exterior house or wood paint. Latex paints are less toxic, easy to apply, and the painting equipment can be cleaned with warm soapy water.

Many modern oil and resin-solvent based paints use new synthetic compounds and resins as binders and/or as part of the vehicle. They also provide the sealing and surface protection characteristics for many special purpose paints.

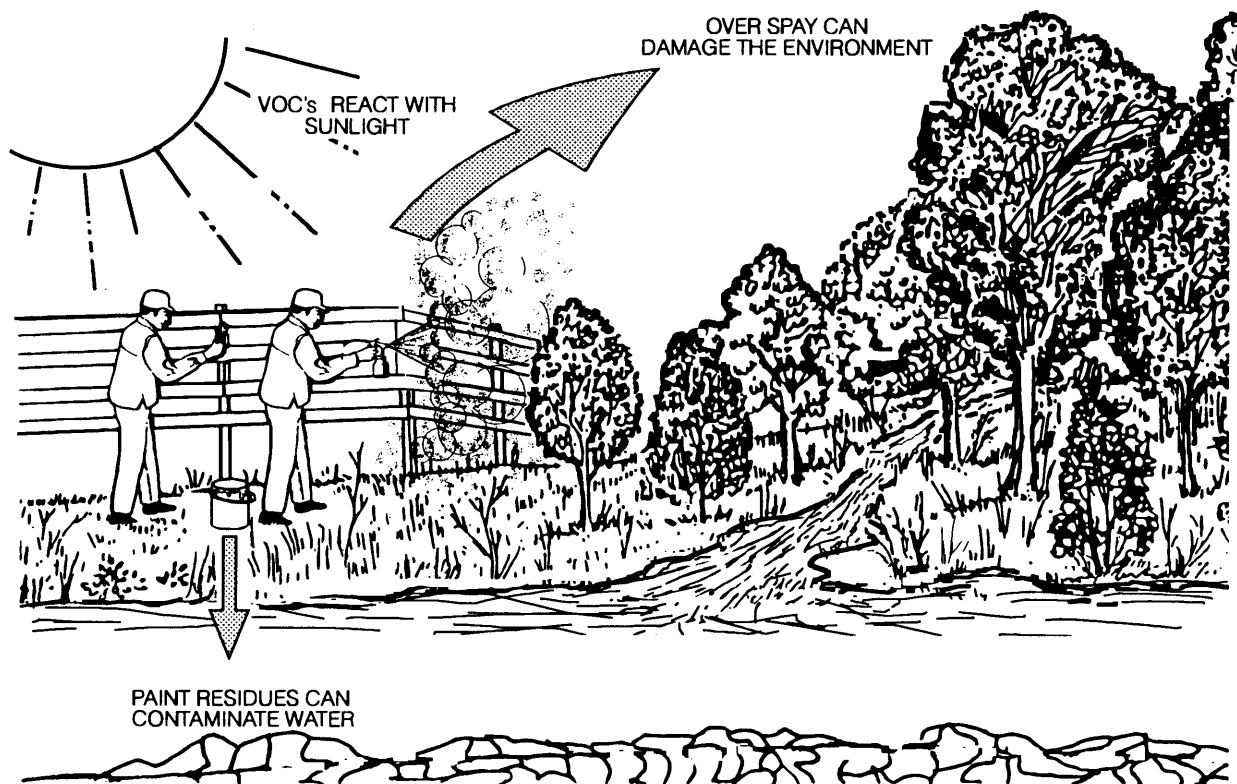
PAINT SAFETY

Transfer efficiency is the ratio of the amount of paint *applied*, to the amount of paint that *actually remains* on the painted surface. Transfer efficiency is very important for economic and environmental considerations. Some spray paint systems create excessive overspray because of the higher air or paint pressures. This decreases transfer efficiency, increases paint usage, and increases the amount of possible **volatile organic compounds (VOCs)** emitted into the environment.



Some types of paints, solvents, thinners, and reducers contain VOCs, or other compounds, that evaporate easily into the air. VOCs react with oxides in the air and sunlight to cause pollution. Paints and paint products may also be toxic or produce flammable vapors.

The Federal Clean Air Act Amendment of 1990, Occupational Safety and Health Administration (OSHA), and other state or local regulatory agencies currently regulate the amount of VOCs that can be released into the environment by industries using paint products. They specify how paint and paint products should be stored and disposed of. These rules and regulations are designed to protect human health and the environment.



Pollution From Paint Products

Presently, many smaller paint shops, agricultural implement dealers, and individuals who use paint are not subject to the strict regulations required for the larger businesses. However, regulations for individuals and smaller businesses are likely to increase in the next few years if voluntary improvements are not made. Everyone should voluntarily strive to protect the environment and help reduce hazardous waste.

Follow label directions and use protective clothing, gloves, paint masks, and respirators when using spray painting equipment. Do not use paints thinners, reducers, or solvents near open flames or equipment that produce sparks. If possible, store all paints and supplies inside specially designed metal storage cabinets to reduce fire hazards.

All empty paint cans, used solvents, and other toxic waste materials from the painting process should be stored in drums or other containers that are clearly labeled. They should be disposed of at EPA approved landfills or disposal centers.

Always follow the painting equipment and paint manufacturers' recommendations. **Your health and safety may depend upon it!**

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- Cooper, Elmer L., *Agricultural Mechanics: Fundamentals and Applications*, Delmar Publishers, Inc., Albany, NY.
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- Spray Painting*, Vocational Agriculture Service, University of Illinois, Urbana, IL.
- Paints and Painting*, Agricultural Engineer's Digest, Midwest Plan Service, Iowa State University, Ames, IA.
- Painting Equipment and Spray Gun Training Series*, Graco Inc., Minneapolis, MN.
- Paint Application Equipment*, Binks Manufacturing Co., Chicago, IL.

Acknowledgements

Mr. Bradley J. Green, Graduate Assistant, Mr. Donald Krobot, Intern, Department of Agricultural Education, Texas A&M University, and Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

TRUE OR FALSE: Circle "T" if the statement is more true than false: Circle "F" if the statement is more false than true.

- T F 1. When thinning paint, it does not matter if a reducer or thinner is used.
- T F 2. Interior paint is recommended for outside use.
- T F 3. All paint products are flammable.
- T F 4. The type of finish desired depends upon the number of coats applied.
- T F 5. Paint increases the life expectancy of structures and buildings.

LISTING: Respond to the following items in the space provided.

6. List five of the eight factors that should be considered when selecting paints, preservatives, and application methods.

(a) _____ (b) _____

(c) _____ (d) _____

(e) _____

7. Paints are composed of primary and secondary ingredients. List the primary ingredients.

(a) _____ (b) _____

(c) _____

8. List the vehicles used in the following types of paint.

(a) water based paint _____

(b) oil based paint _____

(c) resin-solvent based paint _____

SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph. (Use additional paper when needed.)

9. Discuss the use of a viscosimeter and why it is important to check the viscosity of a paint prior to application.

10. Briefly describe what safety or health measures you should take when painting.

11. Describe the reasons why secondary ingredients are added to paints.

12. Describe the functions of pigment found in paint.

ADDITIONAL SKILLS AND ENHANCEMENT ACTIVITIES: Perform the following activities as assigned by your instructor.

1. Go to your local hardware store and inquire about the different kinds of paints available. Find out which paints are most commonly used in your area and why.
2. Obtain several paint samples and experiment by painting several pieces of scrap material. Determine which pieces require additional coats.
3. Interview a person in your community who has just completed painting a large structure or project. Determine what considerations were used in choosing the particular paint they used.
4. Obtain several different types of paints. Read the manufacturer's instructions to find out which thinner/reducer is required for each paint. Report your findings to the class.

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SAFELY APPLYING PAINTS AND PRESERVATIVES

CLEANING AND SURFACE PREPARATION BEFORE PAINTING

Proper surface cleaning and preparation is as important as the correct type and quality of paint and equipment used. Without proper surface preparation, the paint will not bond. The paint film will not be durable, nor will it have the proper finish. As a general rule, paint should only be applied to clean, dry surfaces when temperatures are between 50 and 90°F.

High pressure washers, steam cleaners, and sandblasters are often used to clean equipment and structures before painting. Special detergents and cleaning compounds can be purchased to aid in surface preparation. Always follow the manufacturer's directions when using special equipment or chemicals. In some cases, it may be necessary to use scrapers or wire brushes to remove hard, caked-on materials. Be sure to protect electrical equipment and other equipment from moisture and chemical solutions.



Proper Surface Preparation Begins With
Proper Cleaning

Surface preparation - Metal

Most new unpainted aluminum, steel, and galvanized steel surfaces have an oily, protective film applied during the manufacturing process. Other types of new steel may have a layer of "mill scale." This film and/or mill scale will prevent paint from bonding. It must be removed before a primer or paint is applied.

Aluminum and galvanized steel objects must be washed with hot soapy water, rinsed, and thoroughly dried. New steel with excessive mill scale should be lightly sandblasted, sanded, or buffed. All new metal surfaces should then be wiped with an appropriate metal conditioner.

A **metal conditioner** is a weak acid solution that will lightly etch and clean the metal surface so that the paint will bond. As a final step before painting or priming, the metal surface should be wiped with a tack cloth. A **tack cloth** is a special lint-free cloth dampened with the appropriate solvent or thinner. It is used to remove any remaining dust, dirt, or film. The tack cloth is used right before the first coat of paint or primer is applied.

Metal should be primed as soon as possible after it is cleaned and wiped. Dust will start to settle and the humidity from the open air can cause clean metal to begin to rust or oxidize in a matter of hours.

Problems often arise when attempting to paint metal that has been welded. The slag and dust that forms near the welded area may not have been removed during chipping and brushing. This can cause the paint to flake, peel, or discolor near the welded area.

Another common problem of painting welded metal is over-buffing or **burnishing** the welded area. This is particularly true when a high-speed steel brush or buffing wheel is used. While attempting to clean the oily film, slag, and/or mill scale, the metal surface is burnished. This is similar to how wax or polish is buffed into a floor tile. The surface may appear properly cleaned, but it is too "slick" for the paint to bond properly.

Repainting metal surfaces, or painting rusty metal is also a problem. The rust and old paint may first be stripped back to bare metal by sanding, grinding, or sandblasting. Chemicals or solvents that dissolve or soften old paint may also be used. The metal surface is then cleaned, prepared, and primed in much the same manner as new metal. The amount of sanding required is determined by the type of finish desired. A smooth finish will require more sanding with a finer grit of sand paper.

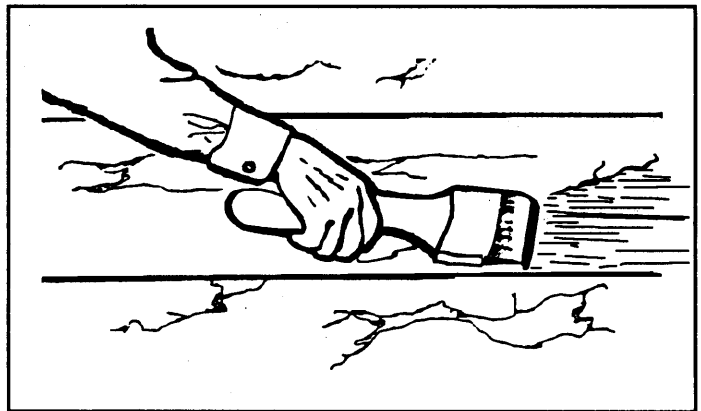
New paint may be applied directly over old paint *only* if the two paints are compatible. A simple test should be made by applying some of the new paint and the thinner or reducer over the old paint. If the old surface blisters, wrinkles, or softens when the new paint is applied, they are not compatible. If they are compatible, the entire surface may need to be lightly sanded. The surface should then be cleaned and wiped with a tack cloth before the new paint is applied.

Surface preparation - Wood

All wood surfaces must be free of oil, dust, wax, and surface moisture before paint is applied. These conditions can cause the paint film to blister, crack, or peel. Approximately 90 percent of all blistering and peeling of paint on wood surfaces is caused by: 1) excessive moisture on the surface before painting, or 2) moisture that is allowed to get under the paint film once it cures.

When repainting a wooden structure, use a wire brush or scraper to remove any loose, cracked, blistered, or peeling paint. Dirt, dust, mold, mildew, and old paint chalk will also prevent the new paint from bonding. If these conditions are present, wash the surface with a strong detergent and water or with a special cleaner such as **trisodium phosphate (TSP)**. Be sure to read and follow label directions before mixing and application. If the surface is washed, it must be rinsed and allowed to dry thoroughly before the new paint or primer is applied.

All cracks, joints, knotholes, or other areas where moisture can enter the wood should be filled with a high quality putty, and/or caulking compound before painting. Make sure the putty and caulking compounds used are paintable. Also, allow ample time for them to cure before they are painted.



Using A Paint Scraper To Remove Old Paint

All new wood, or old wood that has been completely stripped should be primed, or the appropriate undercoat paint used. Wood primers and undercoats contain special sealers and binders. They help to seal the wood surface from moisture and allow the topcoat paint to bond better.

When painting over old painted surfaces, it is important to match paint types, or make sure the paints are compatible. It may be necessary to consult a local paint dealer and/or test a small area for compatibility before purchasing large quantities of paint.

Surface preparation - Masonry

New concrete surfaces that have been recently poured may still have some release agent on them. The **release agent** is an oily or waxy substance that is sprayed on concrete forms to prevent the wet concrete from sticking. When the forms are removed, some of the release agent remains on the concrete surface. The release agent must be removed with a cleaning solvent or by several months of natural weathering before the surface can be painted.

If it is not possible to wait, masonry walls and concrete can be cleaned and prepared by treating it with one part muriatic acid mixed with six to ten parts of water. Brush the weak acid on the concrete until it "fizzes." Rinse the acid solution from the concrete with clear water. Examine the surface, and retreat the spots that are not clean or roughened. Clean, coarse surfaces with an even texture can be painted without an acid treatment.

Special masonry paints are needed to fill all the large pores in concrete, rough bricks, blocks, or stucco. Masonry floors, decks, porches, and patios may also require special paints. If moisture is present, select a paint that can be applied to damp surfaces. Consult your local paint supplier and follow manufacturer's recommendations.

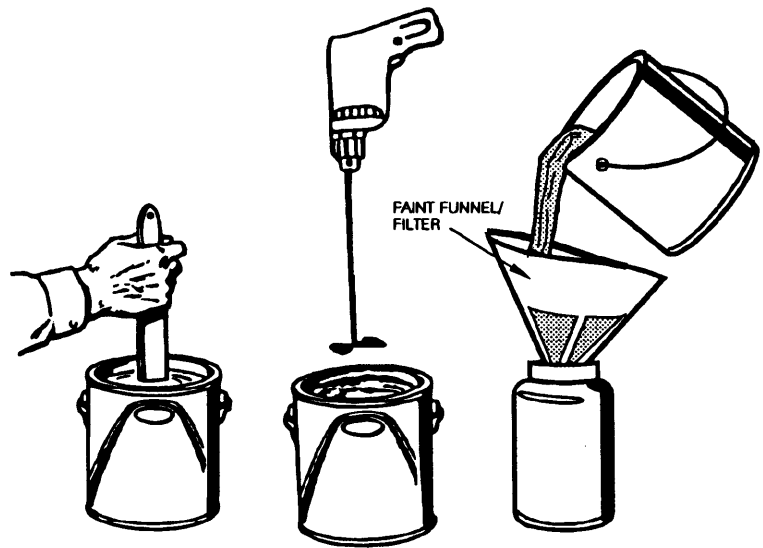
MIXING PAINTS

Most paint suppliers will thoroughly mix paint with a mechanical vibrator/shaker when it is sold. However, if the paint is not used immediately, the color pigments, binders, and extenders will begin to settle. The longer paint is stored, the more settling will occur. A paint skin may also begin to form on the top. *Always* remix paints *before* any thinners or reducers are added.

Paint can be mixed on the job-site by using a small paddle. A paint agitator installed in a low-speed drill can also be used. If the paint can is full, it may be necessary to pour off part of the thin liquid vehicle into another container.

After the remaining vehicle, binders, and pigments are mixed, the two containers can then be poured back and forth together as needed.

Continue to remix until a uniform consistency, appearance, and color are obtained. The viscosity can then be checked and the proper thinner or reducer added as needed. If the paint is to be applied with spray equipment, it will be necessary to strain the paint to remove any lumps of pigment or paint skin that did not mix. A piece of fine screen or cheesecloth, or a specially designed paint filter/funnel may be used.



Paint Must Be Thoroughly Mixed and Strained

METHODS OF APPLYING PAINTS

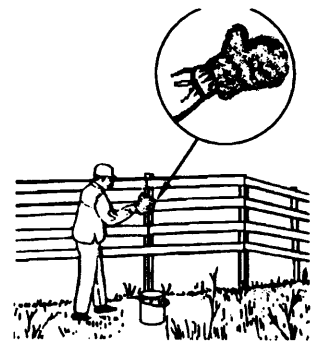
Different methods are used to transfer paints from the container to the desired surface area. Each method requires different equipment and will produce a different finish or appearance.

Dipping

Some objects can be coated by dipping them into a container filled with paint. This method is fast, but may require large quantities of paint, particularly when the objects are large. It is also difficult to get an even coat of paint over the entire painted surface. The paint tends to "run" to the bottom of the object as it is removed.

Wiping

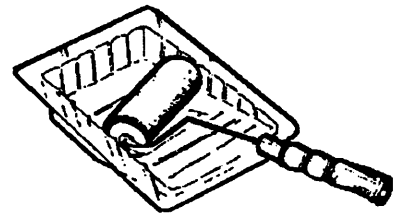
Some types of paints, stains, and preservatives are easily applied by wiping a paint saturated rag or sponge like material across the surface. Special paint mitts worn over a rubber glove can be used for wiping paint on small rods, pipes, wires. etc.



Applying Paints
With A Paint Mitt

Rolling

Paint rollers are an effective way of applying paint to large, flat surfaces. Long slender cylinder sleeves covered with synthetic or natural wool are attached to a roller handle. The sleeve covering is often referred to as the **nap**. Rollers are available with nap from $\frac{1}{4}$ to $1\frac{1}{2}$ inches in length. The longer the nap length, the more paint the roller will carry. Also, longer nap lengths are required to obtain proper coverage if the surface texture is rough or uneven. The roller is dipped in a shallow paint pan then rolled across the surface.



Paint Roller and Pan

Newer models of roller sleeves can be filled with paint. When used, the paint is allowed to slowly seep through small holes into the nap. Other models force paint from a pressurized paint container through a small hose. Paint is supplied through the hose to the roller handle, and then to the roller for a constant paint supply. One disadvantage of using rollers are the small spatters of paint that may be thrown off.



Modern Pressurized
Paint Roller System

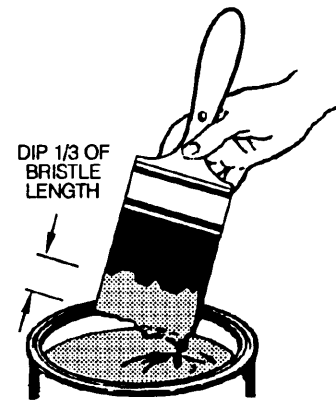
Brushing

Many types of paints can be effectively applied with brushes. Other than dipping, the cost of the equipment required for brush painting is much less than other methods. Brush painting is suitable for irregular shaped metal and wooden projects when a fine, smooth finish is not required. The type and size of brush needed will vary with the type of paint and the quality of the finish desired.

Natural-taper bristle brushes are made from animal hair and are usually more expensive. They are recommended for oil and solvent-resin based paints. Generally, the higher the quality of bristle brush used, the smoother the finish that can be obtained.

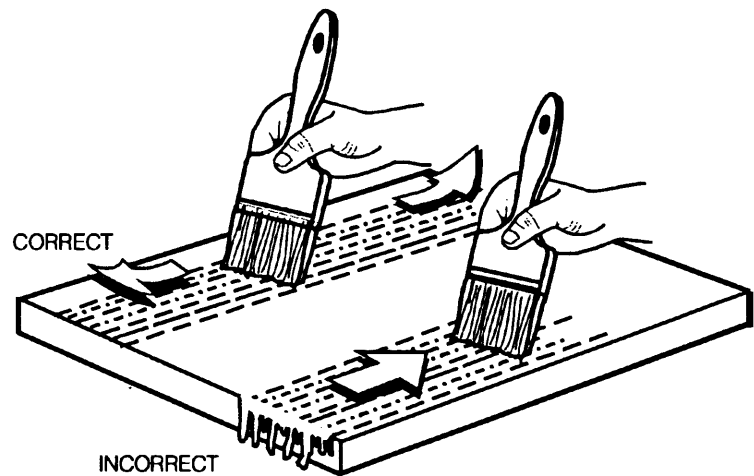
Nylon or polyester bristle brushes are less expensive. They are usually adequate for most latex water-based paints. Brushes are available in widths from 1 to 4 inches. Select a narrow brush for small objects and trim work, and wider brushes for larger, flat surfaces.

To "load" the brush, dip the bristles only about one-third their length into the paint. Gently touch the bristles on the inside of the paint container to remove excess paint and to prevent dripping. Apply paint with the wide or flat side of the brush. Painting with the narrow edge will cause the bristles to separate and provide uneven coverage.



"Loading the Brush"

To apply paint, move the brush back and forth across the surface. Tilt the brush with a slight angle in the direction of travel. Make smooth, even strokes. The final strokes in each section painted should end in a painted area. The brush should be gently lifted at the end of each stroke to "feather out" the paint lines. All strokes should be back and forth in one direction. On wood surfaces, this is usually with the direction of the wood grain pattern. When applying paint with a brush, it is usually better of cover the area with several thin coats rather than to apply one thick coat. Always consult the paint can label for specific recommendations.



Spraying

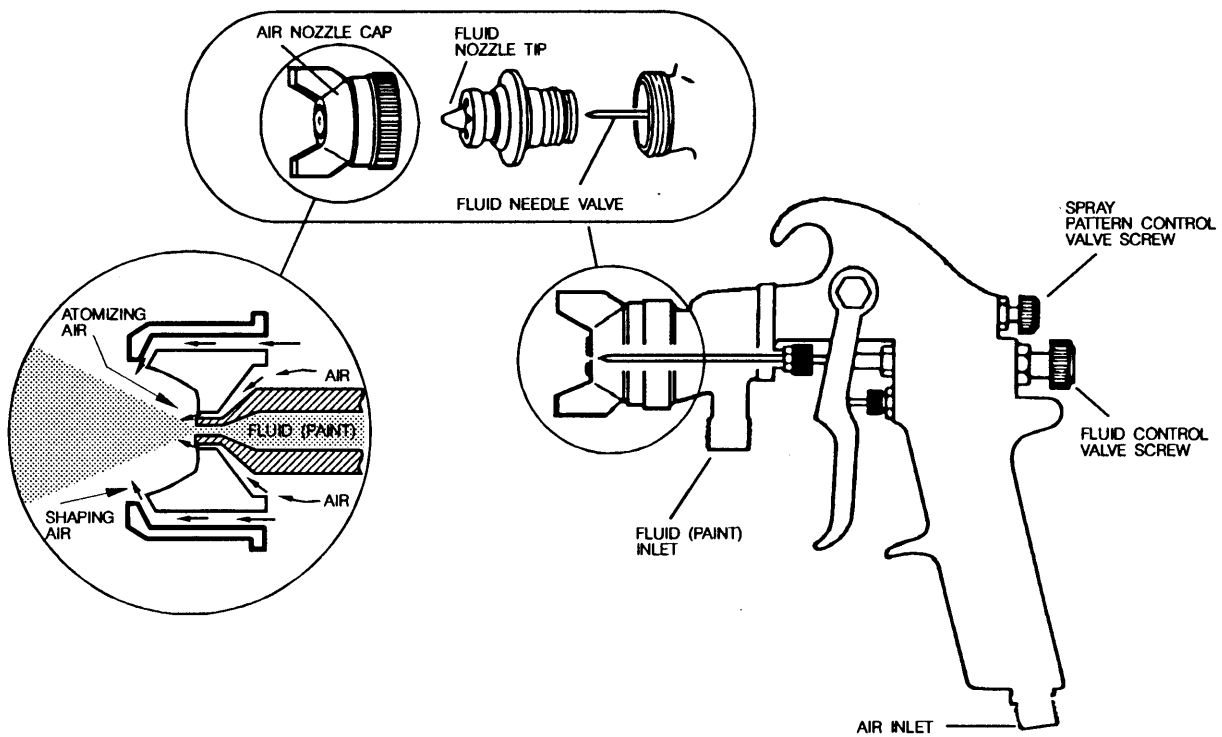
Spray guns are used to atomize paint and apply it to the surface being painted. To **atomize** means to break up a liquid into small particles to produce a fine mist. The fine mist is then applied to the desired surface to produce a smooth, high-quality finish. Most paint spray guns are capable of producing a smoother finish than can be obtained with either a roller or brush. However, some types of spray guns also produce overspray. **Overspray** is the fine mist of extra paint from the spray gun blast that settles on or bonds to surfaces other than where it is intended.

There are three basic types of paint spray gun systems: 1) **air spray**, 2) **airless spray**, and 3) **electrostatic spray**. Spray painting is faster than other methods of applying paint. However, the total painting process may require additional time for setup and cleanup activities.

Air Spray

Air spray systems use pressurized air to atomize the paint. The atomized paint mist is then controlled and carried to the surface in the air stream. Within the air spray systems, there are two basic types. One is a **conventional, high pressure air spray system**. The second is the newer **high volume-low pressure or "HVLP"** air spray systems.

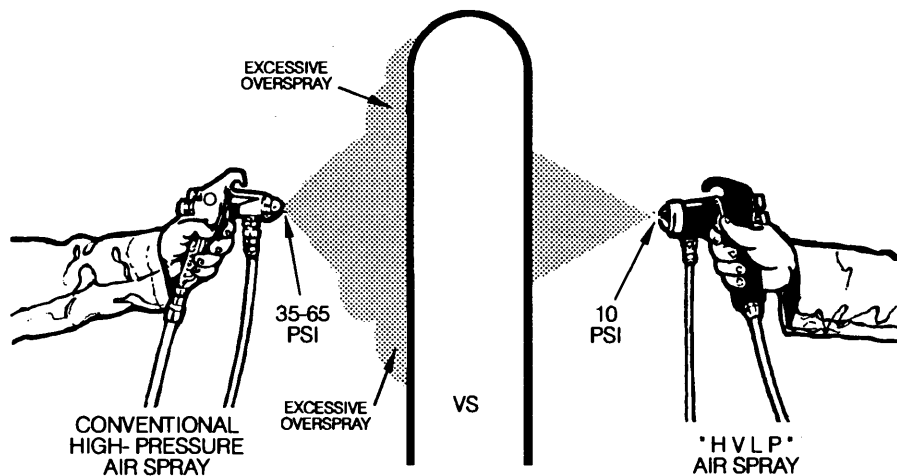
A conventional high pressure air spray system releases a quantity of paint from a fluid nozzle located at the end of the spray gun into the middle of a "high pressure" air stream. The paint is atomized as it leaves the fluid nozzle and enters the air stream. Approximately 30 to 65 psi of air pressure at air cap is used to atomize the paint.



Air Spray Paint System

Additional air streams are emitted from the sides or "horns" of the air cap to: 1) help further atomize the paint, and 2) control the shape of the paint mist spray pattern. High pressure air spray guns create excess overspray and may not be efficient for some projects.

The new high volume-low pressure or HVLP air spray systems are similar in basic design to conventional high pressure spray systems. However, HVLP systems use slightly higher volumes of air delivered from the air cap at ten psi or less air pressure to atomize the paint.



The HVLP system allows for greater pattern control, improved fluid delivery, and smoother feathering for most types of paints. Except when high viscosity paints are used, a HVLP system can produce a high quality finish comparable to those produced with a conventional high pressure air spray system.

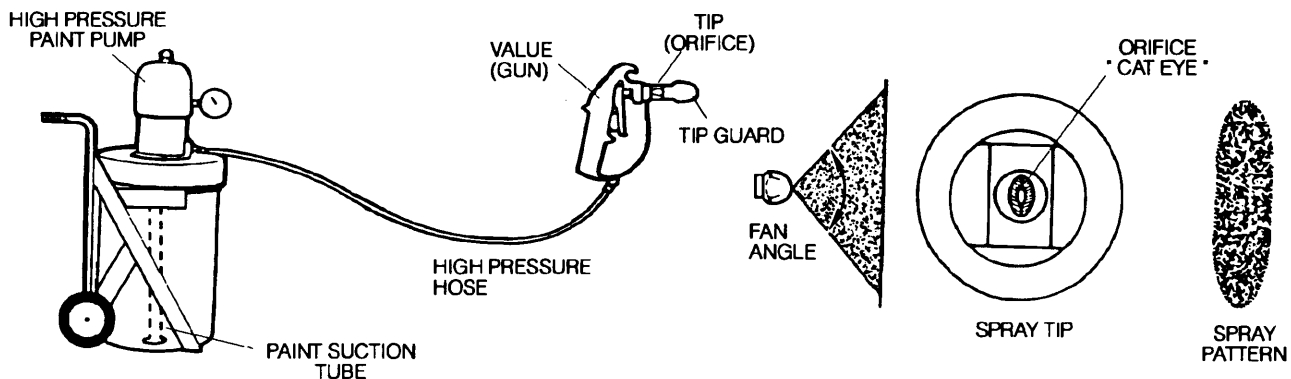
HVLP spray guns and equipment were designed and manufactured because of the new regulations aimed at reducing air pollution and toxic waste. Because less air pressure is used to atomize the paint, much less overspray is produced. This increases transfer efficiency which means less total paint and solvent are often needed.

New emission regulations require that today's painting and finishing equipment comply with increasing stringent air quality standards. To meet these standards, HVLP systems should gradually replace many conventional high pressure air spray systems.

Airless Spray Systems

Airless spray systems are very simple in design. They use a pump to pressurize *only* the paint. On some models, the suction tube can be inserted directly into a one or five gallon paint container.

Airless spray systems can be used to quickly apply large quantities of paint to large objects. Some models can spray up to four times faster than conventional air spray systems.



High Capacity Airless Paint Spray System

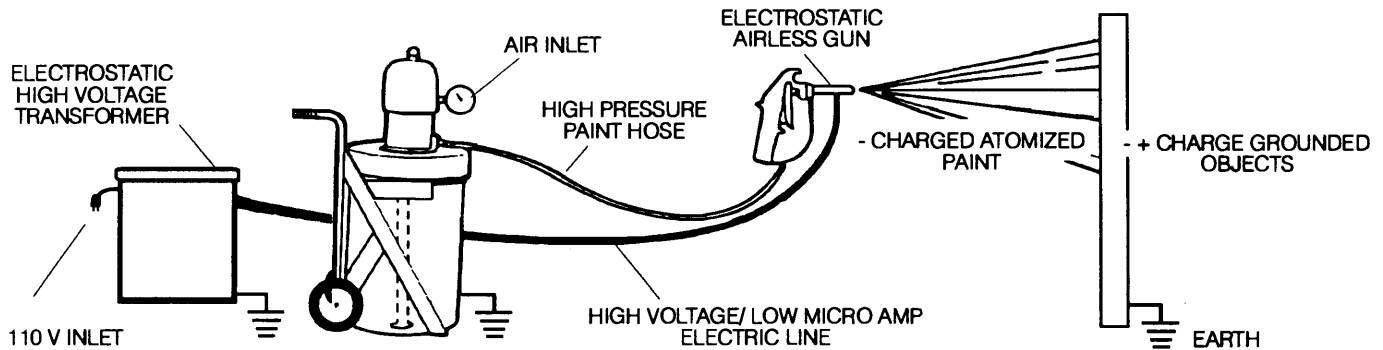
Airless paint pumps operate at between 200 and 5,000 psi. The pressurized paint is atomized as it is released through a small nozzle in the tip of the paint gun. The higher pressures can atomize thicker paints, sealers, and coatings for faster coverage.

However, because an air flow is not used, an airless spray system can not produce a fine "automotive type" finish. The airless spray gun has only one control valve to start and stop the paint flow. The spray pattern is controlled by: 1) the size and shape of the small "cateye" nozzle, 2) the pressure at which the paint is supplied, and 3) the viscosity of the paint. However, one advantage of an airless system is the great reduction in the amount of overspray.

An airless spray gun and equipment should be used with extreme caution. Paints or fluids from high pressure leaks or emitted from the spray nozzle can easily penetrate the skin and cause deep internal infections. Caution should be taken to avoid serious personal injury. Always use the tip guard and follow manufacturer's safety warnings.

Electrostatic Spray

Electrostatic paint spray systems are actually modified air spray or airless spray systems. They are gaining popularity in manufacturing plants because of compliancy requirements with new air quality regulations.



Electrostatic/Airless Paint Spray System

The object to be painted is positively charged and grounded to the earth. The atomized paint particles are negatively charged as they are emitted from the spray gun. This is accomplished with special electrical equipment that is added to a basic air spray or airless spray system. Since unlike particles attract and like charges repel each other, the negatively charged paint particles are attracted to the positively charged object.

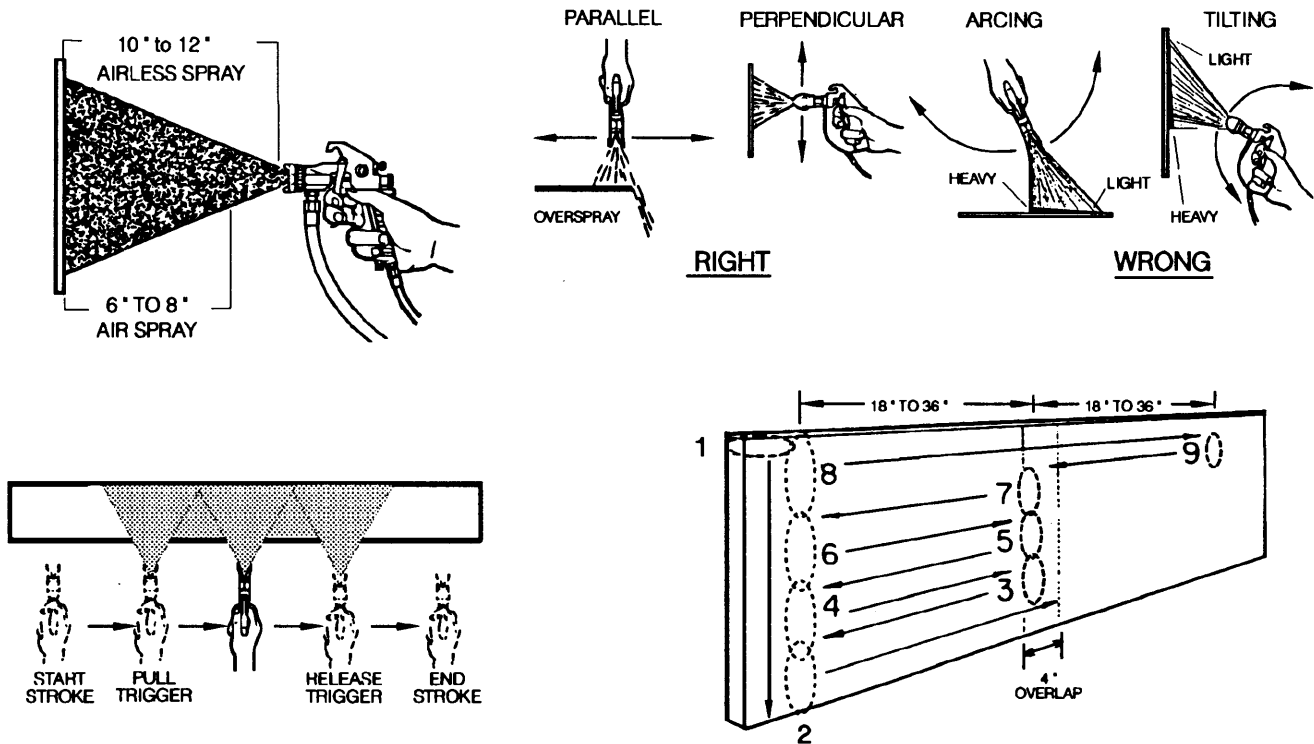
Electrostatic paint spray systems all but eliminate overspray. Also, paint particles are "pulled or attracted" into smaller areas or crevices. This is extremely helpful in painting behind small hard-to-reach areas.

COMMON PAINT SPRAYING PROCEDURES

The spray gun for most models of air spray systems should be held six to eight inches for the surface. The distance is increased to 10 to 12 inches when airless spray systems are used. Hold the spray gun perpendicular to the surface. Move the spray gun back and forth as parallel to the surface as possible.

Triggering should be timed to allow **lead and lag time**. This means the trigger should be pulled just after the stroke begins and released just before the stroke ends to achieve an even spray pattern. Each stroke should overlap the previous stroke to provide even paint coverage. Care should be taken to prevent arching, or tilting at the end of each stroke.

When painting large or long surfaces, use 18 to 36 inch horizontal strokes. It is recommended to paint the inside and outside corners, edges, and uneven areas first. Larger flat areas should be sprayed last to minimize overspray and excessive paint overlap.



Use the lowest pressures and paint flow rates possible while still maintaining the desired coverage and finish. Normally, this will also produce the least amount of overspray. It is recommended to test the spray pattern and make adjustments *before* applying paint to the actual surface. This may be accomplished by using a large piece of heavy cardboard as a test surface.

The compressed air used to clean surfaces and power the spray guns must be clean and dry. Air filters must therefore be installed to remove all condensation and contaminants. There are literally hundreds of different brands, types, and models of air compressors, air pressure regulators, and air and airless spray systems. It is beyond the scope of this topic to go into detailed adjustment procedures. Always consult the proper owner operator's manual and visit with an experienced painter for specific information.

PAINT SAFETY

The Federal Clean Air Act Amendments, OSHA, and many states have mandated new regulations restricting the types of paints, thinners, solvents and painting equipment that can be used. The storage, application, and disposal of many types of paint or paint products are now also regulated.

Some of the new regulations will create an added expense. Some will create an inconvenience. However, most are just common sense and ensure good housekeeping practices designed to protect you and the environment. For current information regarding the environmental laws and air quality regulations in your area, contact your local air quality board, the state department of natural resources, or the EPA inspector.



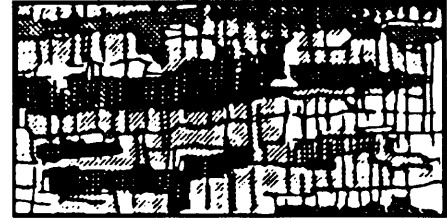
Wear Proper Type Respirator

When using any paint product, *always* follow label directions. Many new types of paints, solvents, and thinners are toxic. Wear protective clothing, gloves, paint masks, and respirators. Paper paint masks will only filter coarse paint particles and dust from the air. If toxic paints are used, toxic vapor respirators must be worn. Paint only in a well ventilated area.

Cover or protect other objects from dripping paint or overspray. All spray gun equipment and objects painted should be properly grounded to control static electricity. Do not use paint thinners, reducers, or solvents around open fires or any equipment that can produce sparks. Store all paints and painting supplies in specially designed metal storage cabinets to reduce fire hazards.

COMMON TYPES OF PAINT FAILURES

Cracking of the paint film can occur if the material that has been painted flexes, expands, or contracts. Paints which contain high quality binders and pigments are more elastic. Thus, higher quality paints are less likely to crack.



Cracking

When excess paint is applied *or* a second coat is added before the first coat has properly dried, the outer surface can "flash off" and seal over. Excessive wet vehicle and binder may be trapped under the outer paint film that has sealed over. The excessive wet paint can run and sag, and/or the outer surface can wrinkle as the complete drying/curing process continues. Running and sagging can also occur when the paint contains too much thinner or reducer.



Runnning and Sagging



Wrinkling

Paint can **blister** and/or **peel** if applied over an oily film, dust, wax, moisture, or any other substance that will prevent it from properly bonding to the base surface (improper cleaning). Blistering and peeling can also occur when moisture is allowed to come through the back side of painted material and evaporate right below the painted surface. Other types of paint failures and the procedures necessary to prevent or correct them are discussed in student topics 8606 and 8224-A.



Blistering

Peeling

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Acknowledgements

Mr. Donald G. Krobot, Intern, Department of Agricultural Education, Texas A&M University, and Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

TRUE OR FALSE: Circle "T" if the statement is more true than false. Circle "F" if the statement is more false than true.

T	F	1. HVLP spray systems use higher air pressures to atomize and deliver the paint.
T	F	2. When using Electrostatic spray systems the paint is pulled to the paint surface by electrical attraction.
T	F	3. Cleaning and preparing the surface is just as important as choosing the correct type and quality of paint.
T	F	4. Prior to using paint in spray systems, the paint should be mixed properly and strained.
T	F	5. A tack rag is "tacked" around objects or structures to prevent overspray from landing on other objects or materials.

SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph. (Use additional paper when needed.)

6. Describe the basic differences between air spray and airless spray gun systems.

7. What is the purpose of using a metal conditioner when preparing metal surfaces for painting?
8. Describe the "HVLP" air spray paint system. Discuss some of the advantages and disadvantages of using this type system.
9. Briefly discuss the process of preparing wood for painting.
10. Describe some of the problems encountered when painting metals that have been welded and discuss procedures to overcome these problems.

FILL IN THE BLANK: Complete the following sentences by inserting the correct word(s) in the blanks provided.

- _____ 11. When using paint brushes, paint with the _____ side of the brush.
- _____ 12. Airless spray guns use pneumatic or electric pumps to pressurize the _____ .
- _____ 13. Spray patterns should be adjusted to minimize _____ .
- _____ 14. The compressed air used in spray painting must be kept _____ .
- _____ 15. _____ from the open air can cause metal to rust or oxidize.
- _____ 16. _____ contain special sealers and binders to seal surfaces from moisture.
- _____ 17. New masonry surfaces are treated with _____ which must be removed before painting.
- _____ 18. If possible, all paints and supplies should be stored in _____ .
- _____ 19. Paper paint masks only filter _____ from the air.
- _____ 20. Spray painting requires additional _____ time.

ADDDITIONAL SKILLS AND ENHANCEMENT ACTIVITIES: Perform the following activities or skills as assigned by your instructor.

1. Contact a local building contractor and an equipment repair shop in your community. Determine the methods of paint application they prefer. If possible, visit a large scale spray painting facility. Observe all safety precautions that are used to protect workers and nearby equipment. List safety measures and discuss them with instructor or classmates. Specifically observe spray painting techniques used in the facility. Ask to observe different spray patterns and spray gun adjustment procedures. **Note! This activity will require prior approval of shop/building supervisor or plant manager.** Follow all safety precautions.
2. Contact a local paint store and inquire about different viscosity paints. Discuss with a sales person the method of application that would provide the best results.
3. Inspect several structures or pieces of agricultural equipment for different types of painted surfaces. Visible paint failures may be apparent. Identify specific areas that are cracking or peeling. Observe all surfaces that are located near moisture. Discuss with instructor the different paints used in the structures. Suggest an alternative paint or method that might eliminate the paint problems that were observed.
4. Obtain several samples of metal to brush and spray paint. Prepare the surface properly. Practice brush and spray painting skills. Compare the methods for appearance and finish.
5. Obtain several wooden objects or boards. Prepare the surface and patch all defects. Brush paint several areas using a light coat of paint. Use a heavy coat of paint in other areas. After the paint dries, compare any differences. Determine if any wrinkling of the paint surface occurred.

6. Apply a new coat of paint over an older painted surface. Determine if the paints used were compatible. While waiting for paint to "flashoff," watch the surface, and visibly inspect the paint film as it is drying. Clean all materials used and store properly.
7. Contact local health department authorities. Determine what rules and regulations concerning paints and painting equipment apply in your community.

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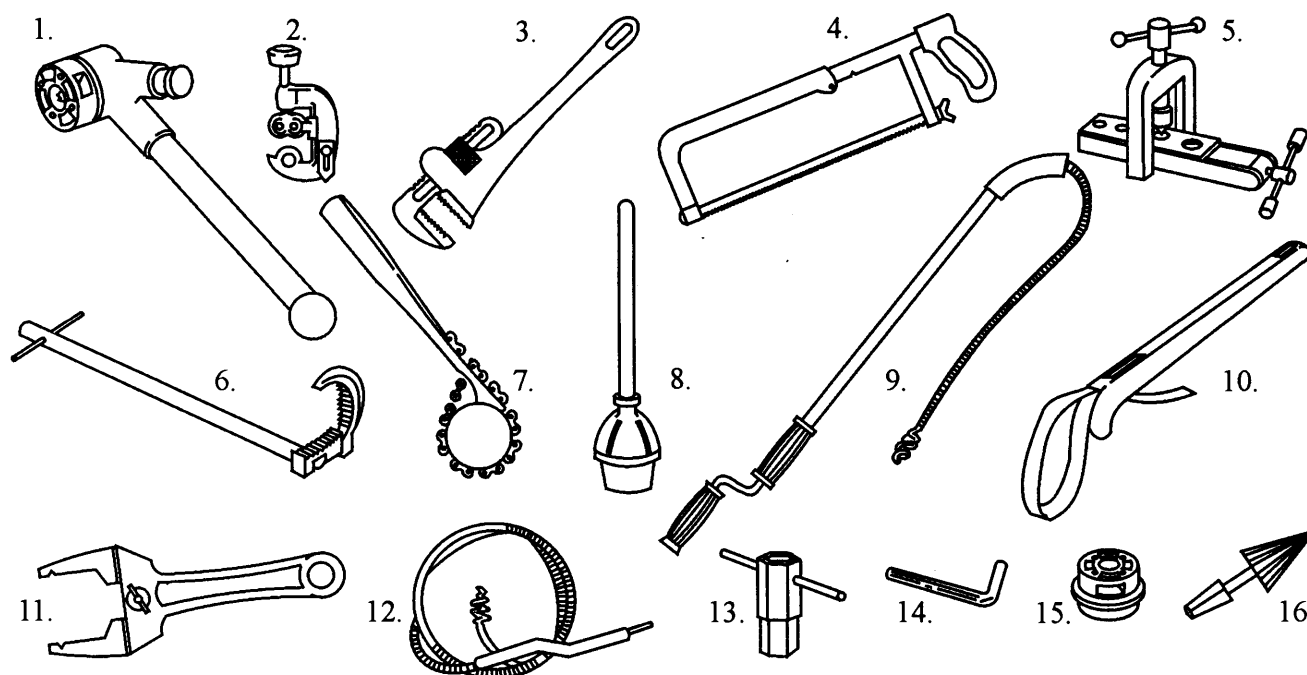
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PERFORMING BASIC PLUMBING SKILLS

Most plumbing problems in the home and on the farm are simple and easy to fix. However, it is a good idea to first speak to your teacher, look at a do-it-yourself plumbing manual, or call a local hardware store and speak to their plumbing expert, even though you think you might know how to fix a leak or other water related problem.

Before you begin to work on plumbing projects, it is necessary for you to know about some of the tools you will need and how to use them. Here are most of the tools you may need to fix various types of plumbing problems.

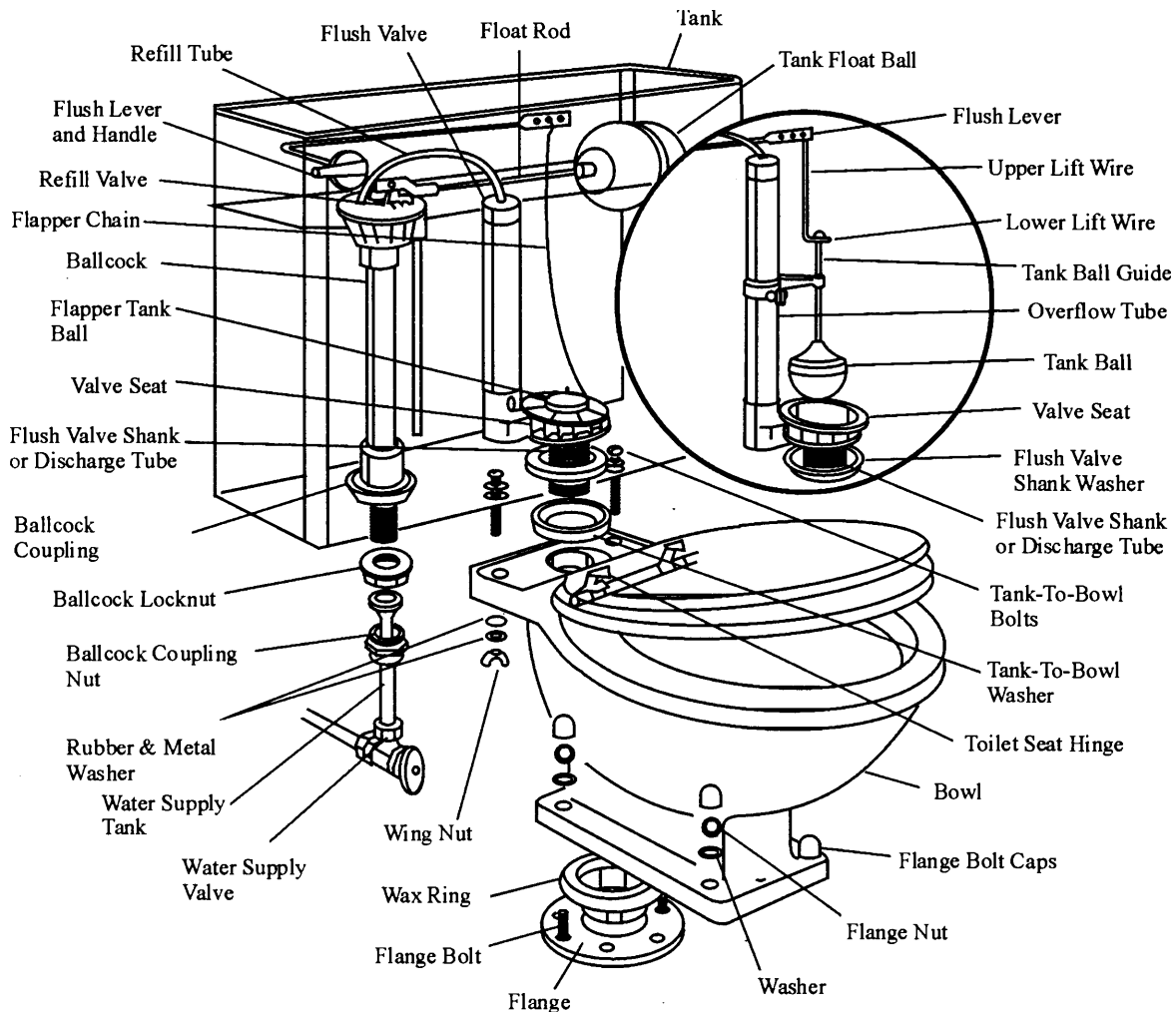


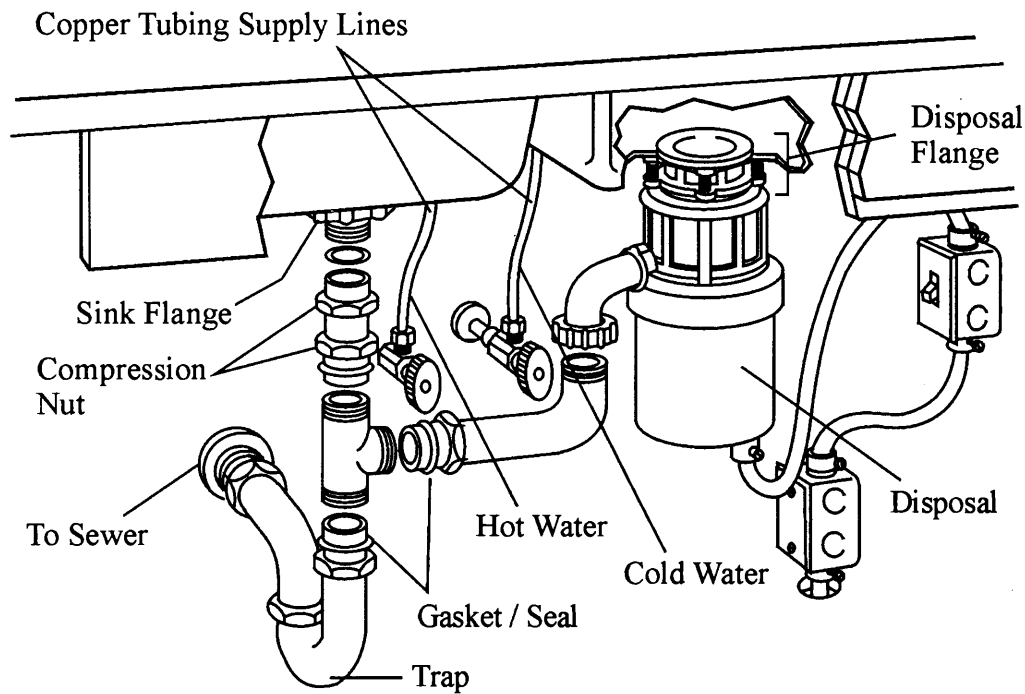
1. Pipe Threading Tool
2. Tubing Cutter
3. Pipe Wrench
4. Hacksaw
5. Flaring Tool
6. Basin Wrench

7. Adjustable Chain Wrench
8. Plunger
9. Plumber's Helper
10. Strap Wrench
11. Spud Wrench
12. Snake

13. Cowbell Socket Wrench
14. Allen Wrench
15. Die-Cutter
16. Reamer

Three of the more common plumbing problems are leaking faucets, dripping sink drains, and continuously running or cycling toilets. You can learn to fix these problems with just a few tools and a little bit of knowledge about each fixture. Every day, new products and new sources of parts for the do-it-yourself person become available. Most water fixtures like toilets and faucets do not change very much as new designs are sold, but the complexity of the components has become unique to each individual product. For this reason, one must exactly identify each piece of equipment so they can find and buy the correct, compatible parts. Examine the following diagrams and identify the major components of each water system. Whom would you call for information about these items?

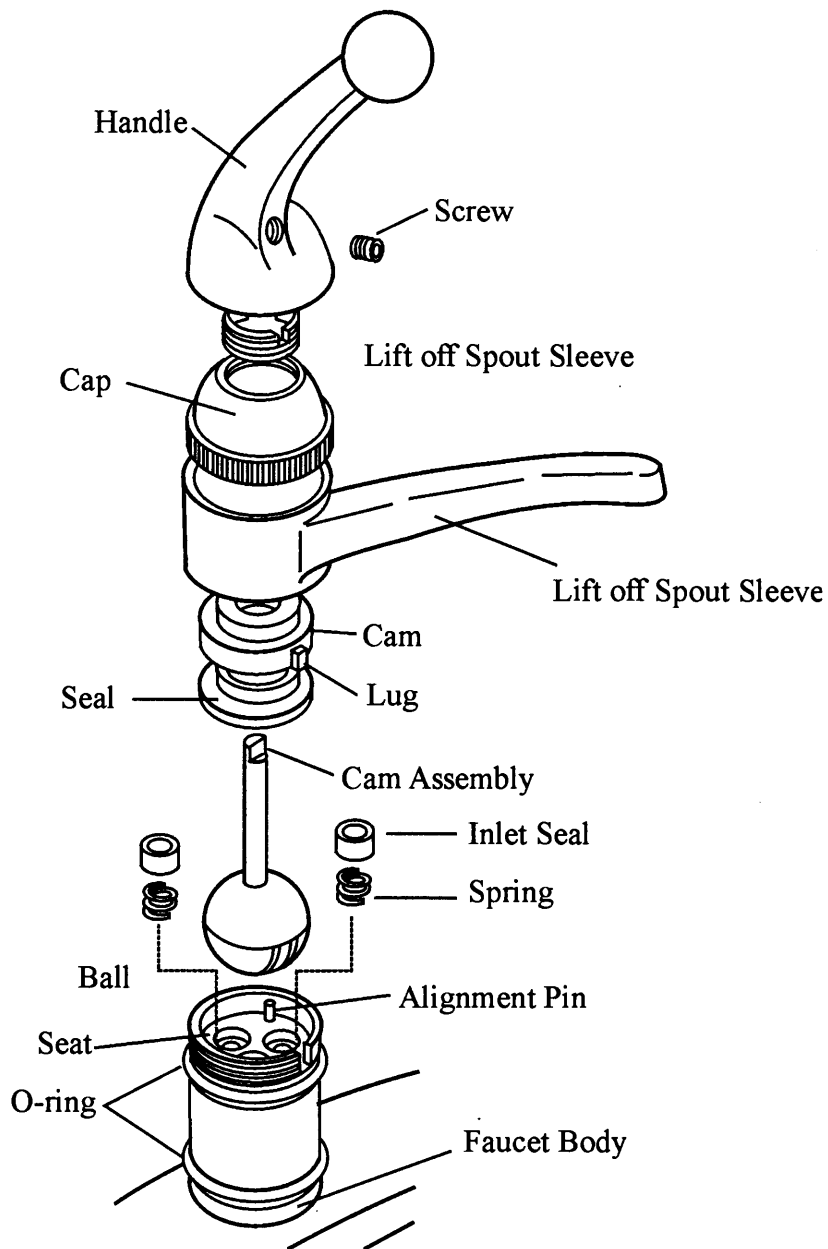




Problem Solving

Diagnosing is just the beginning of solving your plumbing problem. Remember to investigate the leak as much as possible and discover everything you can about the situation. Before you leave for the store, make sure you write down anything you might need, making a note of pipe sizes, faucet brands and models, valve types, and questions you might want to ask the plumbing professional. Writing things down can be very helpful because once you get to the store, the parts may all look the same.

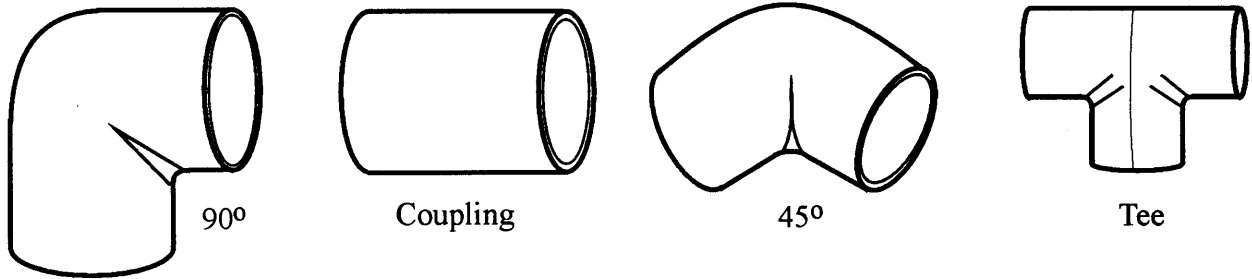
For example, did you know that plastic drain pipe located in your house is called ABS, not PVC? ABS and PVC can be made with white plastic pipe, but the actual diameters of pipe described as 2" are different. This means that fittings such as elbows and tees made for PVC pipe will not fit ABS pipe, and visa-versa. Some manufacturers make ABS in black so a consumer can more easily recognize the difference.



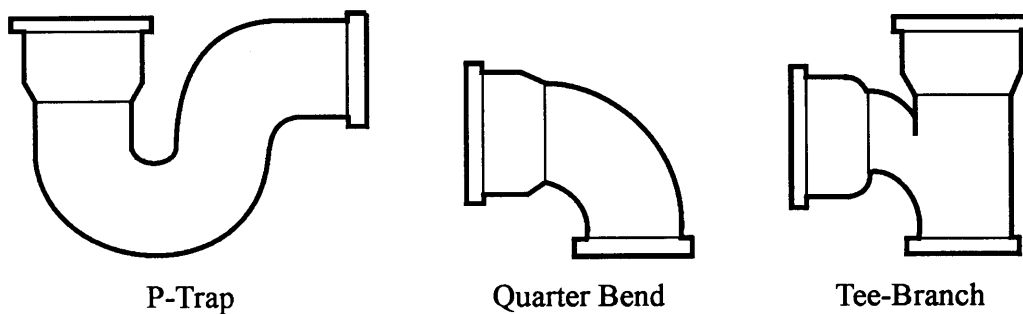
PLASTIC PIPE AND FITTINGS

When buying fittings for your pipe, check to verify that you are purchasing the correct size and type. The fittings traditionally are easy to distinguish from one another. The ABS fittings generally have an expanded outside lip around the opening of the fitting. Look at the fittings on the following page and notice the differences between the fitting shapes and types.

PVC Fittings



ABS Fittings

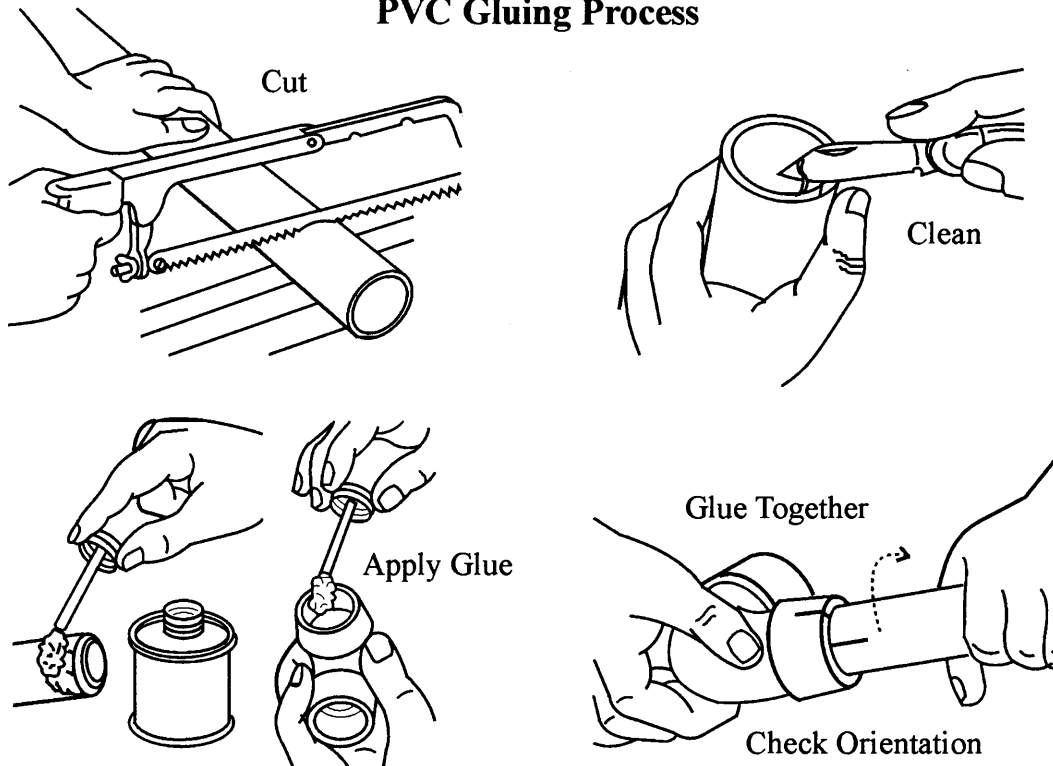


Gluing Plastic Pipe

One basic process to know when working with plastic pipe is how to glue it together. **Attention:** PVC cement vapors are harmful. Only use in well-vented areas and replace the lid of cement can as soon as possible after you are finished. Read label precautions before opening the can. If you become dizzy while working around cement vapors; replace the lid of the can and move away from the work area into some fresh air.

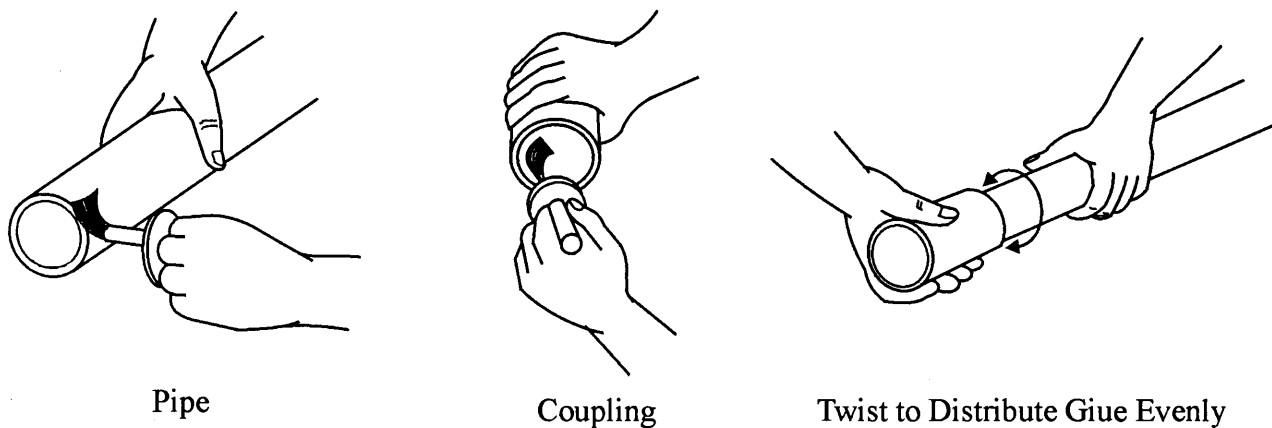
First, identify the correct fitting to be used. Inspect the fitting and check to see if it is clean. Wipe off dirt or grease located on the inside and outside of the pipe and fittings. Remove any burrs or rough outside and inside edges made when cutting the pipe. Slip the pieces together and check the fit. Make a note of the orientation of the fitting as it should be in the final position. If necessary, mark the two pieces with a marker across the joint. This will help save time as the pieces are being oriented during the gluing process. Take careful measurements when choosing the length of pipe you will need to cut.

PVC Gluing Process



When the pieces are ready to cement together, apply an even, thin coat of PVC cement on the connecting surfaces. Quickly push the two pieces together and twist at least 1/4 of a turn. Twisting the pieces as you put them together helps distribute the glue around the surfaces and insures a quality joint. Last, hold the pieces firmly in place for 25 seconds and wipe away any excess cement. Read the label on the PVC cement can to find out how long you should wait until the pipe can be fully pressurized.

Applying Glue To PVC



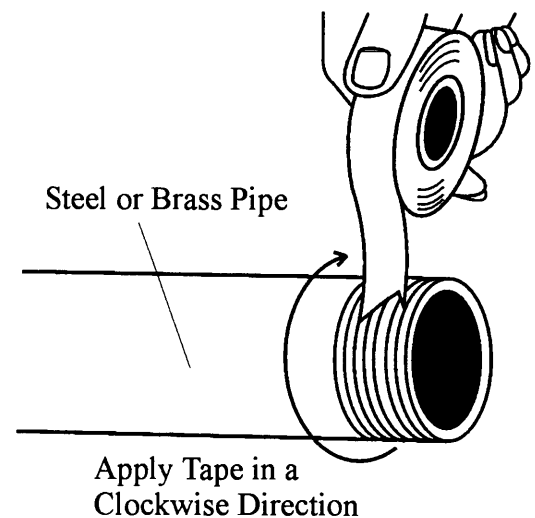
WORKING WITH STEEL PIPE AND FITTINGS

Identifying Galvanized Pipe

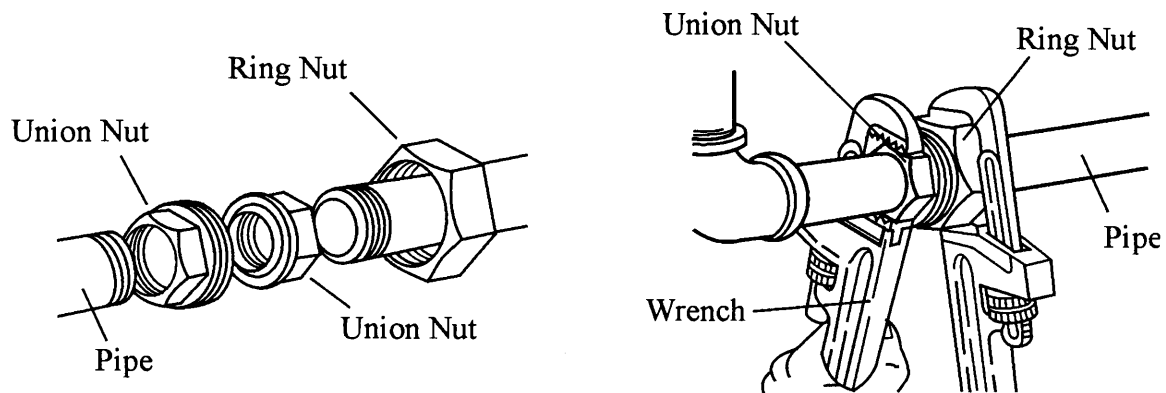
Steel pipe is much more durable than plastic pipe when used in above ground installations. Above ground water pipes located near livestock and heavily traveled areas around barns, buildings, and in well houses will probably be galvanized steel pipe. Galvanized pipe is steel pipe that has a coating of zinc on the surface and looks gray in color. Never weld galvanized steel of any type without removing the zinc coating with a grinder: fumes given off by the heated zinc are dangerous to you and anyone in the work area.

Connecting Steel Pipe

Galvanized pipe threads together with fittings similar to threading a nut onto a bolt. Pipe thread compound or teflon tape must be used when attaching two steel fittings or pipe. When using teflon tape, wrap about two layers of tape around the threads in a clockwise direction as indicated in the drawing. Use a tightening wrench and a back-up wrench to loosen or tighten a joint. Look at the diagram on the following page and notice how the back-up wrench is being used.



Connecting and repairing steel pipe is time consuming because one has to cut the pipe to proper length and thread it. Threading steel pipe is discussed in student topic 8603. If you have a section of pipe you need to replace or an existing system is redesigned, a special fitting called a union may need to be used. Unions are placed in rigid steel pipe systems so one can take apart pipe more easily. Notice in the diagram on the following page the location of the union and discuss with your teacher why a union was placed in the water line.



The union is composed of two nuts and a gasket. Hold the complete union between the two ends of pipe and make sure there is enough room for the union. If there is barely enough room, or if the union is almost too short, place a mark on the pipe which designates the correct position on the end of the union with the nut attached. This will enable the union to be placed on the pipe and tightened without slipping off the end of the pipe. This will also prevent the gasket from misaligning and allowing the joint to leak.

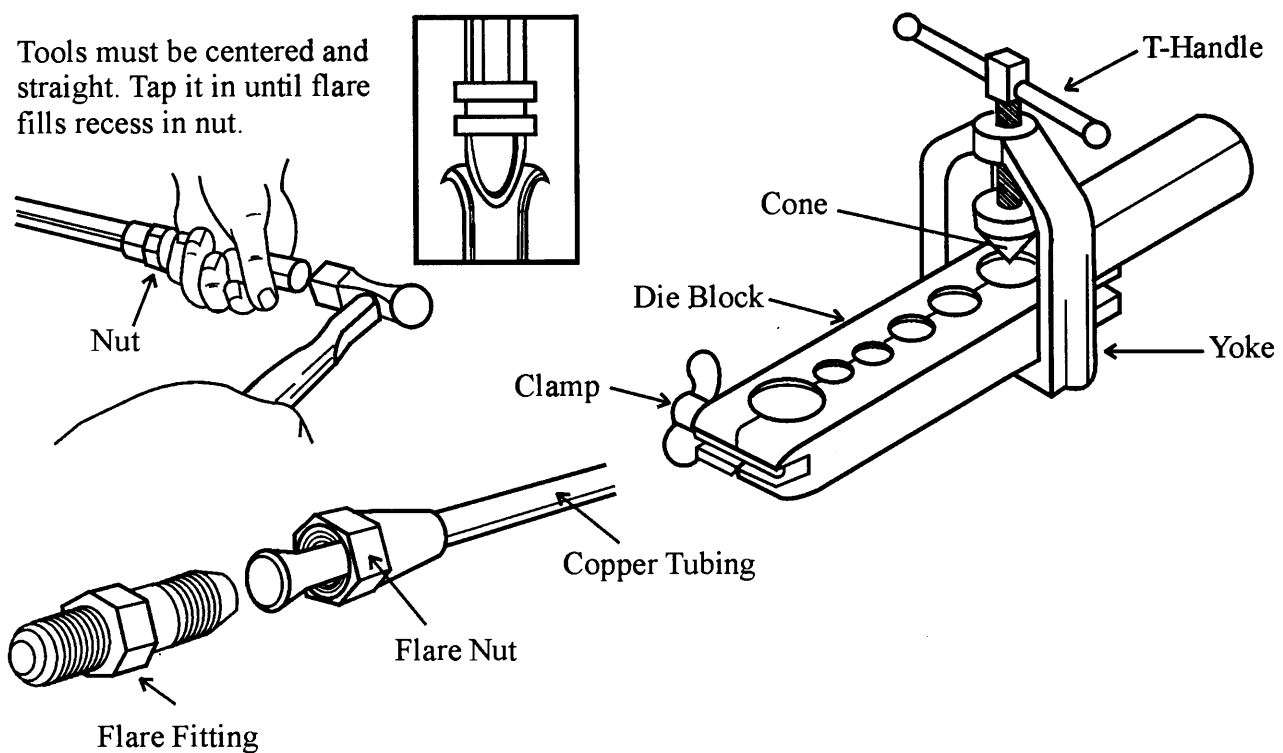
Pipe that has been excavated must be clean and smooth in order for the gaskets to slide and seal easily. Hold the union body in a fixed position and hand tighten both of the union nuts. Once the nuts are hand-tight and the union is in the correct location, tighten the nuts using a pipe wrench and a back-up wrench. Finally, place the backup wrench on the opposite side of the union nut to prevent it from moving while you tighten the gasket.

METHODS TO CONNECT COPPER PIPE

Over the years several methods have been used to connect flexible copper tubing to fixtures and fittings. Today three popular methods: 1) compression fittings, 2) flare fittings, and 3) sweat soldered joints are used to join copper tubing. The strongest joint is the sweat soldered connection but it is the most difficult to make, requiring a heat source, flux, cutting tools, and understanding of capillary action. Although connections made with fittings are weaker, they are easier to make requiring few tools and fitting connections can be easily disassembled and reassembled.

Flaring Flexible Copper Tubing

Cut the tubing to length and deburr the inside and outside edges of the tube. If space is available, cut the tubing longer than you need in case the first attempt to flare the tubing is unsuccessful. Slide the flare nut onto the tube before flaring, insert the tube into the proper sized die, and clamp the die firmly. Allow 3/8" of the tubing to protrude from the die, as shown in the diagram below. Next, place the cone onto the die and screw the handle down until the cone comes into contact with the tubing. Inspect the placement of the cone with respect to the tubing and make sure that the cone is centered on the centerline of the tubing. The correct position of the cone and tubing and the 3/8" allowance for the flare are crucial steps in creating a high quality flare that won't leak. After tightening the cone enough to produce an adequate flare, inspect the flare and look for cracks, dents, dirt, or other imperfections in the flared portion of the tubing that may cause leaking.



Flux

Flux is a cleansing agent that is necessary to facilitate a quality bond of solder to the copper surfaces. Flux prevents the oxidation of the copper during the heating process, helps transfer heat, and reduces the tension of the solder, allowing it to flow more easily. However, flux is corrosive to copper, therefore excess solder must be removed after the joint has cooled. Some fluxes contain rosin or other anti-corrosion additives, but these are not recommended for soldering copper pipe or tubing.

Capillary Action

The liquid solder flows between the copper tube and the fitting because of a phenomenon known as capillary action. Capillary action is the movement of a liquid due to the attraction of the molecules in the liquid for each other and for the surfaces surrounding the liquid. The two factors that govern that attraction are adhesion and cohesion. Adhesion is the attractive force between unlike molecules. The attractive force between copper and solder molecules is called adhesion. Cohesion is the attractive force between two identical or similar molecules; the attractive force between the solder molecules.

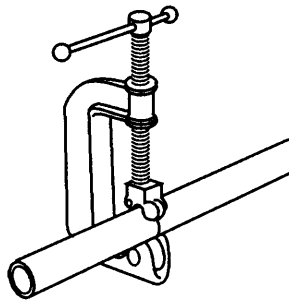
Solder

Environmental Protection Agency (EPA) regulations prohibit the use of lead solder in water supply systems. Solid-core silver solder is best for use with water system construction and repair because it does not contain a rosin core. It is always necessary to use a flux with any type of solid solder in order to achieve a high quality, long-lasting joint.

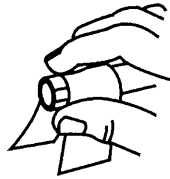
Sweat Soldering Copper Tubing or Copper Pipe to Copper Fittings

Before sweating a copper joint with solder, clean the surfaces that are to be joined. The inside and outside areas of the tubing or pipe should be shiny and clean. Do not sand or file the copper too much; leaving deep scratches or grooves, or decreasing the diameter of the tubing will increase the gap to be soldered. Dirt, grease, fingerprints, or water will prevent the solder from adhering to the copper and creating a good seal.

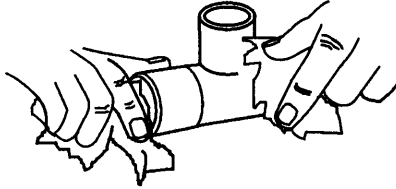
After the connections have been cleaned, apply a thin coat of non-acidic paste flux to the surfaces to be soldered. Push the pieces together, seating the copper pipe into the shoulder of the fitting. Once the tubing has been pushed completely into the fitting, twist the pieces back and forth, insuring even distribution of the flux.



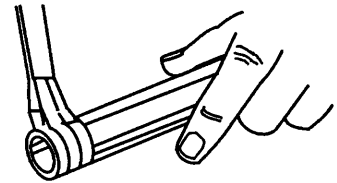
Square Cut



Clean & Polish
Outside

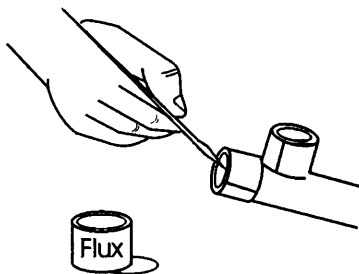


Clean & Polish
Inside

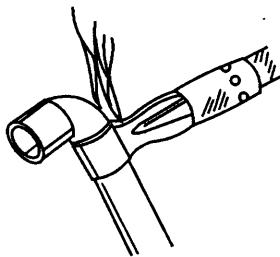


Apply Flux Outside

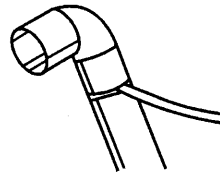
Using a hand held butane torch, preheat the thicker metal by rotating the torch around the entire fitting. Once the fitting and pipe are hot, move the flame away from the joint and touch the solder to the edge of the socket and the tubing. When the joint is hot enough, the solder will flow into the joint by capillary action. Make a continuous bead around the fitting, adding as much solder as necessary to prevent any gaps that allow leakage. After circling the joint with solder, allow the joint to cool. Allow the solder to harden before applying water pressure or moving the connection.



Apply Flux Inside



Position Fitting
And Heat



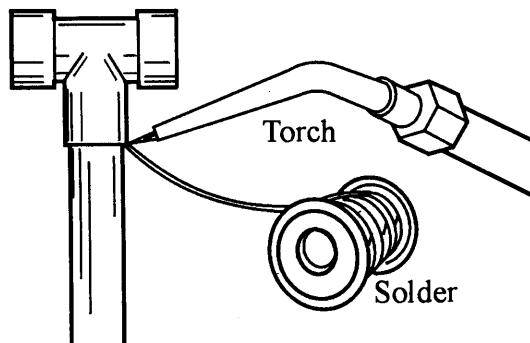
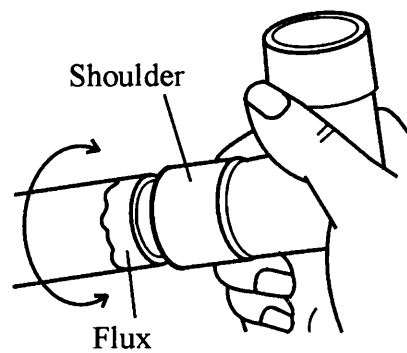
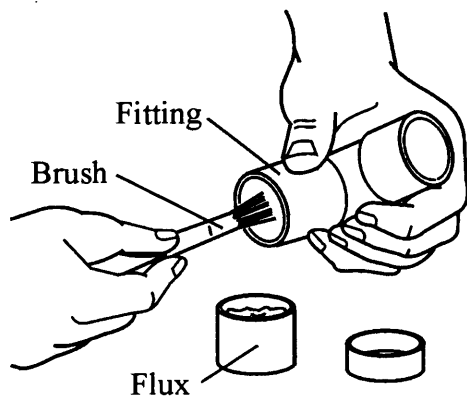
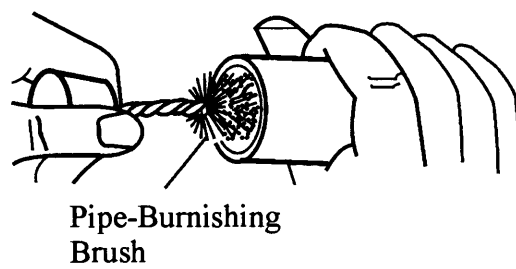
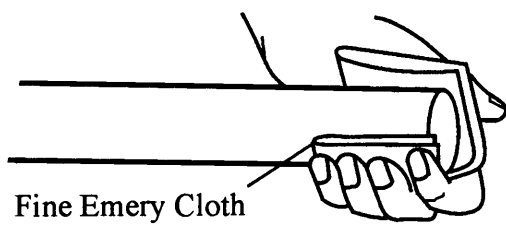
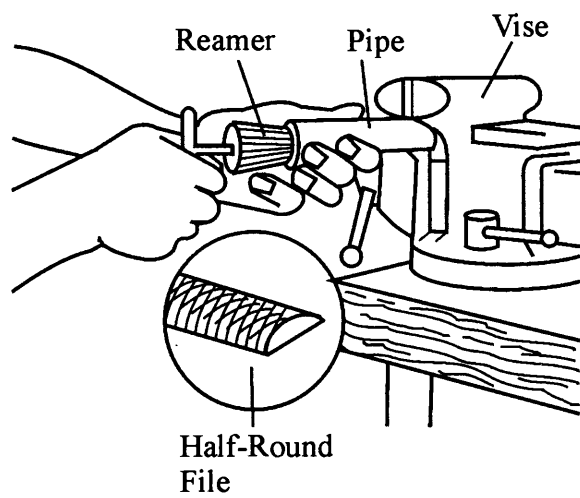
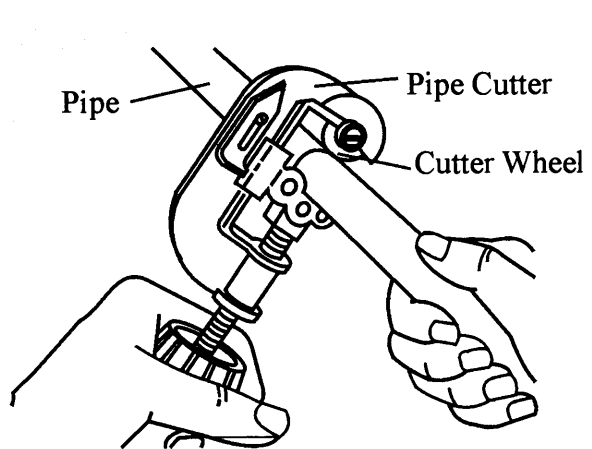
Touch Solder
To Joint



Clean With
A Rag

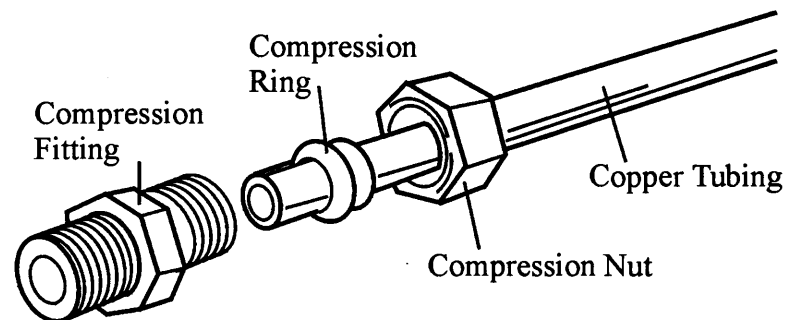
Deburring Copper Pipe and Tubing

After cutting copper tubing with a saw or pipe cutter, it is necessary to remove any burrs that may have been created during the cutting process. Copper tubing can be cut with a pipe cutter or a hacksaw with 24-32 teeth per inch blade. Burrs can then be removed with a deburring tool, reamer, or a half-round file.



Compression fittings

The quickest and easiest method to connect copper tubing is with compression fittings. To install a compression fitting, first cut the tubing to length and remove any burrs. Next, slide a compression nut onto the tubing. The compression fitting utilizes a compression ring that the compression nut squeezes between the tube and the fitting. Although the compression ring becomes deformed, it may be used several times on the same fitting. Tighten the nut with a wrench until the compression ring is fully seated into the fitting. Be sure to use a back-up wrench to protect the fixture or fitting from breakage.



Common Plumbing Terms

ABS (Acrylonitrile butadiene styrene) - rigid black plastic pipe used only for drain lines.

Access Panel - an opening in the wall or ceiling near the fixture that allows access for servicing the plumbing/electrical system.

Adapter - a fitting that unites different types of pipe together, e.g. ABS to cast iron pipe.

Cleanout - a plug in a trap or drain pipe that provides access for the purpose of clearing an obstruction.

Closet Auger - a flexible rod with a curved end used to access the toilet's built-in trap and remove clogs.

Closet Flange - an anchoring ring secured to the floor. The base of the toilet is secured to this ring with bolts.

Coupling - A straight fitting that joins two pieces of pipe.

CPVC (Chlorinated Polyvinyl Chloride) - rigid plastic pipe used in water supply systems, where code permits. CPVC is typically used for hot water supply lines and is usually exhibits a cream color.

Elbow - a pipe fitting with two openings that changes the direction of the line. Also called an ell. It comes in a variety of angles, from 22 1/2° to 90°.

Fall/Flow - the proper slope or pitch of a pipe for adequate drainage.

Fixture - in plumbing, the devices that provide a supply of water and/or its disposal, e.g. sinks, tubs, toilets.

Flux - the paste that is used in soldering metal joints. Flux aids the process by preventing oxidation of the joint.

ID - abbreviation for inside diameter. All pipes are sized according to their inside diameter.

OD - abbreviation for outside diameter.

PB (Polybutylene) - flexible plastic tubing used in water supply systems where allowed by code, usually black or gray.

Plumber's Putty - a pliable, popular putty used to seal joints between drain pieces and fixture surfaces.

PVC (Polyvinyl Chloride) - a rigid white or cream colored plastic pipe used in cold-water systems only, such as supply lines, waste and vent systems.

Reducer - a fitting that connects pipes of different sizes.

Riser - a vertical assembly of fittings and pipes that distributes water upward.

Rough-In - the portion of a plumbing installation that includes running the water supply lines and drain, waste and vent lines to the proposed location of each fixture.

Run - a complete or secondary section(s) of pipe that extend from supply to fixture or drain to stack.

Solder - a metal alloy that is melted to join or mend metal surfaces; also, the act of melting solder into the joint.

Tee - a T-shaped fitting with three openings used to create branch lines.

Trap - curved section of a fixture drain line, designed to hold water thus preventing sewer gases from entering the house.

Union - three-piece fitting that joins two sections of pipe, but allows them to be disconnected without cutting the pipe. Used primarily with steel pipes, but never in a DWV system.

WYE - a Y-shaped fitting with three openings used to create branch lines.

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- <http://www.theplumber.com/> July, 1998. Site contains hints, shortcuts, and answers to plumbing problems and needs.
- <http://www.wqa.org/wqis/Glossary/Capillary.html> July, 1998. WQA Glossary of Terms, Third Edition, Water Quality Association: 1997.
- <http://www.win.bright.net/~lindberg.html>. September, 1998. Site contains links to trade associations, pipe and drain sizing programs, and repair hints.

Acknowledgments

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Christine Stetter, Artist, Instructional Materials Service, prepared the illustrations for this topic.

SUGGESTED STUDENT ACTIVITIES

1. List five tools you may need to fix plumbing problems.
a. _____ b. _____ c. _____
d. _____ e. _____
2. List three steps in cutting plastic pipe.
a. _____ c. _____
b. _____
3. List three kinds of pipe used in plumbing.
a. _____ b. _____ c. _____
4. List three methods for connecting copper tubing.
a. _____ b. _____ c. _____
5. List three people you can talk to about solving plumbing problems.
a. _____ b. _____ c. _____
6. Pipe threads must be coated with either _____ or _____ tape before joining the pipe fitting to the pipe.
7. When soldering copper tubing, always use a paste _____ on the joints.
8. EPA regulations say that you can't use _____ in a water supply.
9. The most durable plumbing material is _____ pipe.
10. The process of joining copper tubing and fittings so that they will not leak is called _____.

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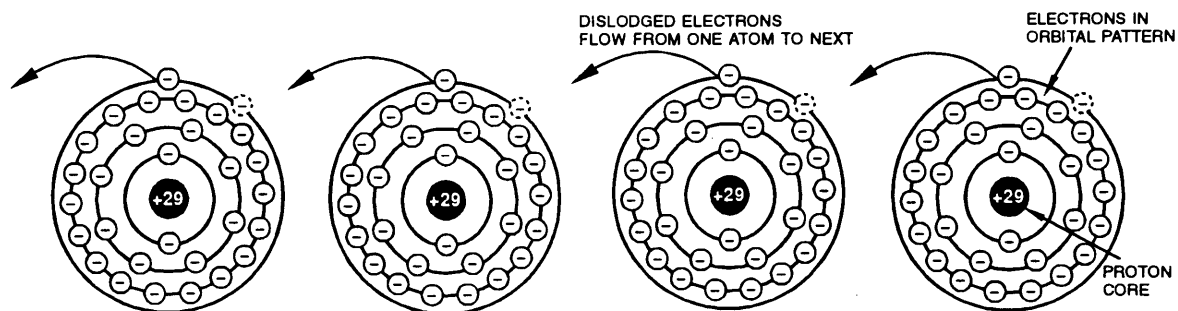
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BASIC PRINCIPLES AND SAFE USE OF ELECTRICITY

Electricity is defined as the flow of electrons from one atom to the next along a conductor. Electricity is used to 1) produce light as it flows through the filament of a bulb; 2) produce heat as it flows through a conductor with high resistance; 3) produce mechanical power through magnetic force; and 4) send and interpret information.

All matter is made up of different elements. The smallest unit part of matter is the atom. All atoms have particles called electrons arranged in an orbital pattern around a core of protons. Each separate element has its own atomic structure, or number of electrons and protons.

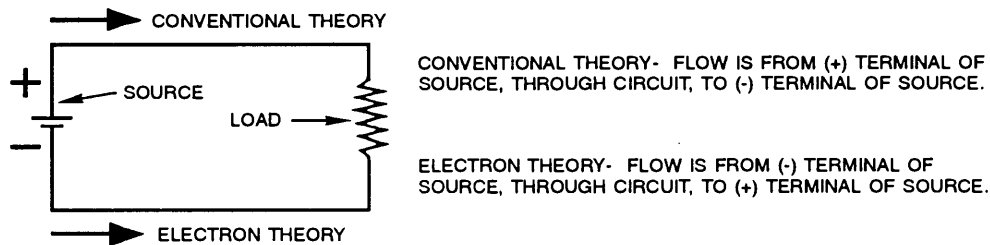
In an electrically neutral state, each atom has an equal number of electrons and protons. Electrons can be forced to leave the outer ring of some elements and attach to the outer ring of an adjacent atom. When extra electrons attach to an atom, the atom becomes **charged**. The atom that gives up an electron has the opposite charge and will try to attract electrons to become neutral again.



Movement of Electrons Through Four Copper Atoms

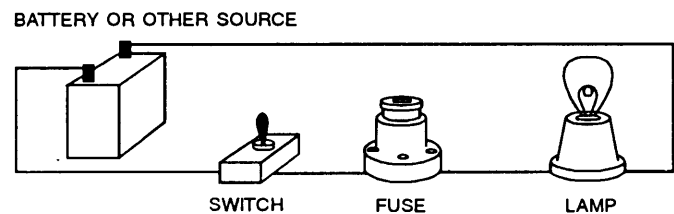
The flow of **electrical current** or electricity is the continuous movement or flow of electrons. **The electron theory of current flow** is the belief that electrons flow from the atom that has a negative charge to an atom with positive charge. Before the electron theory was introduced in the early 1900's, scientists had agreed that electrical current flowed from one point to another.

However, they called the source of current flow the positive end since it had "too much" charge, and the end of the conductor with a "lack of charge," the negative end. This theory is called the **conventional theory of current flow**.



The electron theory calls the source end the negative (-) terminal while the conventional theory calls the source end the positive (+) terminal. Both theories are still used today. Most authors or editors of books will indicate which theory is used in the discussion and diagrams. The important point to remember is not to mix the two in design and discussion. An alternative is to indicate and remember the end of the conductor at which the current is generated as the **source**, and the other end as the **return or ground**.

An **electrical circuit** is the completed path for the flow or exchange of electrons. This flow can continue as long as different charges are maintained at each end of the conductor. A simple circuit must contain 1) a source to start the flow of electrons; 2) a conductor that the electrons flow through; 3) a consumer or load to use the flow of electrons; and 4) a conductor connected from the load, back to the source.



Simple Circuit with Switch and Fuse Added

A **load** or **consumer** is any device that converts electrical energy back into another form of useable energy. For example, a bulb converts electrical energy to light and heat, a heating element converts electrical energy to heat, and an electric motor converts electrical energy back into mechanical energy. Other optional devices, such as switches and fuses, are added to a circuit to control the circuit and protect the equipment.

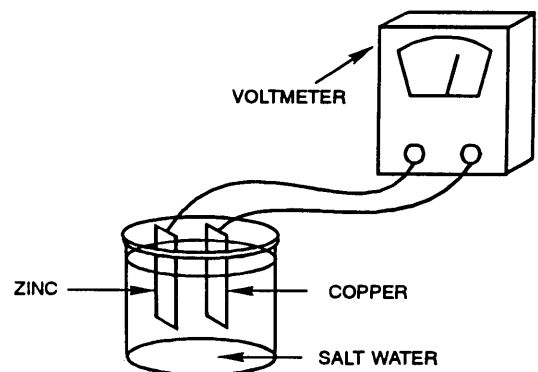
GENERATING ELECTRICAL CURRENT

Since atoms in the conductor are normally neutral, something must occur to start the movement of electrons or electrical current. Causing electrons to flow through the circuit is referred to as **generating electrical energy**. The electrical energy is not created, but converted or generated from other forms of energy. There are six methods of generating electrical energy.

Direct current (D.C.) is electrical current that when generated, flows in only one direction through the conductors. **Alternating current (A.C.)** is electrical energy that reverses or alternates the direction of travel at regular intervals as it is generated and flows through the conductors.

Storage batteries are called **chemical generators**. This is because they generate electrical current by chemical reaction from chemicals *stored* inside the battery. Two electrodes, one positive and one negative, are submerged in a chemical solution or paste called **electrolyte**.

The electrons are dislodged when a chemical reaction occurs between the different chemicals in the electrolyte and the electrodes. The electrons will flow as long as the circuit is complete and the chemical reaction continues. A simple **wet-cell battery** can be easily demonstrated by placing one zinc electrode and one copper electrode in a glass of salt water. The dissimilar metals undergo a chemical reaction with the salt water to produce a low voltage.



A Simple Wet-Cell Battery

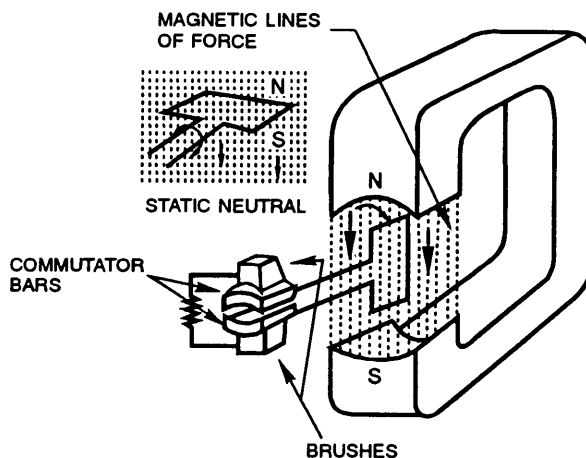
Different types of metals and chemical compounds are used in different types of commercial batteries. The voltage and amperage of the electrical current produced depends upon the speed and strength of the chemical reaction. Common wet-cell storage batteries used in tractors and automobiles utilize lead and lead peroxide electrodes and a sulfuric acid electrolyte.

The small **dry-cell batteries** used in flashlights, etc. utilize electrodes made of carbon and zinc. The electrolyte is an ammonium chloride compound in a paste form, thus the name dry-cell. The electrical current generated from chemical energy will be direct current (D.C.).

Electrical current can be generated from **mechanical energy**. It was discovered that a magnetic force could dislodge the electrons from the atoms of certain metals. By rotating a loop of copper wire within the lines of force of a magnetic field, electrons can be dislodged and electrical current is *induced* in the wire. This process is known as **electromagnetic induction**.

The voltage and amperage of the electrical current induced varies with 1) the strength of the lines of force of the magnetic field; 2) the speed at which the conductor cuts through the lines of force; and 3) the number of conductors that are cutting across the lines of force. Both D.C. and A.C. current can be generated by a mechanical generator.

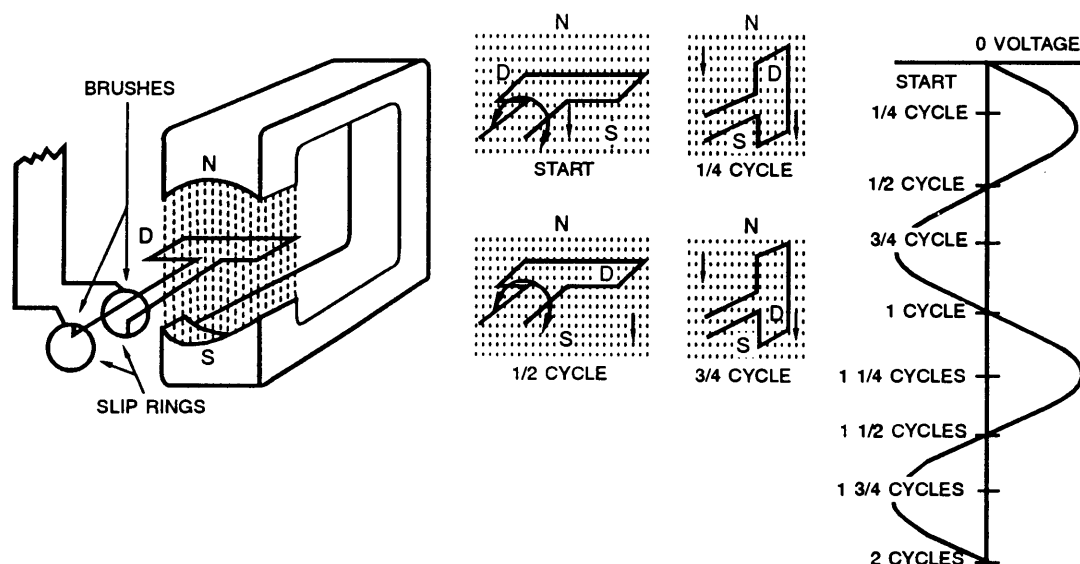
A **basic D.C. generator** is made by rotating a single loop of wire with a **commutator** attached to each end between the N and S poles of a magnetic field. The induced current will flow in a definite relationship to the N-S polarity of the magnetic field. It will flow through **brushes** that ride on the commutator to the rest of the circuit. As the loop rotates, it moves out of the strong magnetic field or to **static neutral** for a split second. At the same instant, the brushes come in contact with the opposite commutator so that as the wire loop re-enters the magnetic field, the induced current continues to flow in the same direction through the circuit.



Basic D.C. Generator

A **basic A.C. generator** is constructed in a similar manner with a magnetic field and a rotating loop of wire. Instead of a split commutator attached to ends of the wire loop, continuous **slip rings** are used. As a loop of wire makes a single rotation through the magnetic field, it completes one cycle, which is divided into four parts.

A cycle starts when the loop is at **static neutral** to the magnetic field. Through the first 1/4th revolution, the current induced is flowing in a definite relationship to the N-S magnetic field. The voltage peaks as the loop moves through the strongest part of the magnetic field. Through the second 1/4th revolution, the voltage decreases until the loop again reaches static neutral.

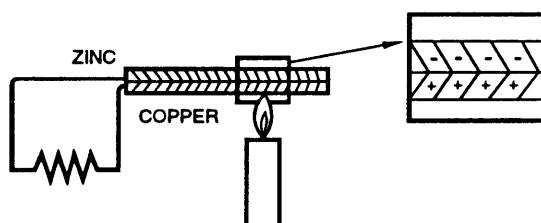
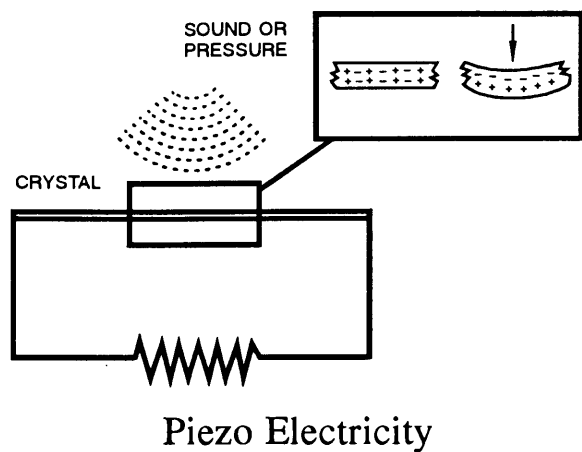


Basic A.C. Generator

As the loop starts the third quarter of the cycle, voltage increases, but current flow is in an opposite direction because the loop is now in an opposite relationship to the N-S poles of the magnetic field. Because the brushes are riding on the slip rings, the connection with the rest of the circuit remains continuous, but the current flow is suddenly reversed. The voltage again rises until the end of the third quarter of the cycle. During the final quarter of the cycle, the voltage again decreases to 0. If the rotation continues, the cycle starts over again.

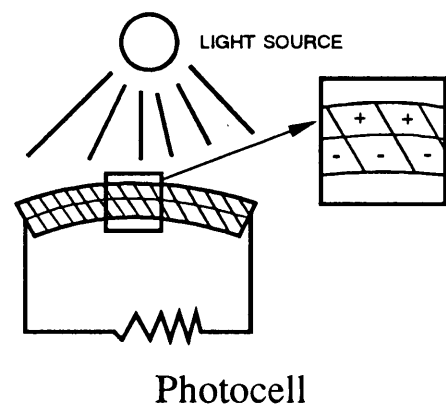
The A.C. current used in the United States cycles at a frequency of 60 times per second. It is called **60 Hertz(Hz) A.C.** However, the alternating pattern is so rapid that one cannot detect the change in direction even in a light bulb. To produce 60-Hz A.C. current, the generator turns 60 revolutions per second or 3600 revolutions per minute. Some countries use 50 Hz current.

Some materials produce electricity when pressure or force is applied that changes their shape in some way. Electrons are dislodged by the twisting or bending when a force is exerted on a thin layer of certain crystal elements such as quartz. The generating current is called **piezo electricity** because of the "piezo" or pressure crystals. This process is used in microphones and sensors to detect sound, pressure, or movement.



Heat energy can cause electrons to flow between two dissimilar metals when they are placed next to each other. This is called the **thermoelectric process**. A **thermocouple** is a device which generates current flow when a bi-metallic strip is heated. The more heat, the more current produced. When the heat is reduced, the current flow will decrease or stop.

Light energy or **solar power** can cause certain elements and compounds such as potassium, sodium, lithium, germanium, cadmium, and lead sulfide to release electrons. A **photocell** contains two such elements and is used to generate electrical current. Photocells are used extensively in sensor and control devices.



Friction can mechanically dislodge electrons in certain materials. **Static electricity** is generated on the soles of your shoes as you walk across a carpet or as you pull a comb through your hair. It is called static electricity because the electrons can build up at one point until there is enough force to jump an air gap to an area where there is a lower number of electrons. Static electricity has little practical value because it is difficult to predict and control.

CONDUCTORS AND INSULATORS

The flow of electrons or electrical current is easier in certain elements or materials than in others. Any tendency of an element or material to prevent electrical flow is called **resistance**. The higher the resistance in the conductor, the more heat that is produced as current flows. This is because of the higher number of electrons being held in the outer ring and their stronger bond or attraction to their own core of protons.

Elements that have fewer than four electrons in their outer ring are good **conductors** and have low resistance. Most metals are considered conductors. The best conductors are gold, silver, copper, aluminum, and bronze -- in that order. Because of the expense, gold and silver are seldom used except in special electronic circuits.

Copper wire is the most commonly used conductor because it has only one electron in its outer ring. This single electron can be easily dislodged which gives copper a very low resistance to current flow. Copper is also soft, can be easily shaped, and is relatively inexpensive. **Aluminum** has a slightly higher resistance than copper. If the same amount of electrical current flows through the same size aluminum wire, there will be more heat build-up. Thus, aluminum wire is used primarily in outdoor applications where the heat can be dissipated into the open air.

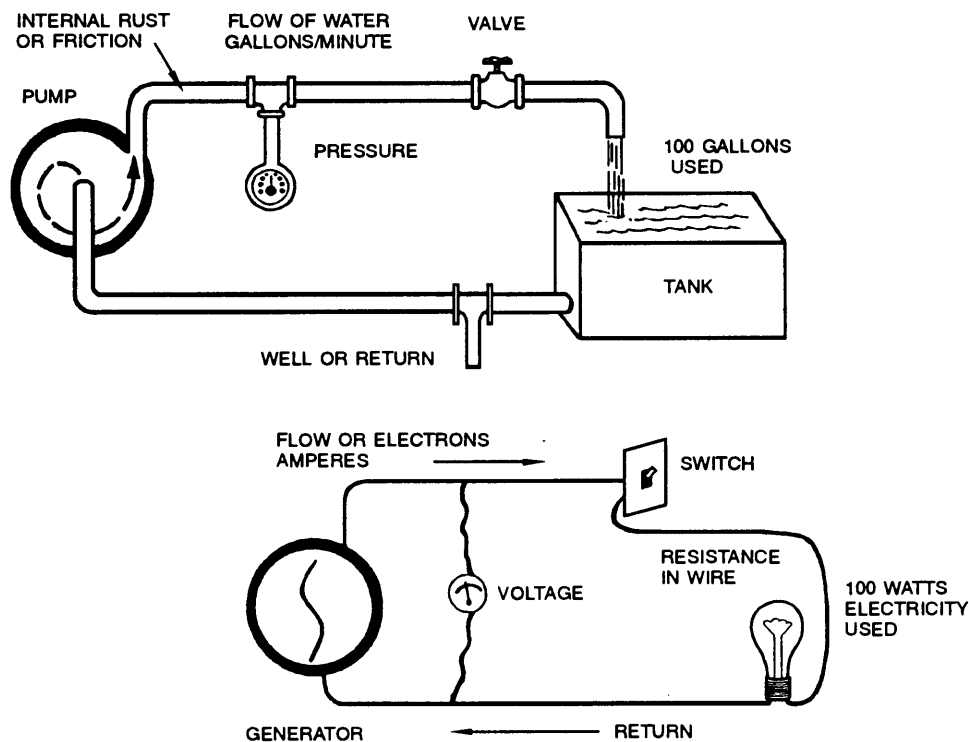
Elements with more than four electrons in the outer ring are considered **insulators**. They do not readily allow electrical current to flow through them. Materials such as glass, paraffin, rubber, porcelain, silk, cotton, dry wood, and most plastics are mixtures of these elements and are used as insulators. However, many of these materials may "lose" all or part of their insulating ability when they become wet or even damp on the surface. The water conducts the flow of electricity around or through the insulating material.

Semiconductors are elements, such as silicon and germanium, which have four electrons in their outer ring. The use of semiconductors was discovered in the mid- to late-1940s. These elements are neither good conductors or insulators. **Diodes** and **transistors** are made by mixing and treating these semiconductor elements with other elements.

Diodes and transistors act as "switches" in low voltage circuits to control current flow. They allow current to flow in only one direction and/or only under certain conditions. These conditions include the voltage and amperage of the electricity, temperature, light intensity, and other factors.

HOW ELECTRICAL ENERGY IS MEASURED

The battery, generator, or other device used to produce the electrical energy is similar to a pump used to force water through pipes. The flow of water is measured in *gallons per minute*. The flow of electrons through the conductor is called **electrical current** and is measured in **amperes (A or amps for short)**. **Amperage** is the rate of electrical current flow (electron flow) through a conductor per second. One amp of current is approximately 6,280,000,000,000,000 electrons passing a certain point in a conductor per second.



Comparing an Electrical System to a Water System

Voltage (V or volt for short) is the electromotive force (**emf**) or potential force that causes current to flow in the conductor. Voltage is compared to *pounds per square inch of pressure* (psi) in the water pipe. A battery or generator can have the potential of producing so much voltage or "pressure." Voltage can exist and be measured between two points without current flow. However, current cannot exist and flow without the pressure of the voltage to force it through the conductor.

Voltage exists when there is a positive charge at one point and a negative charge at the other. The greater the difference in the charges, the greater the voltage or emf. One volt is the amount of electrical pressure required to push one amp of current through one ohm of resistance. Common voltage sources include 1.5 volt dry-cell flashlight batteries, 6 and 12 volt wet-cell storage batteries, 120 volt circuits for most lights and small motors, and 240 volt circuits for larger heating elements and electrical motors.

Electrons do not flow freely through even the best conductors, just as water must overcome internal friction of the pipe wall and scale to flow through a pipe. **Ohm** (shown by the symbol Ω) is a unit of measure of the resistance to electrical current flow. **Resistance** is caused by the attraction of an atom's electrons to its own core of protons and by the collision of electrons as they move through a conductor. This resistance causes heat in the conductor as current flows.

The total ohms of resistance in a circuit is affected by 1) the elements of which the conductors are made; 2) the length of the conductors; 3) the cross-sectional area of the conductors; and 4) the temperature of the conductors. One ohm is the amount of resistance overcome by one volt to cause one amp of current to flow.

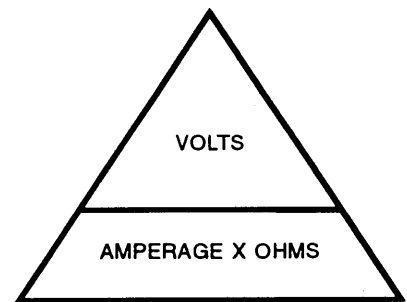
Resistance is proportional to the length and diameter or surface area of the wire. If the length of wire is doubled, the resistance is doubled. If its diameter is reduced by half, the resistance is doubled. The hotter a wire or conductor, the more the resistance to current flow.

However, when planned, it is desirable to have high resistance in certain parts of the circuit. For example, the filament in a light bulb is a short piece of wire which has high resistance. As current flows, the filament gets hot and glows. The heating elements inside an electrical stove, dryer, or heater are also made of a special high resistance conductor.

High resistance can be harmful if it is not planned and controlled. Loose and corroded wiring terminals and connections in effect reduce the size of the conductor because of the limited surface area that is actually in contact. As the amount of clean surface area in contact decreases, resistance to current flow through the connection increases. As the resistance increases, heat buildup increases. As heat increases, the resistance increases even more. If the same amount of current continues to flow through the conductor, the connection may get hot enough to melt the insulation and/or start a fire.

RELATIONSHIPS BETWEEN VOLTAGE, AMPERAGE, WATTS, AND OHMS OF RESISTANCE

Ohm's law states that voltage is always equal to the amperage times the ohms of resistance in a circuit. The flow of electricity through the conductor is always directly proportional to voltage that produces it. If the resistance in a circuit increases while the voltage remains constant, the amount of current flow or amperage is decreased proportionally. Thus, when any two values are known, the other can be calculated.



Ohm's Law in Triangle Expression

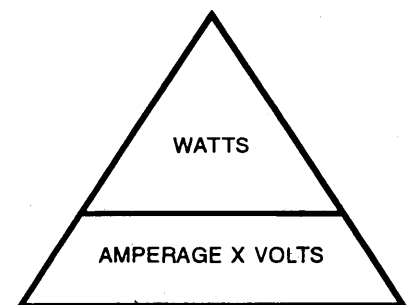
$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}} \quad \text{or} \quad \text{Volts} = \text{Amperes} \times \text{Ohms} \quad \text{or} \quad \text{Ohms} = \frac{\text{Volts}}{\text{Amperes}}$$

For Example:

$$20 \text{ A} = \frac{120 \text{ V}}{6 \text{ Ohms}} \quad \text{or} \quad 120 \text{ V} = 20 \text{ A} \times 6 \text{ Ohms} \quad \text{or} \quad 6 \text{ Ohms} = \frac{120 \text{ V}}{20 \text{ A}}$$

$$6 \text{ A} = \frac{12 \text{ V}}{2 \text{ Ohms}} \quad \text{or} \quad 12 \text{ V} = 6 \text{ A} \times 2 \text{ Ohms} \quad \text{or} \quad 2 \text{ Ohms} = \frac{12 \text{ V}}{6 \text{ A}}$$

A relationship also exists among amps, volts, and watts in all electrical circuits. A **Watt (W)** is a measure of electrical power, or the amount of electrical energy the load or consumer uses or converts by back to light, heat, or mechanical energy. The higher the wattage rating, the faster the electrical energy is being converted.



Wattage Formulas in Triangle Expression

$$\text{Volts} = \frac{\text{Watts}}{\text{Amps}} \quad \text{or} \quad \text{Watts} = \text{Volts} \times \text{Amps} \quad \text{or} \quad \text{Amps} = \frac{\text{Watts}}{\text{Voltage}}$$

Sample Problems:

Suppose six large 200-watt bulbs are to be installed in a 120 volt electrical circuit. How many amps must flow when the lights burn at rated wattage? The source of electrical current will supply 120 volts of pressure. Six bulbs will draw 1,200 watts of power or energy ($6 \times 200 = 1,200$ watts).

$$A = \frac{W}{V} \quad \text{or} \quad 1200 \text{ watts} \div 120 \text{ volts} = 10 \text{ amps}$$

A wire large enough to allow at least 10 amps of current to flow is needed.

Suppose a 120 volt power supply has been installed. A wire of sufficient size to allow 15 amps of current has been attached. Can a large space heater with an element that will consume 2400 watts of energy be safely installed?

$W = V \times A$ or $120 \text{ volts} \times 15 \text{ amps} = 1,800 \text{ watts}$. Because 2,400 watts are needed, this circuit would not have sufficient capacity to install the desired heater.

Suppose a 12 volt accessory circuit used on an automobile or tractor is wired for 15 amps and has a 15 amp fuse installed. How many watts of electrical energy should be available for safe operation?

$$12 \text{ volts} \times 15 \text{ amps} = 180 \text{ watts}$$

If extra lights or accessories above 180 watts are installed in the circuit, a failure will occur.

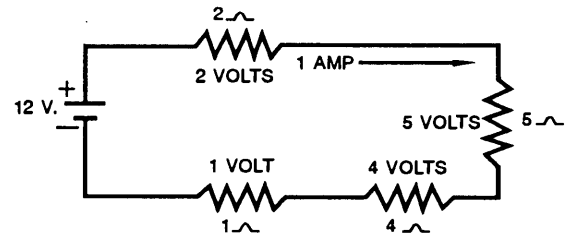
Some books and references may also refer to amperes as I, volts as E, and ohms as R. Thus, amperes = **Amps** = **A** = **I**. Voltage = **Volts** = **V** = **E**. Ohms = Ω = **R**. Metric prefixes are used to simplify terms when very large or small amounts of electricity are being measured. **Kilo** means 1,000 and **milli** means 1/1,000. One kilovolt = 1,000 volts, 1 kilowatt = 1,000 watts, and 1 milliamperere = 1/1,000 ampere.

Kilowatt-hour (kWh) is unit of electrical energy. It is the product of electrical power used (in kW) and time (in hours). In the example of the circuit with six 200 W light bulbs installed, 1,200 watts or 1.2 kW of electrical power is converted to light energy ($1,200 \text{ W} \div 1,000 = 1.2 \text{ kW}$). If the lights burn for one hour, 1.2 kWh of electrical power is used ($1.2 \text{ kW} \times 1 \text{ hr} = 1.2 \text{ kWh}$). A **kilowatt-hour meter** is an instrument that accurately records the consumption of electricity.

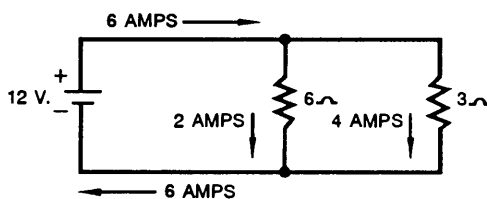
TYPES OF CIRCUITS

There are three basic types of circuits. **Series circuits** have only one path from the source through the loads back to the source. If one of the loads is disconnected or burns out, the current will stop flowing through the rest of the circuit. Certain types of Christmas lights utilize series circuits.

The amperage through each load in a series circuit is the same. The voltage drop across each load will be different if the resistance in the load is different. The sum of the voltage drops equals the source voltage. Series circuits are not common in residential or agricultural applications except in appliance control circuits, some lower voltage automotive, tractor, and equipment electrical systems, and in electronics applications.



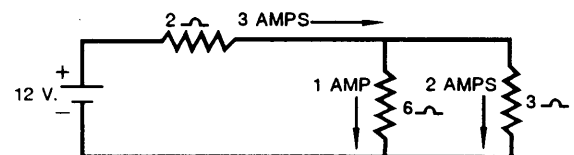
Series Circuit with Four Loads



Parallel Circuits With One Load Each

Parallel circuits have separate paths from the source to each load and back to the source. The voltage across each load is the same. The amperage through each load will be different only if the resistance in each load is different. The sum of the separate amperage loads is the total amperage load in the circuit. If one load in a parallel circuit is turned off or burns out, the rest will stay on.

Series-Parallel circuits have some loads connected in series and some in parallel. In a series-parallel circuit, the laws for the series are obeyed in that portion of the circuit. Likewise, the parallel laws are obeyed in the parallel circuit portion. Series-parallel circuits are used primarily in control and sensing units.



Series-Parallel Circuit

VOLTAGE DROP

When electrical current flows through a circuit, part of the voltage or pressure is "used" trying to overcome the resistance in the conductors. This reduction in voltage is called **voltage drop**. This is similar to the loss in pressure used to overcome the friction and scale on the inside of a pipe. **Ampacity** is the current flow in amps a certain size wire can carry continuously under normal operating conditions without causing excessive voltage drop and overheating problems.

The longer the conductors, the smaller the diameter of the conductors, or the more resistance through faulty or corroded connections in the circuit, the more the voltage drop. The total voltage drop in 120 V A.C. circuits must be planned for and kept to an acceptable minimum of four to five percent or less for the system to operate properly.

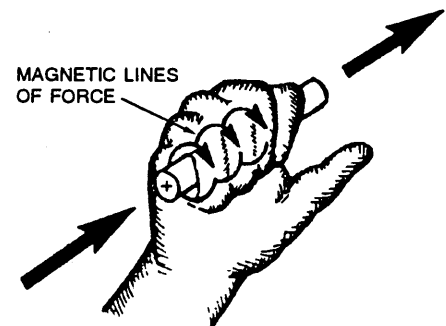
For Example: source voltage = 120 V voltage at the load = 118 V
 $120 \text{ V} - 118 \text{ V} = 2 \text{ V drop}$
 $2 \text{ V drop} \div 120 \text{ V source voltage} = .0167 \times 100 = 1.67 \text{ percent voltage drop}$

RELATIONSHIP BETWEEN ELECTRICITY AND MAGNETISM

As discussed, electrical current can be induced in a conductor by passing a loop of wire through a magnetic field. This process is called **electromagnetic induction**.

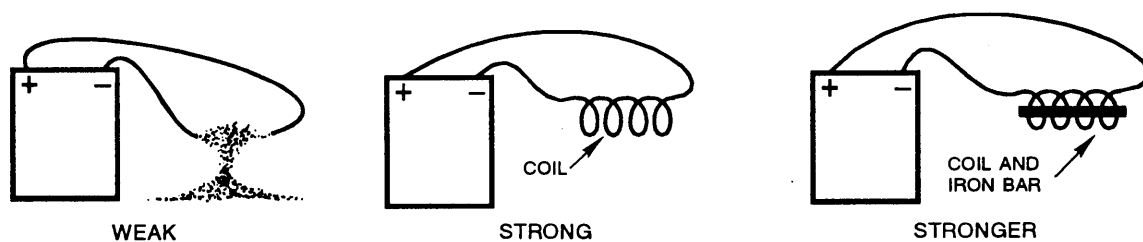
The opposite relationship also exists between electricity and magnetism. That is, a magnetic field is produced around a wire or conductor as electrical current passes through it. The magnetic lines of force are in a definite relationship to the direction of current flow through the conductor.

By pointing the thumb of the right hand in the direction of current flow from positive to negative as in the conventional theory, the fingers point in the direction in which the lines of magnetic force surround the conductor.



Right Hand Rule

Now consider the **basic principles of electromagnets**. A single loop of wire carrying current has a weak magnetic field around it. The higher the current flow through the conductor, the stronger the magnetic field.

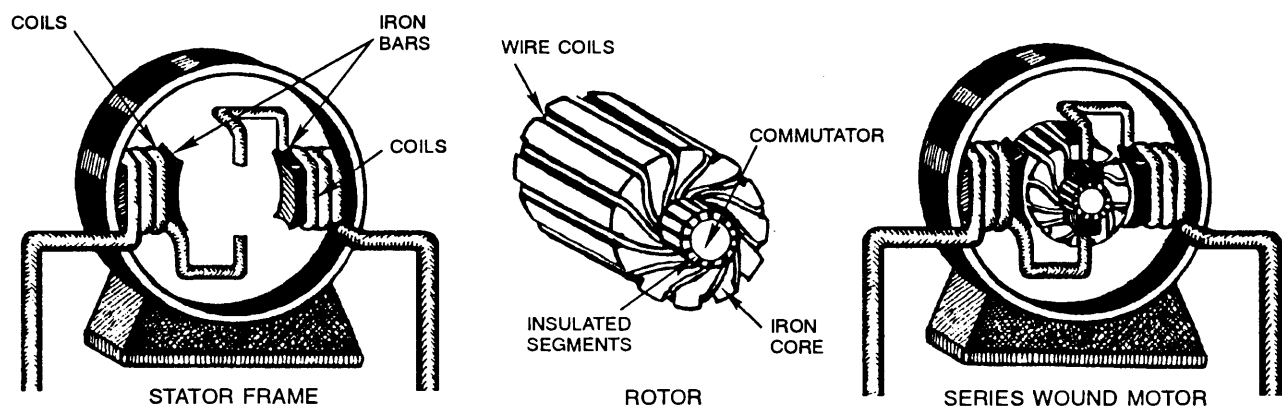


Basic Electromagnets

When a number of loops or wraps of wire are combined to form a coil, the magnetic field is strengthened proportionally since each wire adds its magnetic force to the total field. When the coils are wound around an iron bar, the magnetic field is strengthened even more. This is because iron is approximately 2,500 times better at conducting the lines of force of a magnetic field than air. The assembly becomes an **electromagnet**.

OPERATION AND USE OF ELECTRIC MOTORS

Electrical motors operate on the basic principles of electromagnets and electromagnetic induction. Permanent magnets and/or electromagnets are placed in a circular pattern in the outside of the stationary part or **stator** of the motor. The magnetic poles of the magnets or electromagnets face toward the inside of the motor. Depending upon the motor design, additional permanent magnets and/or electromagnets are placed on an **armature** or **rotor** which can rotate inside the stator. The magnetic poles of the rotor face outward toward the stator poles.



Basic Operation of An Electric Motor

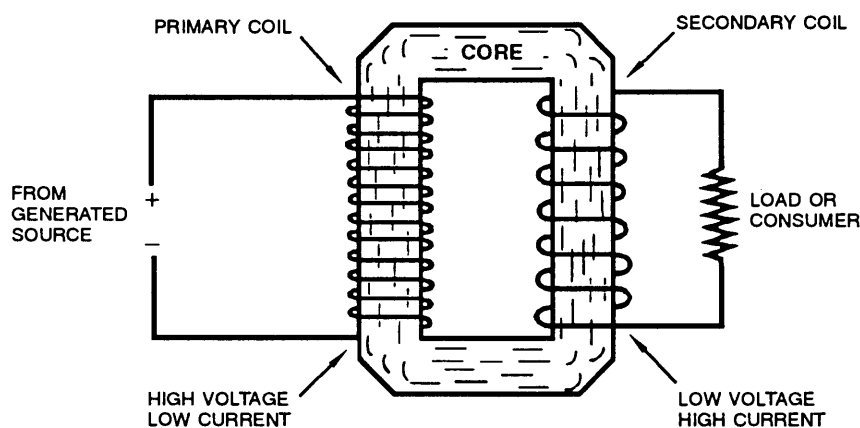
By sending and/or inducing current into the appropriate coils in the stator and rotor, magnetic fields are created. The iron bars or plates strengthen the magnetic fields. Because unlike poles attract and like poles repel, the magnetic fields push and pull against each other and cause the rotor to turn.

There are many different designs of electric motors. As the rotor starts to turn, various means are used to reverse the current flow in the appropriate coils at the correct time. As the current flow in a coil reverses, the polarity of its magnetic field reverses. This allows a continual push-pull in the appropriate coils so that the rotation of the rotor is smooth and continuous. Electrical energy is thus converted back to mechanical energy. The larger the motor, the more coils of wire, thus the higher the resistance in the circuit.

OPERATION AND USE OF TRANSFORMERS

A **basic transformer** consists of two windings called a **primary coil** and a **secondary coil**. The coils are wound around a hollow iron core. Electrical current from a power source flows through the primary coil and creates a strong magnetic field. The magnetic field created in the primary coil then **induces** current flow in the secondary coil through magnetic induction.

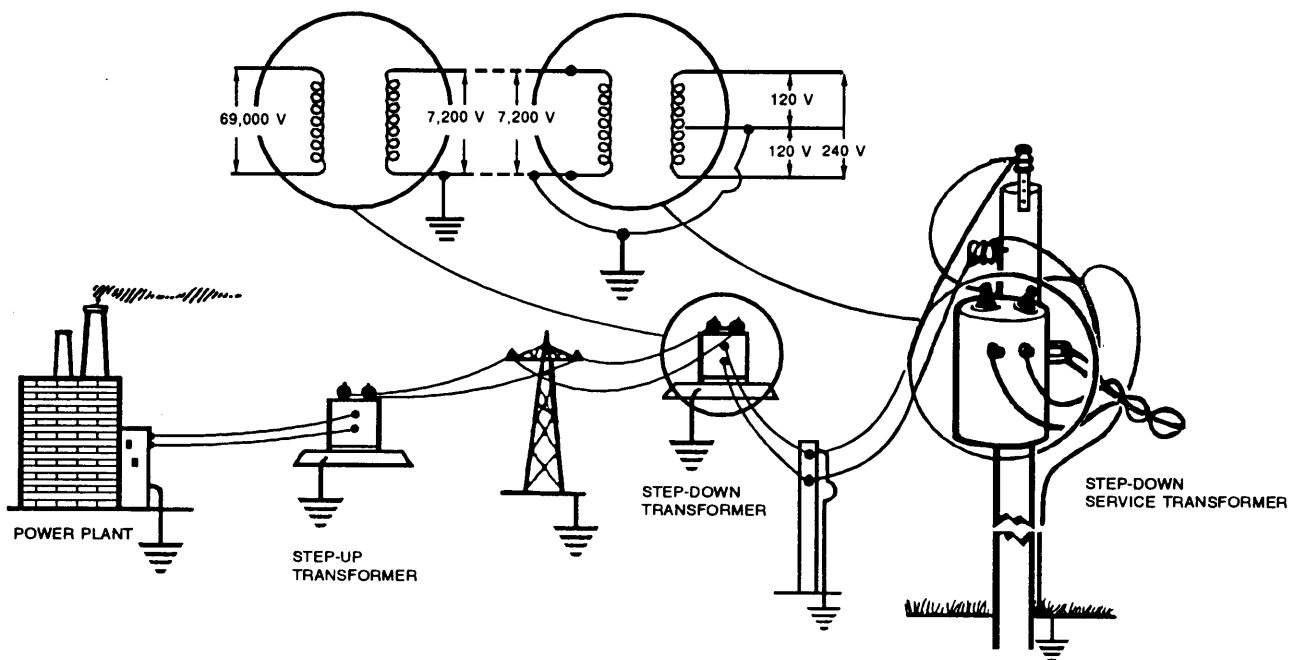
The primary and secondary coils are not actually connected and current does not flow between them. The metal core is used to hold the coils in shape and to strengthen the magnetic fields.



Operation of a Basic Transformer

A **step-down transformer** has less wraps or **turns** of wire on the secondary coil side than it does on the primary side. It is used to decrease voltage. **For example:** When the number of turns in the secondary coil is one-half the number in the primary coil, the voltage induced in the secondary side is one-half of that flowing into the primary side from the source. A **step-up transformer** will have a greater number of turns on the secondary side and is used to increase voltage.

Wattage = voltage x amperage. Thus, as the voltage induced in the secondary side increases or decreases, the amperage increases or decreases proportionally. Resistance to high amperage current flow creates heat and consumes electrical energy (voltage drop). Power supply companies use step-up transformers near the generating plants to increase the voltage to thousands of volts while lowering amperage to a minimum. The increased voltage can then be distributed hundreds of miles through smaller aluminum wires on the cross-country high lines more economically.



Use of Step-up and Step-down Transformers in the Distribution of Electrical Power

At the point near where the electrical current is to be used by the customers, step-down transformers reduce voltage and increase amperage to safer useable levels. The distribution lines that run by your home, school, or agricultural business are probably 7,200 V. This voltage is reduced to 120/240 V by a **final step-down service transformer** located near the service entrance.

Transformers are also used in other applications where it is beneficial to increase or decrease current flow. Examples include high voltage ignition coils, low voltage control circuits, door bell circuits, and electronics.

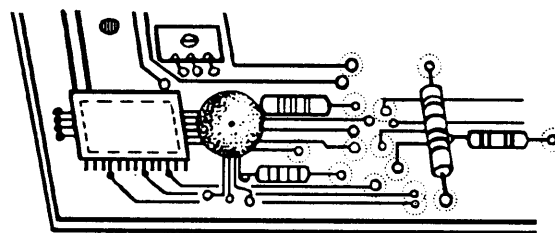
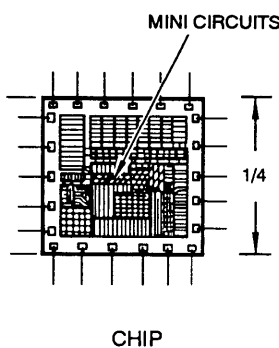
ELECTRONIC CIRCUITS

The use of electronics has changed the way we think about electricity. Electronics use transistors, semiconductors and integrated circuits for information gathering and processing, and to control other electrical circuits and mechanical functions.

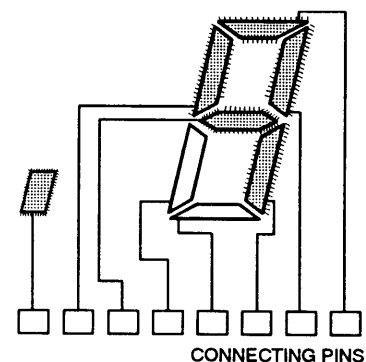
For most purposes and discussion, **electronic circuits** are considered circuits which use direct current of below 8 volts with the flow measured in **milliamps**. Although older tractors and automobiles use 6 volt systems, these systems are not considered electronic circuits. They use mechanical circuit control devices, larger conductors, and much higher amperage.

Many electrical devices now utilize "hybrid circuits." That is, a combination of high voltage and electronic voltage circuits are used. The higher voltage is reduced through the use of step-down transformers. If an A.C. power source is used, it is converted to D.C. through the use of a rectifier. **Rectifiers** are diodes made of special semiconductors that allow current to flow in only one direction. Only one side of the alternating positive-negative wave pattern of the alternating current is allowed to flow through. A.C. current is thus converted to D.C. current.

Resistance is the opposition to current flow. **Resistors** are devices with higher resistance than the normal conductor. Resistors are purposely placed in some circuits. By controlling the resistance, the amperage and voltage in the circuit can be controlled. **Transistors** combine several semiconductors into one component to act as a switch or switches under certain conditions.



CIRCUIT BOARD



ONE DIGITAL DISPLAY IS
ACTUALLY 8 SMALL LED'S

The switches can either be normally open or normally closed. Transistors can be constructed to allow one switch to simultaneously operate other switches thus controlling the current in several circuits. Some electronic resistors and transistors are temperature sensitive. They are able to control current in other circuits based upon the surrounding temperature.

Other devices that have reduced the size of electronic circuits are **light emitting diodes** or **L.E.D.s**, and **liquid crystal displays** or **L.C.D.s**. L.E.D.s are tiny diodes that emit light as current passes through them. They have replaced large incandescent lamps as signals in electronic circuits because of their long-life and fast on-off switching capabilities. L.C.D.s reflect light when no voltage is applied, but they absorb light when voltage is applied and current is flowing.

Many of the original electronic devices were constructed inside bulky glass vacuum tubes. When the first solid-state semiconductors were used in the mid-1960s, as many as 1,000 different circuits could be placed on a small three-inch by five-inch circuit board.

Today, thousands of mini circuits can be placed on a computer chip less than 1/4-inch in size. These chips are made with sophisticated microscopic equipment. Circuit patterns are etched on the surfaces of tiny silicon semiconductors. The grooves are treated so that the semiconductors act as diodes, transistors, resistors, capacitors, or conductors to form **integrated circuits**. The microscopic series and parallel circuits are connected to slightly larger wires and finally to larger terminals. These terminals are then connected to circuit boards and other components.

Microprocessors are basically thousands of these mini circuits through which electronic current or impulses can flow. Electronic impulses or "**input**" may flow from keyboard switches, sensors, and monitors. There are literally thousands of possible circuits in the microprocessor for the input to flow through. Each of these circuits have electronic switches that are either open or closed.

Imagine literally thousands of "if-then" "and-or" situations in life. *If* this, *and-or* that occurs, *then* something else will happen. This is basically what happens inside a computer or any other electronic device. It is the ability of electronic circuitry to send or sense impulses that allows information to be stored and processed by electronic devices.

The input flows through the mini-circuits depending upon certain if-then, and-or conditions which are the way semiconductor switches are opened or closed. The switches open or close depending upon how they were set by the computer program or the function the electronic device is designed to perform. In electronics terms, these semiconductor switches are sometimes called "**flip-flops**".

As input flows, it can cause other switches to be opened or closed by the electronic transistors. Information may be stored for future use by the way certain flip-flop switches are left open or closed, and by the N - S polarity patterns left on magnetic surfaces. After input has been processed and/or stored, it can flow back out as "**output**" in the form of electronic impulses to activate printers, L.E.D.s, L.C.D.s, buzzers, gauges, etc. Through the use of step-up transformers, electronic output voltage can be increased to operate electrical control devices.

CIRCUIT FAILURES

There are different types of failures that can occur in circuits. An **open circuit** is a break or interruption that occurs when a wire or conductor breaks, is cut, or a connection becomes loose and is not making good contact. An open circuit may occur instantly and completely, or gradually. Corrosion can slowly increase resistance in a connection until the circuit is completely open. When there is an open circuit, there is no current flow.

A **short circuit** occurs when the electrons find an unintentional path to return to the source before going through all or part of the loads in the circuit. A **short** commonly occurs when two or more wires in one or more circuits are touching because of damaged insulation. When a load (light, heater, or motor) is bypassed, a major portion of the resistance in the circuit is immediately eliminated. When resistance decreases, current flow increases. As current increases, heat build-up may increase to the point further damage, melting of insulation, and/or igniting of flammable materials can occur.

An **electrical spark** or **arc** occurs when there is sufficient voltage (pressure) in a conductor for current to jump a narrow opening or air gap to another conductor thus completing a circuit back to the source.

ELECTRICAL SAFETY

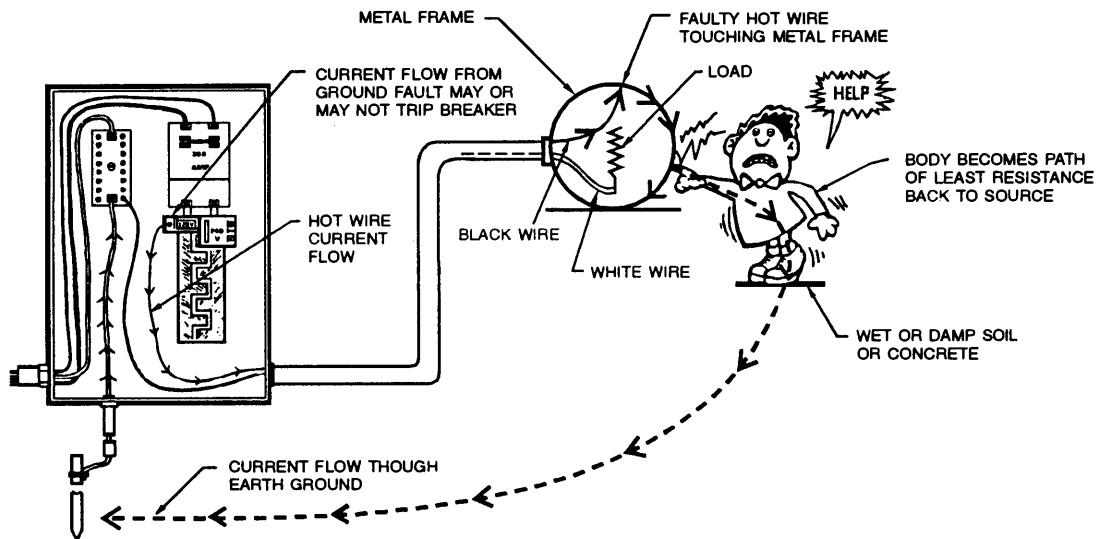
Electrical current will flow from where it is back to its source following a completed path of the least resistance. This is an important safety factor to remember when working around electricity.

A human or animal may become part of a circuit by being in direct contact between any electrically charged wiring, metal frame, faulty electrical equipment, or wet surface *and* a path back to the source. Potentially dangerous conditions exist when 1) connections on the neutral or return side of a circuit become loose or corroded; 2) insulation on wiring is damaged; 3) wires or equipment are improperly connected or grounded; 4) undersized wiring is used; or 5) when equipment and metal framework becomes charged because of an accident or failure.

Electrical shock occurs when electricity flows through the body. Normally, when voltage is less than 50 V, the potential for current flow (amperage) through the body is not high enough for the shock to be harmful to most humans. However, at higher voltages, even the slightest current flow can cause muscular reactions, skin burns, damage to internal organs, or even death. Regardless of the voltage, do not take chances with electricity. Your safety and the safety of others depends on it.

As little as one milliamperere (0.001 A) of current can cause a tingling sensation in most people. Approximately 10 to 15 milliamperes (0.010 to 0.015 A) of current through the body may contract and paralyze the muscles. A person is unable to let-go and move away from the electrically charged conductor. This is called the **let-go threshold**. Approximately 15 to 50 milliamperes (0.015 to 0.050 A) of current flow can cause serious burns and is sufficient to cause fibrillation or heart stoppage in some humans. These levels are far *below* the amperage required to blow a 15 A safety fuse or trip a 15 A circuit breaker.

A potential for shock can also exist when electrical equipment or wiring that is not designed and insulated for use in wet conditions comes in contact with a wet surface that is connected back to an "earth ground". Since the neutral or ground side of the A.C. electrical system is connected to an earth ground, current can flow from the source, through a person, to the wet surface, through the damp earth, through the grounding electrode and back to the source. For example, a shock can occur when a hair dryer falls into a sink or bath tub that is connected back to the earth through the water in the plumbing.



If Not Properly Protected, The Human Body Can Become Part of the Circuit

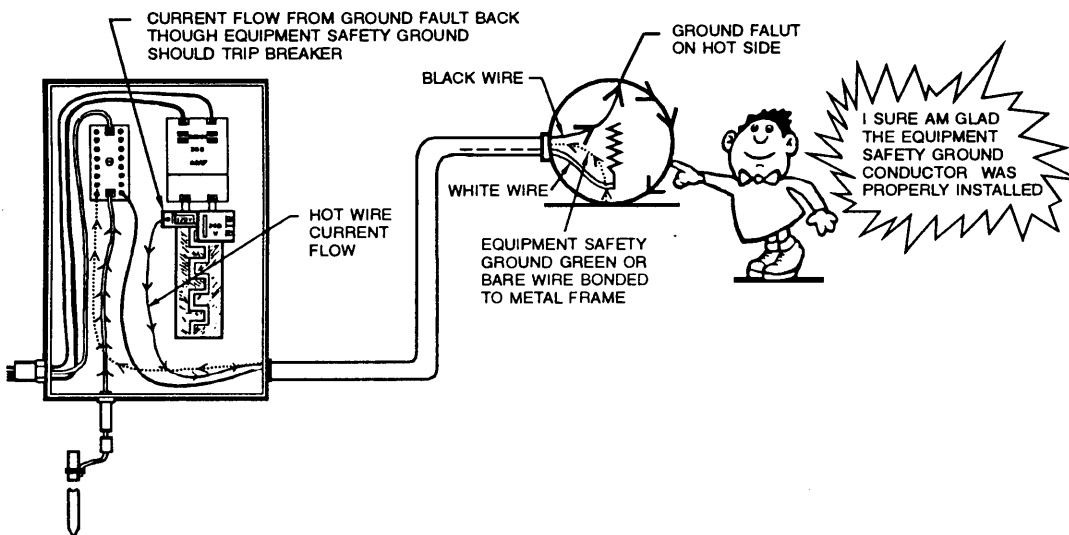
If someone is receiving an electrical shock, do not attempt to grab and pull them free. You may become part of the "circuit" and be shocked yourself. Try to locate the switch, circuit breaker, plug in, or other disconnect and turn off the power source to the circuit as quickly as possible. If it is not possible to locate a switch or other disconnect, use a dry board, a thick dry piece of rubber or plastic, or other dry non-conductor material to push or pull the "hot conductor" and the victim free from each other. Remember, above all, do not become part of the completed circuit yourself.

Contact the proper authorities for assistance and instructions as quickly as possible. If the shock is severe, start CPR and artificial respiration immediately. The actual effects of the shock may depend upon how moist the skin is, the duration of the shock, and what part of the body the current flows through. For example, a very severe shock may occur when the current travels from one hand to the other, or from one foot to an arm or hand, and passes through the chest and vital organs.

Fuses and circuit breakers are safety devices which limit the flow of *higher* amounts of current in a circuit. They are designed to protect electrical equipment and wiring from damage due to higher current overloads or short circuits.

An **equipment safety grounding conductor** is the bare copper or green-colored wire that connects and bonds all metal frames, equipment cabinets, and portable tool frames together which are not normally intended to carry current. The equipment safety ground is added to provide a low resistance alternative path directly back to the system ground/neutral at the service entrance.

The purpose of the equipment safety grounding conductor is to help prevent accidental shock should any part of the metal frame or equipment become electrically charged as shown in the illustration. The equipment safety grounding conductor is the "**third wire**" in the 120 V circuit. It is connected by the "**third or round prong**" in 120 V receptacles and plug-ins. Cutting or breaking off the third prong of an extension or power cord eliminates the safety feature of the equipment safety ground.



Equipment Safety Grounding Conductor Provides Low Resistance Path Back to System Ground/Neutral

Ground fault circuit interrupters (GFCIs) provide a completely different type of protection. They are designed specifically to protect humans and animals from electrical shock caused by very low levels of "stray or leaking" current that is not sufficient to trip the circuit breaker or blow a fuse. The installation of a GFCI does not replace the need to use a circuit breaker or fuse in a circuit. Neither does the use of a circuit breaker or fuse replace the need for a GFCI.

GFCIs constantly compare the current flowing out from the source through the "hot leg or wire" of a circuit and that returning back to the source through the system ground or neutral. **System ground** is another term for the neutral or return side to the circuit.

If there are "faulty" connections or insulation, or if the electrical equipment is in contact with wet surfaces, current will follow the path of least resistance and "leak." GFCIs are designed to trip within a fraction of a second if they sense more than 5 milliamperes difference in the current flowing out through the hot wire of the circuit and that returning through the system ground or neutral side.

GFCIs are currently recommended by the **NEC** (National Electrical Code) for use in new residential construction for all 120 V/15 and 20 A receptacle outlets that are installed outdoors; in garages; in all bathrooms; within 6 feet of kitchens sinks; and around swimming pools (wet or damp areas). They can be installed as replacement equipment in older homes and buildings. GFCIs are also recommended for use in outdoor and wet locations that exist with agricultural buildings and are required on all construction sites.

The operation and installation procedures for GFCIs, fuses, circuit breakers, equipment safety ground conductors, and grounding electrodes are discussed in more detail in topic #s 8152-B & C, and 8231-B.

Numerous agencies and organizations have been established to help insure the safe use of electricity. Most electrical wiring and equipment are now manufactured to standards established by the **National Electrical Manufacturers Association (NEMA)**. Another organization called **Underwriters Laboratories** was set up by the **National Board of Fire Underwriters** as a national testing service. On a voluntary basis, manufacturers can have samples of their products tested under conditions that are more severe than actual normal use. "To be approved" means that samples of a particular item have met the standards for that type of product.

After the samples have passed the test, the "**Approved by Underwriters' Laboratories**" or "**UL**" label may be attached or printed on the products. Not all manufacturers chose to have their electrical equipment **UL** tested. When a person has a choice, it is strongly recommended that only **UL** approved materials be used even though they may cost more. It is impossible to put a real dollar value on the loss of life or property.

The **National Fire Protection Association (NFPA)** together with the **American National Standards Institute (ANSI)** sponsor the **National Electrical Code (NEC)**. The **NEC** sets minimum standards and installation procedures for the types of electrical wiring and equipment that should be installed in different applications. There are codes for different types of building and operating conditions. For example, there are regulations for: public buildings, private residential homes, mobile homes, industrial buildings, and different types of agricultural buildings, just to name a few.

The **NEC** by itself is only a list of minimum recommendations and installation procedures deemed necessary for a safe system. However, most state and local governmental agencies officially adopt the **NEC** recommendations as their laws, regulations, and codes. The purpose of the **NEC** is to safeguard people and property from electrical and fire hazards. The **NEC** is reviewed and revised every three years.

Before any electrical work is planned or performed, the local power supplier and city and county government offices should be contacted to determine what codes apply in your community. The average home owner and agricultural worker are not qualified to install or repair electrical wiring or equipment without considerable assistance and training. Many local laws and codes require major electrical installations and repairs be performed **only** by a trained and licensed electrician. Others allow home or business owners to perform the work on their own property, but may require the work to be inspected before it is put into use.

Article #547 of the **NEC** contains regulations that apply to agricultural buildings. Even though many agricultural buildings do not presently fall under the specific jurisdiction of city or county building codes, it is recommended that the **NEC** still be followed. Many insurance companies refuse to write insurance on buildings unless the electrical system meets the minimum **NEC** recommendations and **UL** approved materials are installed.

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Fundamental of Service: Electrical Systems, Deere and Company, Moline IL.
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Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the information in this topic. Mr. Greg Stark, Executive Director, Texas Agri-Business Electric Council provided technical assistance. Ms. Hannah Kerby, Graduate Assistant, Department of Agricultural Education, Texas A&M University, developed the student activities.

SUGGESTED STUDENT ACTIVITIES

Fill-In-The-Blank: Complete the following statements by inserting the correct word(s) in the blanks.

- _____ 1. _____ are elements that have four electrons in their outer ring and thus are neither good conductors nor insulators.
- _____ 2. _____ is the conductor most commonly used for electrical wiring in homes and businesses.
- _____ 3. Ohms are the measure of _____ to electrical current flow.
- _____ 4. _____ is the electromotive force (emf) or potential force which causes current to flow through a conductor.
- _____ 5. A _____, or _____, converts electrical energy back into another form of usable energy.

- _____ 6. Storage batteries generate electricity through the use of _____ energy.
- _____ 7. Electrical current can be induced in a conductor by passing a loop of wire through a _____ field.
- _____ 8. Causing electrons to flow through a circuit is _____ electrical energy.
- _____ 9. _____ are diodes made of special semiconductors which allow current to flow in only one direction.
- _____ 10. Transistors combine several semiconductors that act as _____ under certain conditions.
- _____ 11. A(n) _____ circuit occurs when the electrons find an unintentional path to return to the source before going through all or part of the loads in the circuit.

TRUE OR FALSE Circle "T" if the statement is more true than false. Circle "F" if the statement is more false than true.

- T F 12. Direct current (D.C.) is electrical current that flows in one direction.
- T F 13. Insulators readily allow electrical current to flow through them.
- T F 14. Amperage is the rate of electrical current flow through a wire or conductor per minute.
- T F 15. Series circuits have loads connected so that current can flow along only one path.
- T F 16. Storage batteries generate alternating current through the use of chemical energy.
- T F 17. LCDs are diodes that absorb light as current is applied.
- T F 18. The direct current used in electronic circuits is measured in milliohms.
- T F 19. As little as 10 milliamperes of current can contract and paralyze muscles.
- T F 20. The **UL** symbol on a product means it has met safety standards set up by the National Board of Fire Underwriters.

SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph. (Use additional paper when needed.)

21. Name four primary uses of electricity.
22. Describe a thermocouple and explain what it does.
23. State the formula for Ohm's Law.
24. Which metal is actually the best conductor of electricity but is only used in special electronic circuits because of the expense?
25. Name the process and brief explain how a generator produces electrical current?
26. What can affect the total ohms of resistance in a circuit?
27. What should you do if someone is receiving an electrical shock?

MATCHING: Match the letter of the option in the right-hand column with the term in the left-hand column it best matches.

_____ 28. Electricity	_____ 29. Electrical circuit
_____ 30. Photocell	_____ 31. Integrated electronic circuit
_____ 32. Ground fault circuit interrupter (GFCI)	
- a. A small silicon semiconductor with microscopic circuit patterns etched on it.
 - b. The flow of electrons from one atom to the next along a conductor.
 - c. A device designed to protect humans and animals from electrical shock by detecting leakage of very low yet harmful levels of current.
 - d. The completed path for the flow or exchange of electrons.
 - e. Produces electricity through the use of elements which react with light and release electrons.

ADDITIONAL SKILLS AND ENHANCEMENT ACTIVITIES: Perform the following activities as assigned by your instructor.

1. Obtain a current copy of the NEC and review codes that apply to agricultural buildings.
2. Visit with a Medical Doctor or a licensed Emergency Medical Technician (EMT) for the latest practices and procedures to use when dealing with an electrical shock victim.
3. Contact the local power supply company and county governmental offices to determine what electrical codes apply in residential and rural agricultural areas.
4. Examine old or damaged computer chips, circuit boards, or other electronic devices with a magnifying glass or microscope. See if you can follow any of the mini-circuits.
5. Disassemble and inspect a generator and a motor. Compare the parts of each. Discuss how the basic principles and relationships of electricity, electromagnetic induction, and electromagnets are used to produce electrical current and how electrical current is used to produce magnetic fields to perform work.
6. Inspect different types of electrical and electronic sensors, monitors, controls, etc. With the help of your instructor, try to determine how each device operates. Use the different principles and relationships of electricity, electromagnetic induction, and electromagnets to explain how they operate.

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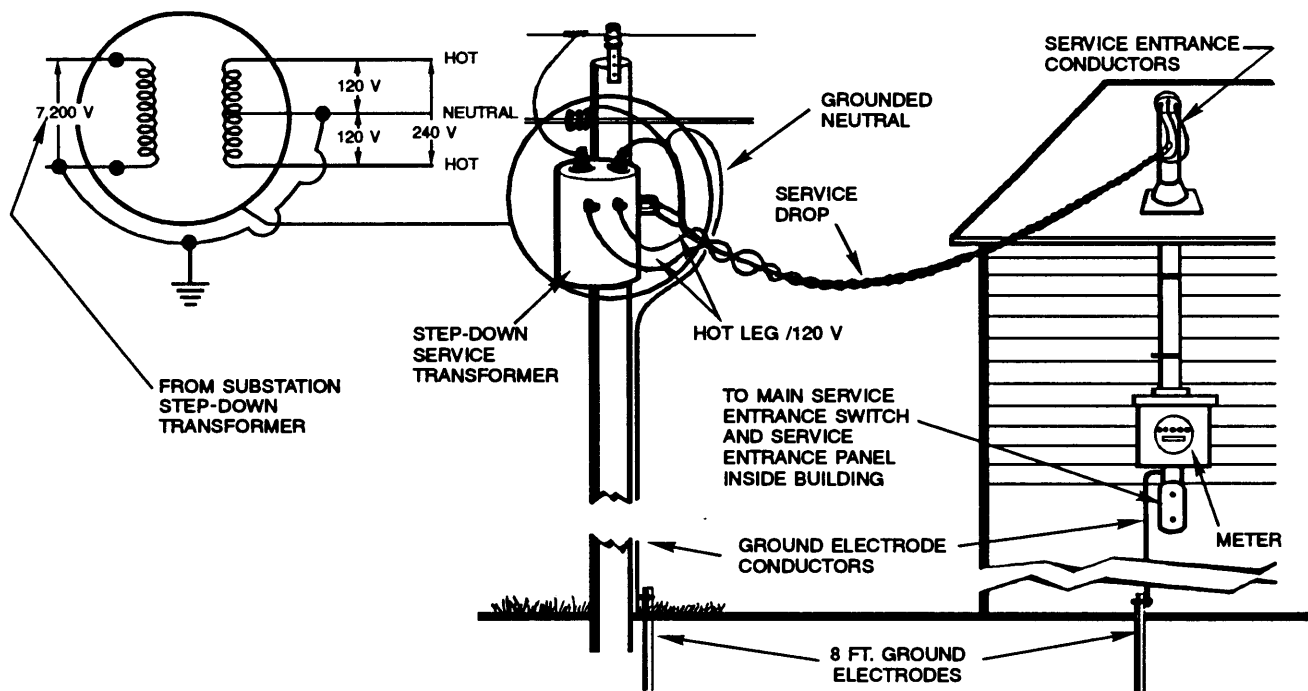
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PLANNING ELECTRICAL CIRCUITS

Proper planning and installation of electrical systems is crucial for safe and efficient use of electricity. According to recent reports, approximately 70 percent of all fire-loss insurance claims from agricultural businesses are caused by failures in the electrical system. Just because an electrical system "works" does not mean that it is safe.



Typical Service Transformer, Service Drop, and Service Entrance

THE A.C. SERVICE ENTRANCE AND SYSTEM GROUND

It is important to understand the basic operation of a 120/240 V A.C. service entrance and the system ground. For our discussion, the *source* may be considered the final step-down service transformer. This is the point the electricity we actually use is induced into the coils on secondary side of the transformer. The *source* of the induced electrical current in the distribution lines is actually the substation transformers located miles away.

The final **service step-down transformer** may be located at the top of a high-line pole or on the ground inside a large metal container. Most service transformers are equipped with two coils on the secondary side. Through magnetic induction, a 120 V alternating current is induced into each secondary coil.

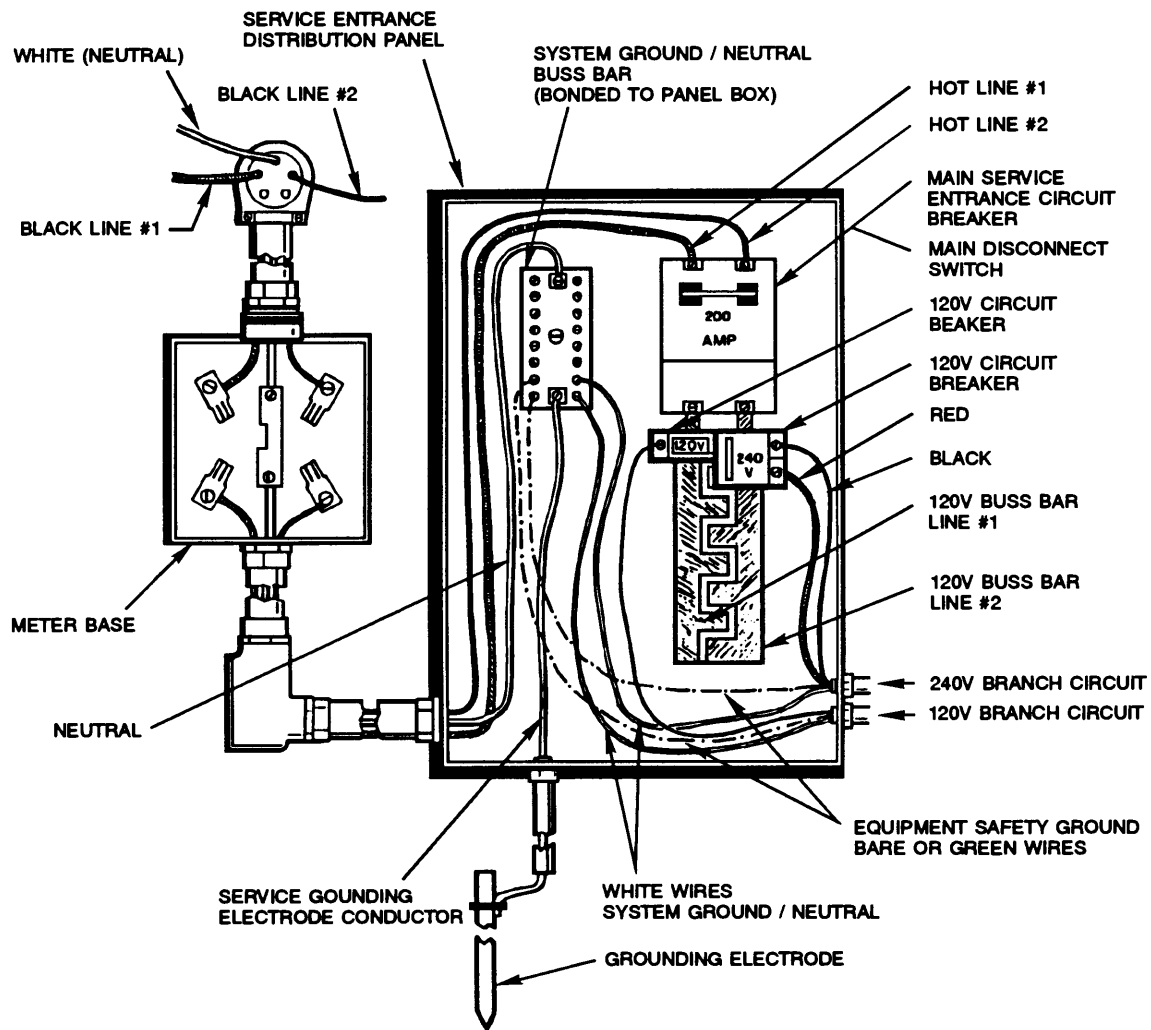
The induced alternating current leaves each coil through the source side or **hot wire**. The current actually stops, temporarily alternates direction, and starts 60 times in a second. However, for all practical purposes the flow is continuous. When the circuit is complete, 120 V of current flows through the hot wire to the loads and the **neutral wire** carries it back. Thus, in each circuit, 120 V is measured between each hot wire and the neutral wire. The neutral wire in the service transformer is large enough to serve as the return path for both of the 120 V circuits.

Both the hot and neutral wires are considered current carrying conductors when the 120 V circuit is complete. Hot wires are identified by the black or red coloring of the insulation. Neutral wires are identified by their white or gray colored insulation, or the bare wire on the service drop.

To produce a 240 V circuit, the hot wire from each 120 V coil in the service transformer is connected. The 120 V current from each circuit combines as it flows through the hot wires to form a 240 V circuit. The two - 120 V hot wires are referred to as **line #1** and **line #2** or **#1 leg** and **#2 leg**.

The large wires coming from the service transformer are called the **service drop**. The service drop wires are attached to **service-entrance wires** that are then connected to a **kilowatt-hour meter**. This allows the amount of electrical energy being used to be measured. The power supply company generally installs the service drop and provides the kilowatt-hour meter. The customer is generally responsible for the proper installation and maintenance of the service entrance, meter base and everything from the kilowatt-hour meter on.

A **service entrance switch** (also called a **main disconnect**) is installed directly after the kilowatt-hour meter. This is used to start and stop all current flow beyond that point. A **main service entrance overcurrent protection device** (a large fuse or circuit breaker for each leg) is installed after the main disconnect. It must have enough ampacity for all the current beyond the service entrance.



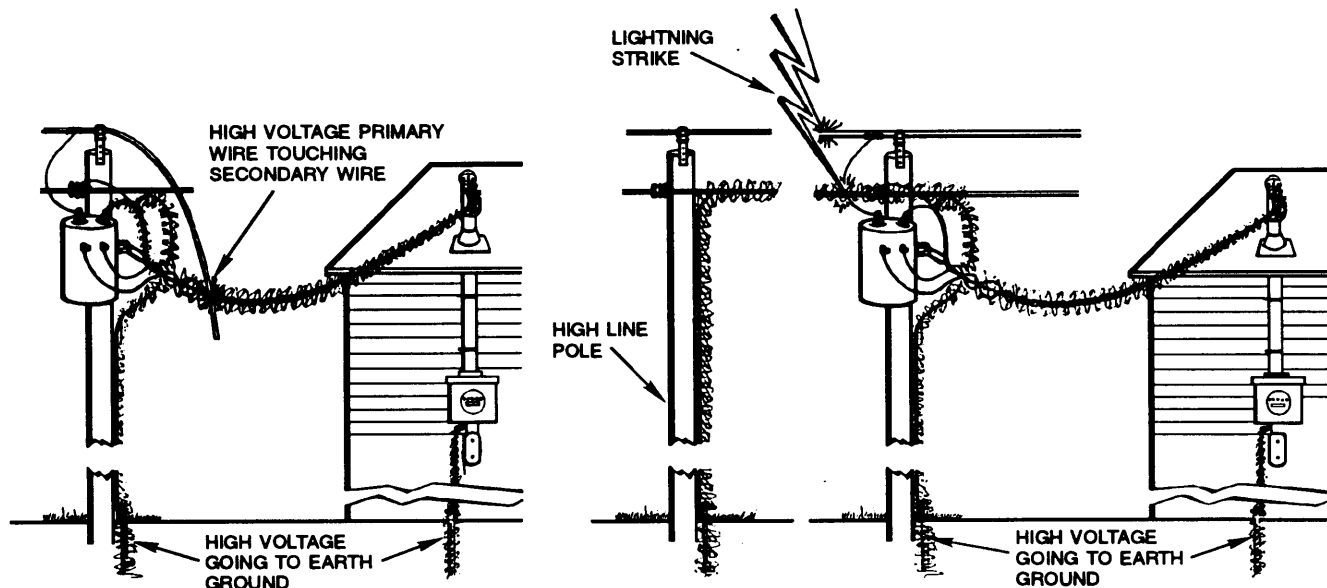
The main disconnect and the main overcurrent protection device may be installed in separate cabinets, or in one large cabinet called a **main service entrance distribution panel**. Service entrance distribution panels are available in standard sizes of 30, 60, 100, 125, 150, 200, and 400 amps.

Electrical power supply companies try to provide an actual 120 V through each leg of the service entrance transformer. Thus, the "nominal name" 120/240 V service. However, the actual voltage will vary from approximately 110 V to slightly over 120 V in each leg, or 220 to 240 V between the two legs. This depends upon the voltage drop in the distribution lines, resistance in the step-down transformers, and voltage drop in the branch circuits. A minimum of 110/230 V should be available at the furthest outlet or appliance. The NEC and most electrical equipment manufacturers use an average of 115 V and 230 V. This provides a margin of safety when designing and rating equipment and calculating wire sizes.

Electrical current will always travel from where it is back to its source if given a completed circuit to follow. This return path is normally considered to be the **neutral wire** in the circuit. A **ground** is an electrical connection to the earth. The moisture in the soil will also carry electrical current and provide a current return path back to the source under certain conditions. For safety, the NEC specifies that the neutral wire of the service entrance be connected to the **earth ground** at 1) the service step-down transformer and 2) at the service entrance panel.

Thus, the neutral wire on the secondary side of the service transformer becomes known as the **system ground/neutral**. Some references may also refer to it as the **system grounded conductor**, **system ground**, or **grounded neutral**.

Grounding electrodes or rods are commonly used to make electrical contact with the earth ground. Grounding rods are generally eight-foot long, copper-plated steel rods. They are driven into the earth near the service entrance panel and near the service entrance transformer. In most conditions, the rods are long enough to reach moist soil. They must be installed to NEC recommendations and protected from physical damage. The **grounding rod conductor** is the large solid copper wire that connects the **neutral buss bar** of the service entrance panel to the grounding rod.



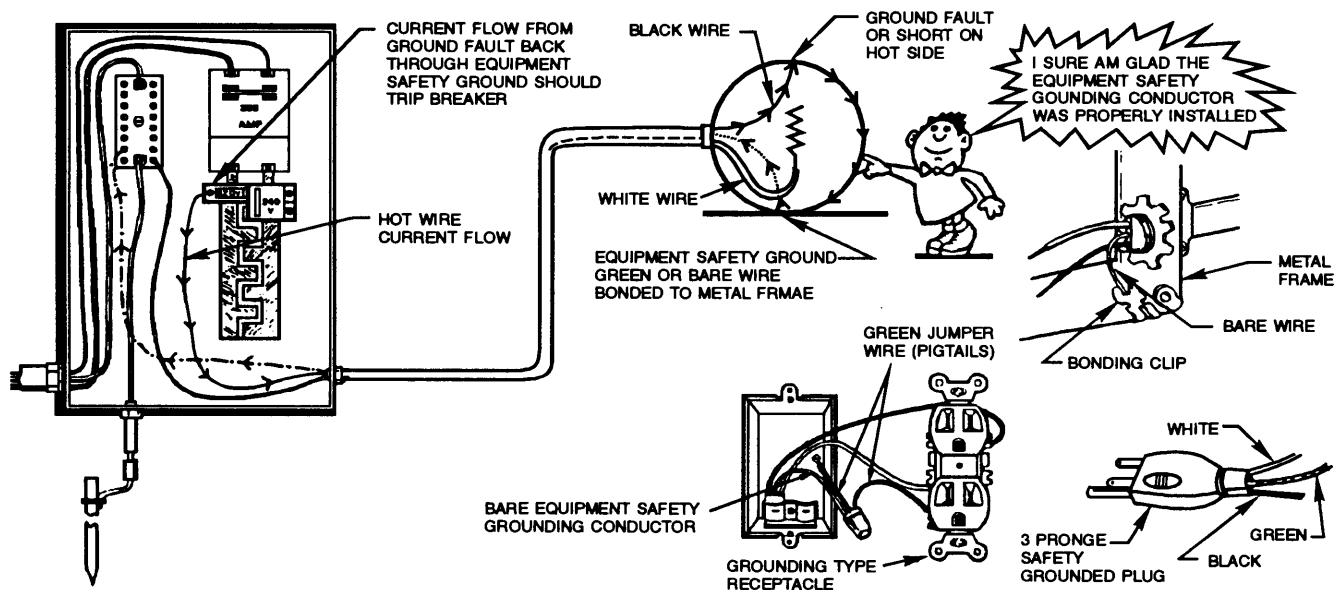
The purpose of grounding the system neutral to the earth is to 1) prevent high voltage from entering in the wiring system should the primary side wire accidentally touch a secondary side wire at or near a service transformer, 2) help limit high voltage from being induced into the secondary side of the service transformer should lightning strike the distribution line, and 3) to assist in the blowing or tripping of a fuse or circuit breaker if an electrical fault occurs in the secondary side wiring. If you damage a grounding rod or conductor, or observe one that has been damaged, contact the power supply company or an electrician immediately.

Electricity follows the shortest path of least resistance back to the source. A **ground fault** is an accidental connection of a normal circuit wire to the earth, or to any conductor that is connected to the earth. In other words, current is "leaking" from the circuit because of faulty insulation, or damaged or improperly used electrical equipment to the earth following a path *other* than the planned system ground/neutral.

Current can be leaking 1) from the hot side of the circuit, 2) from within the load itself, or 3) from the system ground/neutral side. When current is leaking, anything that comes in contact with the ground fault, such as metal equipment frames, motor housings, metallic junction boxes, or any material that will conduct electrical current, may become electrically charged.

A human or animal body has a fairly low resistance to current flow. If a person or animal should touch any object that has become electrically charged because of a ground fault, **and** that person or animal is touching an earth ground or a conductor that is connected to the earth ground -- the person or animal can receive an electrical shock.

An **equipment safety grounding conductor** is the bare copper wire or the wire with green-colored insulation that connects and bonds all metal frames, junction boxes, equipment cabinets, and portable tool frames together that are not normally intended to carry current. This wire is permitted to be connected to the earth only at the main service entrance neutral buss bar through the grounding conductor. The purpose of the equipment safety grounding conductor is to provide a low resistance alternative path directly back to the system ground/neutral buss bar at the service entrance. Thus, it helps to prevent accidental shock of humans or animals should any part of the metal frame or equipment become electrically charged.

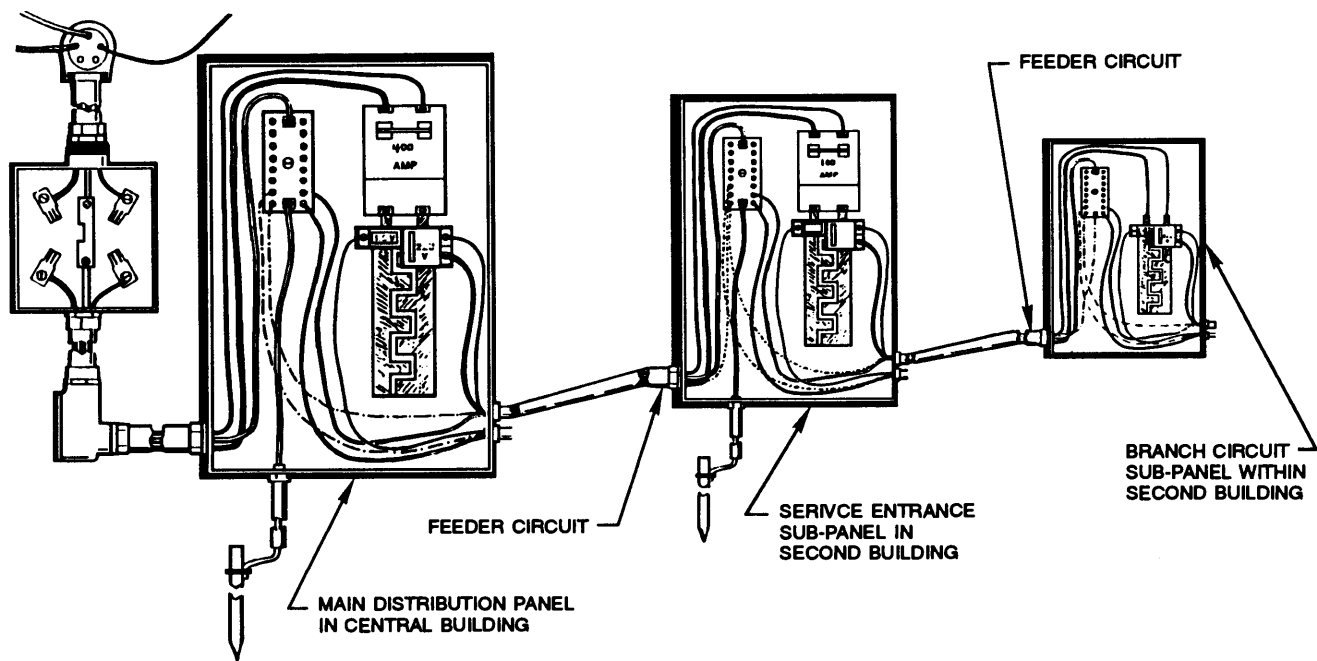


The equipment safety grounding conductors are connected to 1) the "third" or "round" prong and sockets in 120 V power cords and receptacles, 2) the green hex-shaped screws on electrical fixtures, and 3) to metal frames of electrical equipment and metallic junction boxes with special bonding clamps.

At one time, the NEC allowed continuous metal conduit that connected all electrical equipment and metal junction boxes back to the main service entrance panel box to serve as the equipment safety grounding conductor when installed in agricultural applications. However, this code has been changed. Even when continuous metal conduit is installed for physical protection of wiring, an equipment safety grounding conductor wire must still be included. Under normal conditions, there should be no current flowing through the equipment safety ground conductor.

FEEDER CIRCUITS

Feeder circuits are used to supply current from the main service entrance panel to other buildings or sites. The feeder circuits to other buildings or sites may be installed overhead or underground. Feeder circuits can also be used within the same building as the main service entrance to supply higher amperage service to a concentrated area before it branches out into the smaller branch circuits.



When feeder circuits are used for separate buildings or sites, an additional **service entrance subpanel** must be installed before connecting the branch circuits. The subpanel must also be equipped with a main service entrance switch and an overcurrent protection device for all electrical service beyond that point. When feeder circuits are used within the same building, a **branch circuit subpanel** must be installed.

BRANCH CIRCUITS

Electrical circuits "branch off" from the main distribution panel or feeder circuit subpanels to supply lower amperage current through smaller wires to convenience outlets or receptacles, lights, motors, etc. A **branch circuit** is described as a circuit that extends beyond the last overcurrent protection device (fuse or circuit breaker). Each branch circuit must have an overcurrent protection device sized for the maximum amperage load it is designed to carry.

Branch circuits are classified by their planned use and their current-carrying capacity. There are three general types of branch circuits used in most residential and agricultural wiring: 1) lighting, 2) general purpose, and 3) special purpose or appliance.

Lighting circuits are generally 120 V and are designed at either 15 A or 20 A. The NEC allows #14 AWG (American Wire Gauge) wire to be used for some 15 A lighting circuits. However, #12 is normally recommended especially if there is any excessive voltage drop. Number 12 wire is required on all 20 A lighting circuits. Up to 10 - 150 W light fixtures may be installed on one 20 A lighting circuit.

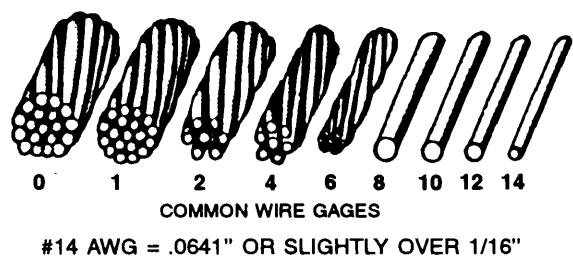
General purpose circuits are 120 V and are wired for a maximum of 20 A. This allows a combined peak load of 2,300 W for all the equipment operating on the circuit at any one time ($115 \text{ V} \times 20 \text{ A} = 2,300 \text{ W}$). General purpose circuits are designed for a combination of lights and receptacles. Receptacles are capable of supplying electrical power for 1/3 Hp or smaller electric motors, portable electric heaters of 1,500 W or less, and portable tools and equipment that operate at 15 A or less. Up to 10 receptacles can be installed on one general purpose circuit. Some general purpose branch circuits may have up to five receptacles and 5 - 150 W light fixtures if individual loads do not exceed 1.5 A each.

Special purpose individual circuits are designed to supply current to individual pieces of equipment. Special purpose circuits may be either 120 or 240 V. They are used for 1) 1/2 Hp or larger motors, 2) individual pieces of equipment rated at 20 A or higher, 3) stationary equipment rated over 1,500 W, 4) equipment that requires continuous service, such as water systems, 5) all 240 V equipment, and 6) individual equipment regularly operated for several hours at a time at a current load that would exceed 50 percent of a general purpose circuit amperage rating.

Approximately one-half of the 120 V branch circuits that will be operating at one time should be attached to one 120 V leg and the other half to the other 120 V leg. This is called **balancing the load**.

SELECTING CONDUCTOR (WIRE) SIZES

When planning the electrical system, wire sizes and equipment amperage and voltage ratings should be selected according to NEC and/or local code requirements. Common AWG sizes used in agricultural applications range from #14 to #0. Voltage drop should



not exceed three percent for exterior wiring, and two percent for interior wiring. NEC recommendations limit the combined voltage drop from the service entrance to the most distant load to less than five percent.

The wiring and equipment in the system should have sufficient amperage ratings to properly handle present loads. However when planning, some consideration should be given to making allowances for future expansion. It may be more economical to install larger wiring, and additional branch circuits now rather than rewire the system later. To select the proper wire size for a branch circuit:

1. Determine the maximum amperage that the wire has to carry. Increase this figure by 25 percent if the circuit will carry a full-demand load for more than 15 minutes at a time, or if an electric motor is to be installed. This is because some types of electrical equipment, such as motors, temporarily pull extra amperage load during startup.
2. Determine the actual length of run for the wiring (one-way).
3. Select the appropriate table from an Agricultural Wiring Handbook that covers the correct wire type (copper or aluminum), correct voltage, insulation type, and voltage drop allowance.
4. On the left side of the table, locate the row for amperage load needed. Locate the vertical column for the type of insulation to be used. Note the wire size where this column and the amperage row intersect. Move to the right side of the table and select the column for the length of run needed. Follow this column down until it intersects with the proper amperage load row. Compare this wire size to the size first noted on the left side of the table and select the larger (smaller AWG #). When the amperage load and/or length of run needed falls between two choices, always select the larger.

MINIMUM ALLOWABLE SIZE OF CONDUCTOR										COPPER UP TO 200 AMPERES, 115-120 VOLTS, SINGLE PHASE BASED ON 2% VOLTAGE DROP																		
										LENGTH OF RUN IN FEET																		
LOAD IN AMPS	IN AIR CABLE OR CONDUIT				DIRECT BERRIAL		OVERHEAD IN AIR*			COMPARES SIZE SHOWN BELOW WITH SIZE SHOWN TO LEFT OR DOUBLE LINE.																		
	UF**	RH, RW, THW, THWN, USE	SE	THHR	UF**	USE	SINGLE	TRIPLES		USE THE LARGER SIZE																		
5	14	14	14	14	14	14	10	8		30	40	50	(80)	75	100	125	150	175	200	225	250	275	300	350	400			
7	14	14	14	14	14	14	10	8		14	14	14	14	14	12	12	10	10	10	10	8	8	8	8	6	6	6	6
10	14	14	14	14	14	14	10	8		14	14	12	12	10	10	8	8	8	6	6	6	6	4	4	4	4	4	4
15	14	14	14	14	14	14	10	8		12	12	10	10	10	8	6	6	6	4	4	4	4	4	4	3	2	2	2
(20)	12	(12)	12	12	12	12	10	8		12	10	10	(8)	8	6	6	4	4	4	4	3	3	2	2	1	1	1	1
25	10	10	10	10	10	10	10	8		10	10	8	8	6	6	4	4	4	3	3	2	2	1	1	1	0	0	0
30	10	10	10	10	10	10	10	8		10	8	8	8	6	4	4	4	3	2	2	1	1	1	0	0	00	00	00
35	8	8	8	8	8	8	8	8		10	8	8	6	6	4	4	3	2	2	1	1	0	0	00	00	00	00	00
40	8	8	8	8	8	8	8	8		8	8	6	6	4	4	3	2	2	1	1	0	0	00	00	00	00	00	00

ADAPTED FROM AGRICULTURAL WIRING HANDBOOK, NATIONAL FOOD AND ENERGY COUNCIL

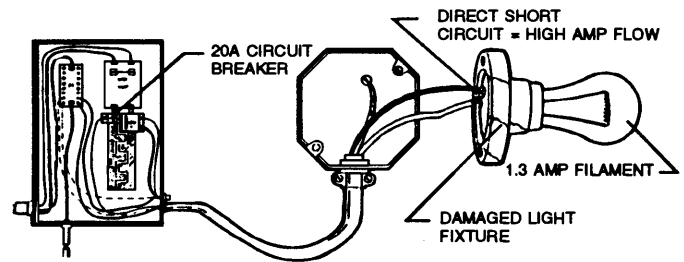
If the same 1-Hp motor is wired to operate at 240 V, it only pulls 8 A to provide the same power ($120\text{ V} \times 16\text{ A} = 1,920\text{ W}$ or $240\text{ V} \times 8\text{ A} = 1,920\text{ W}$). To allow for the 25 percent increase for a motor circuit, 10 ampacity wiring is needed ($8\text{ A} \times 125\% = 10\text{ A}$). According to both sides of the table, #14 AWG wiring could be used. However, if any future expansion of the business required a larger motor, installing #12 wire would allow up to a 20 A load at 240 V.

MINIMUM ALLOWABLE SIZE OF CONDUCTOR							COPPER UP TO 400 AMPERES, 230-240 VOLTS, SINGLE PHASE BASED ON 2% VOLTAGE DROP																
LOAD IN AMPS	IN AIR CABLE OR CONDUIT			DIRECT BURIAL		OVERHEAD IN AIR*		LENGTH OF RUN IN FEET															
	UF**	RH, RHW, THW, THWN, USE, NM SE	THHR	UF**	USE	SINGLE	TRIPLES	COMPARE SIZES SHOWN BELOW WITH SIZE SHOWN TO LEFT OR DOUBLE LINE. USE THE LARGER SIZE															
5	14	14	14	14	14	10	8	50	60	75	100	125	150	175	200	225	250	275	300	350	400		
7	14	14	14	14	14	10	8	14	14	14	14	14	14	14	12	12	12	12	10	10	10		
10	14	14	14	14	14	10	8	14	14	14	14	14	14	12	12	12	10	10	10	8	8		
15	14	14	14	14	14	10	8	14	14	14	12	12	10	10	10	10	8	8	8	8	6		
20	12	12	12	12	12	10	8	14	12	12	10	10	10	8	8	8	6	6	6	6	4		
25	10	10	10	10	10	10	8	12	10	10	8	8	6	6	6	6	4	4	4	4	3		
30	10	10	10	10	10	10	8	10	10	10	8	6	6	6	4	4	4	4	4	3	2		
35	8	8	8	8	8	8	8	10	10	8	8	6	6	4	4	4	4	3	3	2	2		

250

CIRCUIT PROTECTION AND CONTROL DEVICES

Overcurrent circuit protection devices are considered the safety "weak links" in the circuits. They are designed to limit the amperage that can flow through the wiring to a safe specified level. Circuits must be protected against both short circuits and overloads. A **short circuit** is the accidental connection between two wires or parts of a circuit that instantly decreases the total resistance and allows excessive current to flow.



A Short Circuit

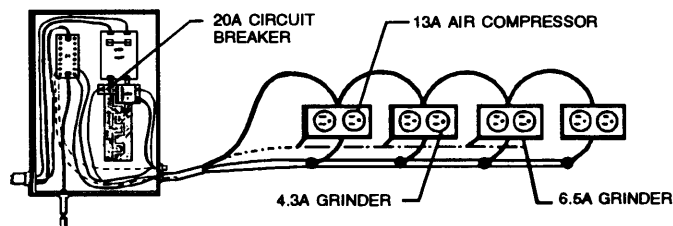
For example: In a 20 A branch circuit, electrical current flows from the hot wire, through the element inside a light bulb, and back to the source through the system ground/neutral. A typical 150 W bulb allows only 1.3 A of current to flow through the high resistance element ($150\text{ W} \div 115\text{ V} = 1.3\text{ A}$). The 1.3 A of current could continuously flow through the rest of the circuit with no problems of overheating.

Suppose the light fixture is suddenly damaged and the hot and neutral wires touch allowing the current to bypass the light bulb. An arc or spark will occur when the two wires touch. Remember, volts divided by ohms equals amps. Copper wire has a low resistance, which is usually less than one ohm. There is now little resistance in the circuit to limit current flow.

In theory, 115 or more amps of electricity could instantly try to flow through the #12, wire which only has a 20 A capacity. This is assuming 1 ohm or less resistance in the accidentally shorted circuit ($115\text{ V} \div 1\text{ ohm} = 115\text{ A}$). The excessive current flow will cause the wire to instantly overheat and the insulation to melt or burn. This could possibly shock someone and/or start a fire.

An **overload** occurs when too much current tries to flow through a wire to meet the needs of all the electrical equipment being operated at one time. The current is normally following the intended path through the circuit, but is much higher than the designed ampacity.

For example: Consider a 20 A branch circuit with four receptacles wired with #12 copper wire. An air compressor motor rated at 13 A is plugged into one receptacle and is used continuously. A grinder rated at 4.3 A is being used on the same circuit. Another grinder rated at 6.5



An Overload on a 20 A Branch Circuit

A is plugged into the same branch circuit. When only the compressor and first grinder were operated, the amperage load is within the limits ($13.0 + 4.3 = 17.3$ A). When all three power tools are used at once, the total amp load exceeded the 20 A capacity by 3.8 A ($13.0 + 4.3 + 6.5 = 23.8$ A 23.8 A - 20 A = 3.8 A overload). A slight overload may not cause the wires to instantly overheat and melt insulation as a short circuit will. However damage will gradually occur. The higher the overload, the more the current flow; thus, the faster the heat buildup.

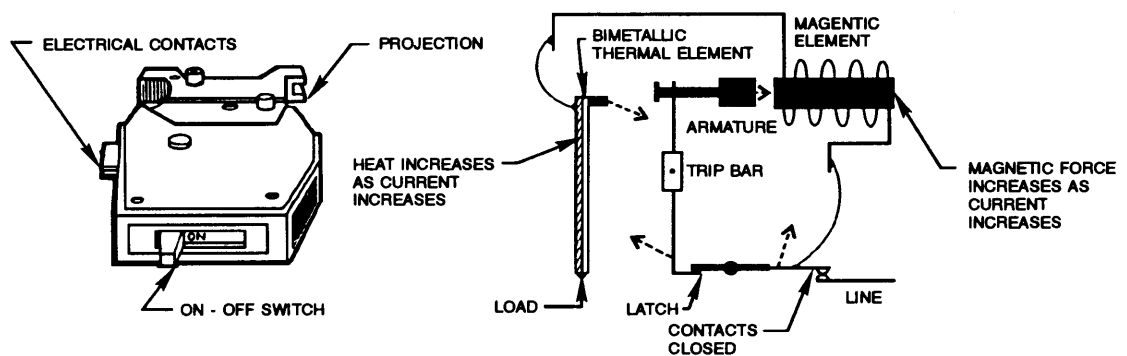
All wires in a circuit must be protected according to their ampacity. **For example:** The #0 copper wires installed in a service entrance have an ampacity rating of 150 A. This means they can carry a combined load of 150 A for the branch circuits that are operating at the same time before they begin to overheat. A main service entrance overcurrent protection device rated at 150 A should be installed to limit the total current flow through the service entrance to that amount.

The overcurrent protection device for an individual branch circuit protects only that circuit. Number 12 copper wire has a maximum ampacity rating of 20 A. When an individual branch circuit is wired with #12 copper wire, it must be protected with an overcurrent protection device that is set to open when current flow exceeds 20 A.

It is important that properly rated overcurrent protection devices be installed at both the service entrance and for the individual branch circuits. From the examples above, note that the possible 115 A flow from the short circuit would not be enough to trip the main service entrance circuit breaker rated at 150 A. However, it would immediately trip the individual 20 A branch circuit breaker.

Some types of equipment, such as motors, temporarily pull an extra amperage load during start-up. This can cause a temporary circuit overload for several seconds. For this reason, a certain amount of **time-delay** must be designed into overcurrent protection devices used with motors, yet still provide protection for an instant short circuit.

A **circuit breaker** is an overcurrent protection device that trips automatically when an overload or short circuit occurs. **Thermal circuit breakers** have two contacts held together by a spring-loaded latch. As a short circuit or overload occurs, the bi-metallic strip slowly overheats, bends, and trips the latch to open the circuit.



Typical Thermal/Magnetic Circuit Breaker

Magnetic circuit breakers are equipped with an electromagnet. As the current flow through the electromagnet increases, the magnetic pull increases. When current flow exceeds the rated capacity because of an overload or short circuit, the stronger magnetic pull will instantly trip the latch and open the contact points.

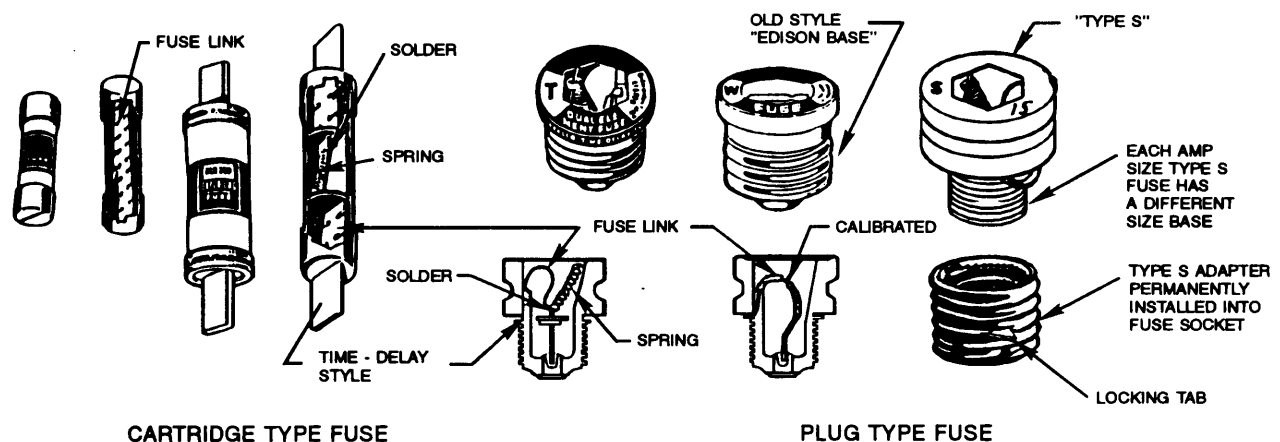
A circuit breaker also provides a switch to disconnect the circuit for service or repair. Some circuit breakers are equipped with both a slower acting bi-metallic strip for protection against occasional overloads, and an electromagnet that instantly trips should a direct short circuit occur. A circuit breaker can be reset when the problem in the circuit is corrected and the bi-metallic strip has cooled.

A **fuse** is a broad name for an overcurrent protective device that contains a "fuse link." The fuse link is made of a mixture of **lead** and **tin** called **solder**. The fuse link has a very low melting point. When a short circuit or overload occurs, the heat from the excess current flow will quickly melt the fuse link and open the circuit. Fuse links are calibrated to carry a specific amperage load before they will melt.

There are two basic types of fuses: **plug type** and **cartridge type**. Plug type fuses screw into sockets, while cartridge fuses snap or slide into the fuse holder. All older style "**Edison base**" plug fuses have the same size base. **For example:** This has allowed a 20 or 30 A fuse to be installed where only a 15 A fuse was needed. This created a very unsafe condition. According to the NEC, Edison base fuses are now permitted only as replacements and should not be installed in any new construction.

New tamper resistant "**Type S**" plug fuses are available up to a 30 A capacity. Each amperage range has a different size thread base and adapter. **For example:** A 15 A size adapter should be permanently installed in the fuse socket for a 15 A branch circuit. Thus, only a 15 A or lower Type S plug fuse can be installed.

Cartridge type fuses are available with ferrule or knife blade style ends. Newer cartridge type fuse panels and fuses are also tamper resistant. Different amperage capacity fuses are different sizes physically and can not be interchanged.



Some fuses have a time-delay feature built in. One end of the fuse link is attached to a solder cup. A small spring constantly pulls on the fuse link. If a sudden short circuit occurs, the fuse link will instantly melt to open the circuit. As an overload occurs, the solder cup will heat and slowly soften. If the overload continues, the solder cup will continue to soften until the spring pulls the fuse link loose to open the circuit.

Overcurrent circuit protection devices should be installed only on the "hot side" of the circuit. In the case of 240 V circuits, an overcurrent protection device is installed in each 120 V line or leg.

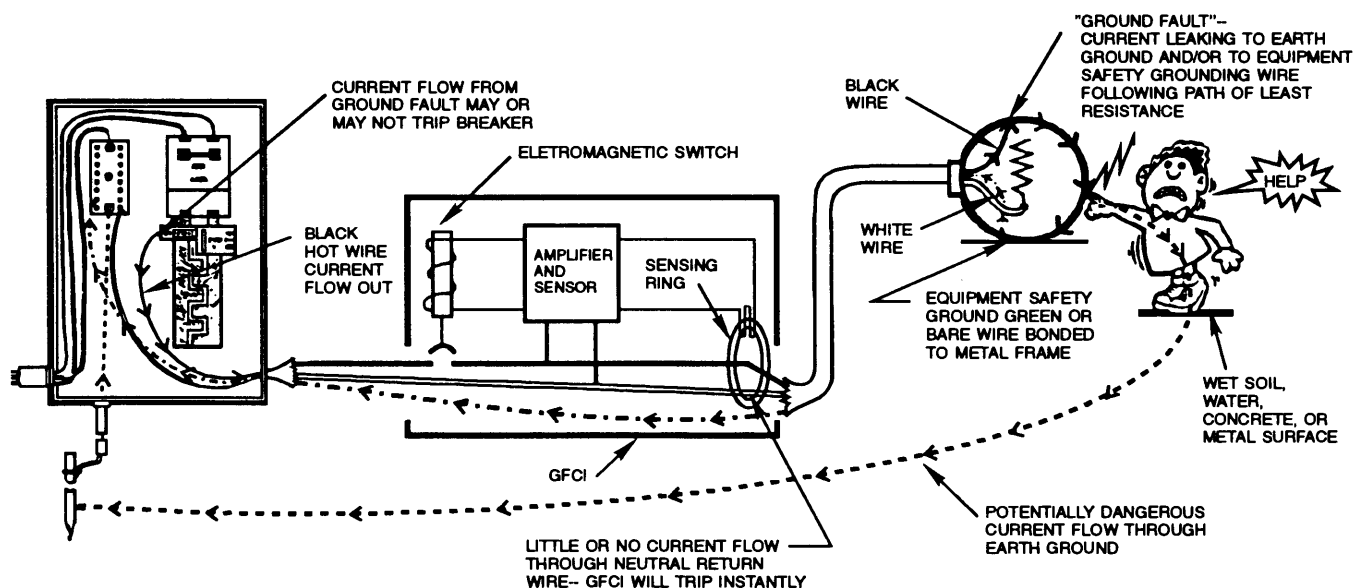
Refer back to the circuit overload example with the air compressor and hand grinders. This overload could be eliminated by not operating all the equipment at the same time. However, the next time all the equipment was operated at the same time, the problem would reoccur and the insulation and equipment would be further damaged. If it is necessary to operate all the equipment at the same time, an additional circuit must be used or installed.

Under no circumstances should a fuse or circuit breaker be installed in a circuit that has a higher amperage than the circuit wiring is designed to carry. When a fuse blows or a circuit breaker trips, something is wrong. The problem must be corrected.

GROUND FAULT CIRCUIT INTERRUPTERS

Ground-fault circuit interrupters (GFCIs) are designed to provide protection for people and animals against electrical shock caused by low levels of stray or leaking current especially in wet or damp areas. This protection **is in addition to** that provided by the equipment safety grounding conductor and the short circuit and overload protection provided by the fuse or circuit breaker.

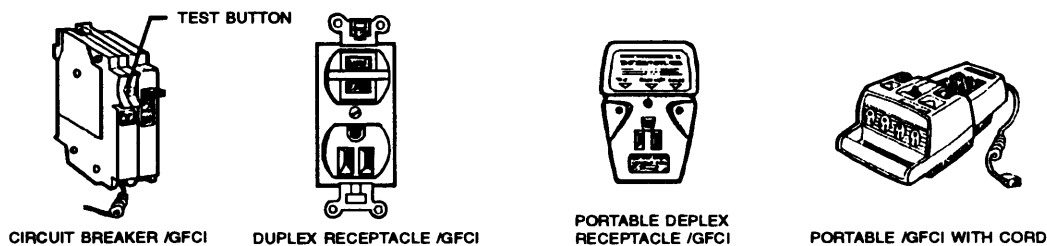
GFCIs are solid state electronic devices that constantly compare the current flowing out from the source through the hot wire of a circuit and that returning back through the system ground/neutral. They are equipped with a small sensing ring, amplifier, sensing device, and an electromagnetic switch.



Operation of a GFCI

A **ground fault** exists when 1) damaged insulation, 2) broken parts, or 3) improperly used electrical equipment in contact with wet surfaces allows current to "leak" from the normal circuit to ground. The leaking current may not be of high enough amperage to melt the fuse or trip the circuit breaker, but may be high enough to electrocute a person or animal. For safety, GFCIs are designed to trip automatically within 1/40th of a second if they sense more than 5 milliamperes difference in the current flowing out on the hot wire and that returning on the neutral.

For convenience, several types of GFCIs are available. The **circuit breaker/GFCI type** has the GFCI built directly into the circuit breaker. This type can be permanently installed in the distribution panel to protect the complete service entrance or individual branch circuits.



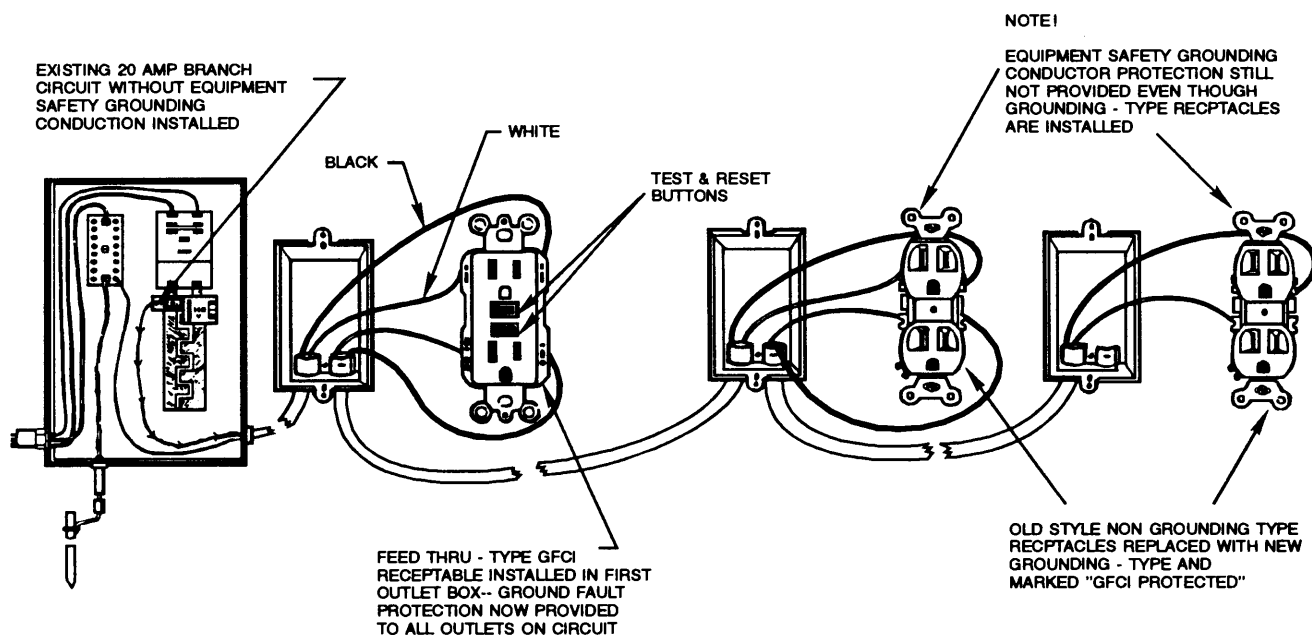
A **duplex receptacle GFCI** has the GFCI built into the receptacle. This type can be installed in regular outlet boxes in individual branch circuits. **Portable GFCIs** can be plugged directly into existing grounding-type duplex receptacles. This provides protection from tools and equipment plugged into the portable outlet. This type can be moved from one duplex receptacle to another as needed.

To ensure maximum protection, all GFCIs should be tested once a month. They are equipped with test and reset buttons. If the GFCI is operating properly, it should trip immediately when the test button is pushed and can be reset for normal operation.

ADDING GFCI PROTECTION TO OLDER BRANCH CIRCUITS

Many older branch circuits are not equipped with the equipment safety grounding conductor and grounding-type receptacles. Most new appliances, extension cords, or portable tools are now equipped with the equipment safety ground or are double insulated. Many people are tempted to cut off the third prong from plug-ins so they will "fit" old nongrounding receptacles. **This is not** a recommended practice. When practical, an equipment safety grounding conductor and new safety grounding-type receptacles should be added to upgrade the branch circuit.

When it is not practical or possible to add the safety grounding conductor, "article 210-7(d), exception" of the NEC now recommends a ground-fault circuit-interrupter-type receptacle be installed in place of the old style nongrounding receptacle. This will provide protection against shock from ground faults. It will also allow three prong cords to be used without the need for adapters even though the equipment safety grounding protection is not provided.



Installing a GFCI in an Old Branch Circuit

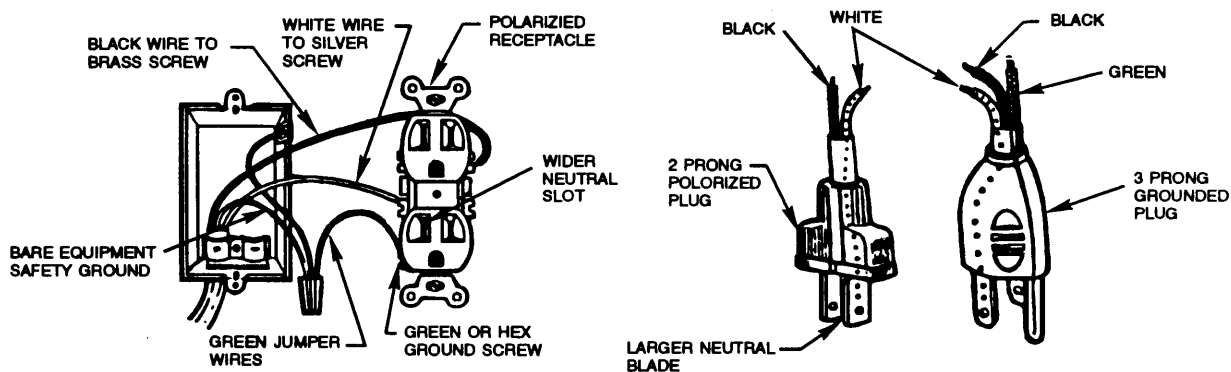
When a **feedthru-type ground-fault circuit-interrupter receptacle** is properly installed in the outlet box nearest the fuse or circuit breaker, GFCI protection can be provided to the rest of the outlets on the same circuit. The other old-style nongrounding receptacles in that same circuit must then be replaced with safety grounding-type receptacles and marked "***GFCI protected.***" Refer to the latest NEC and pamphlets included with the GFCIs for specific recommendations and installation procedures.

MAINTAINING POLARITY OF AN ELECTRICAL CIRCUIT

Polarity is the direction of current flow through a circuit. For proper operation and safety, the electrical system must be polarized. **Polarizing** a system is a method of using wires with specific colors of insulation for specific purposes. It also involves installing switches, circuit breakers, and other control devices in specific locations within the circuits and connecting specific colored wires to specific terminals.

The system ground/neutral (white or natural gray) wire is always connected to the silver colored screw or to the terminal, which is lighter in color. If there is no distinct difference in the color of the terminal screws, the letter "W" or "white" should appear beside the system ground/neutral terminal. Hot wires, which are red, black, or colors other than green or bare, should be connected to brass colored screws.

A bare or green colored equipment safety ground wire should never be used as either a system ground/neutral or a hot ungrounded conductor. The green colored or bare wires should be connected to the green colored-hex shaped terminal screws and/or bonded to metal boxes.



To Maintain Polarity, Wires Must be Connected to the Proper Terminals

New 120 V receptacle outlets now have one plug slot slightly larger than the other. To be wired properly, the white or gray system ground/neutral wire is connected to the silver colored screw, which is connected internally to the larger slot. Many attachment plugs on new two-wire cords for small appliances are also polarized. The neutral blade is slightly larger than the hot blade. It will plug into new style receptacle outlets only one-way.

If an electrical system has been properly installed and polarized, a person should be able to determine at a glance which wires *should be* hot, which *should be* neutral, and when current *should be* flowing through each. This is determined by 1) observing the color of the wires and 2) knowing the position of the various switches and control devices.

The NEC permits the following color code for circuits when individual wires are installed in conduit:

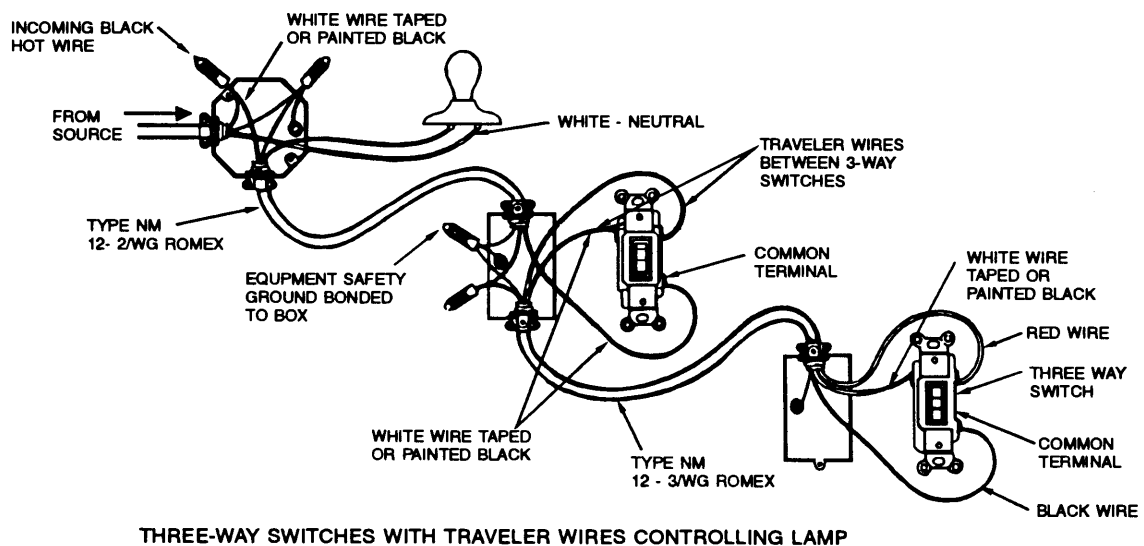
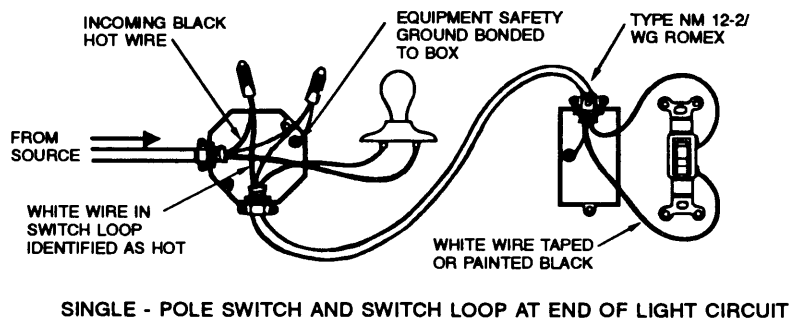
1. equipment safety grounding conductor = green, green with yellow stripes, or bare copper wire
2. system ground/neutral conductors = white or natural gray

3. hot/ungrounded conductors = black, red, or any color other than white, gray, or green

Although the white or gray colored wire is considered the neutral, ground, or return wire, **it is** carrying electrical current when the circuit is complete. It **must** be treated with the same respect as the hot wire.

When branch circuits are installed using cables instead of single wires in a conduit, it is not always possible to follow this color code. **For example:** "Type NM 12-2/WG" contains a black, white, and a bare or green wire. "Type NM 12-3/WG" contains a black, red, white, and a bare or green wire.

When cable is used, NEC allows the hot ungrounded conductor to be black, red, or any color other than green or bare. Under this part of the code, a hot wire can be white, but **only** under specific situations and only if identified. Examples of a **switch loop** and **traveler wires** used in light switch circuits are shown in the illustrations. The wires connected between two 3-way switches and between the 3-way and 4-way switches are called traveler wires.



Examples of Using the White Wire in a Cable for a Switch Loop or Traveler Wire

The first rule of thumb to remember is the neutral wire is always white or gray, but the white or gray wire is not always neutral. The following rules apply when using a white or gray colored wire in a cable for a hot ungrounded conductor:

1. Where visible in a junction box, the white or gray wire used as a hot ungrounded conductor should be painted or covered with tape in a color other than white, gray, or green.
2. A white or gray wire in a cable connected to a switch is considered to be a hot wire and should be marked with tape or paint.
3. If a white or gray wire in a cable is spliced to a wire of a color other than white, gray, or green in a switch loop, the white or gray wire is considered to be a hot wire and should be marked with tape or paint.
4. In a switch loop, the wire from the switch to the lamp should not be white or gray. However, if a white or gray wire to the lamp must be used, it must be identified as black or another acceptable color with tape or paint.

On some types of flexible cords and cable, the same colored rubber or thermoplastic insulation is used on all the individual wires. The individual wires are molded together side by side. During the manufacturing process, small ridges or grooves are molded into the insulation of one wire to properly identify it as the system ground/neutral.

For safety's sake, **do not** assume anything when working with electricity. Always use a test light, safety probe, or volt-ohm meter to verify the condition of an electrical system before touching, disconnecting, or connecting any wires. You may not be aware of who has previously worked on the system, if the wires were correctly connected, or what malfunctions or damage may have occurred. **Note !** The wire colors on the inside of appliances, motors, etc., are not required to follow the same color code patterns as building circuits. The NEC requires that a separate wiring diagram be included with motors and appliances to help identify internal wires.

OPERATING ENVIRONMENTS OF ELECTRICAL EQUIPMENT

The operating environment(s) in and around agricultural structures can be divided into four categories: 1) **dry**, 2) **damp or wet**, 3) **corrosive**, and 4) **dusty**. Different parts of the same structure may fall into two or more categories at the same time.

Moisture can cause major problems with electrical equipment in structures such as greenhouses and dairy barns. Moisture increases the chances of electrical shock and causes electrical equipment to deteriorate rapidly. Moisture from high humidity air can condense on or inside electrical equipment because of heating and cooling cycles. This can occur even when the equipment is not exposed to direct sources of water.

Animal waste in and around livestock confinement buildings produces ammonia. This combines with moisture to form a corrosive substance. **Corrosion** can damage wiring, contact points, and other types of electrical equipment. Many agricultural chemicals and fertilizers are also highly corrosive.

Many agricultural structures are normally considered to be **dry**. Others may be dry, but are also **dusty**. Dust and other fine particles of feed, hay, chemicals, etc., from processing or storage buildings can settle on and/or inside electrical equipment. These particles are often flammable and can be easily ignited from an electrical spark or by heat. The dust and other particles that settle can become soaked with water or absorb moisture from the air. This condition can form a "temporary conductor" that may create a potential short or ground.

Electrical equipment is often subject to physical damage from animals, rodents, machinery, etc. **Concealed wiring** means the majority of the wiring and equipment are installed in concealed areas such as between walls or behind permanent coverings. **Exposed or surface wiring** means most wiring, conduit, and other equipment are installed on outside surfaces. This is the most common type used in agricultural buildings because it saves time and money, and is often easier to install.

Article # 547 of the NEC lists the minimum recommendations for electrical systems installed in agricultural applications where these different operating environments are present. Both the owner and the persons installing or repairing the electrical system should be aware of these and/or other codes and follow them. As a public service, many power supply companies offer assistance in planning electrical systems. In addition, some provide periodic inspections to ensure the work is performed properly.

REFERENCES

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Surbrook, Truman C. & Mullin, Ray C., *Agricultural Electrification*, South-Western Publishing Co., Palo Alto, CA.

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Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the information in this topic. Mr. Greg Stark, Executive Director, Texas Agri-Business Electric Council provided technical assistance. Ms. Hannah Kerby, Graduate Assistant, Department of Agricultural Education, Texas A&M University, developed the student activities.

SUGGESTED STUDENT ACTIVITIES

FILL IN THE BLANK: Complete the following statements by inserting the correct word(s) in the blanks.

- _____ 1. A _____ must be installed directly after a kilowatt-hour meter to start and stop all current flow beyond that point.
- _____ 2. _____ are the most common means by which electrical contact is made with the earth ground.
- _____ 3. A(n) _____ occurs when too much current tries to pass through a wire to meet the needs of all the electrical equipment being operated at that time.

- _____ 4. A(n) _____ circuit is the accidental connection between two wires or parts of a circuit that instantly decreases the total resistance and allows excessive current to flow.
- _____ 5. Wires in a circuit must be protected according to their _____.
- _____ 6. A _____ is designed to trip automatically when an overload or short circuit occurs.

MATCHING: Match the letter of the description with the number of the term it fits best.

_____ 7. Hot wire	_____ 8. Neutral
_____ 9. Kilowatt-hour meter	_____ 10. Ground
_____ 11. System ground/neutral	_____ 12. Ground fault
_____ 13. Branch circuit	
_____ 14. Special purpose individual circuit	

- A. Neutral wire or conductor on the secondary side of the service transformer
- B. A circuit which extends beyond the last overcurrent protection device
- C. Source side of an AC circuit
- D. Measures the amount of electrical energy used
- E. An electrical connection to the earth
- F. Designed to supply current to individual pieces of equipment that require 20 A or more of current
- G. Return side of an AC circuit
- H. Accidental connection of a normal circuit to the earth or any conductor connected to the earth

SHORT ANSWER

15. Name the four categories for the environment in and around agricultural buildings that affect the type of electrical wiring and equipment that can be installed.

16. List and describe the different types of ground-fault circuit interrupters. Where can each be installed?
17. What do the following colors of wire signify?
 - a. green or bare?
 - b. red or black?
 - c. white or gray?
 - d. any color other than white, gray or green?

ADDITIONAL SKILLS AND ENHANCEMENT ACTIVITIES: Perform the following activities as assigned by your instructor.

1. Visit several agricultural businesses in your community. Determine the type(s) of operating environment that exist in and around different types of structures. Determine if the correct type of electrical wiring and equipment was used in each environment.
2. Contact your local power supply company. Invite a representative to visit your class to discuss electrical safety and proper planning procedures.
3. Use appropriate charts to determine the size of wiring needed for different sizes and types of branch circuits.

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N1993

INSTALLING AND REPAIRING ELECTRICAL CIRCUITS AND EQUIPMENT

A properly planned and installed electrical system should be 1) able to serve present loads, 2) safe for humans and animals, 3) reliable, 4) convenient, 5) economical, and 6) easily adaptable for future needs.

Many electrical systems are installed in agricultural buildings located in rural areas. At present, some rural areas, and/or land zoned for agricultural use may not fall under the jurisdiction of city and county electrical or building codes. Some people may feel that because official licensing and inspections are not required, it is OK to "cut corners" to save time and money. They may think, "it's just a barn"; "those receptacles will only be used once a month"; "it is an *interior-use-only* fixture, but rain should not blow under the eave"; or "it is not U_L approved, but it looks the same and costs less."

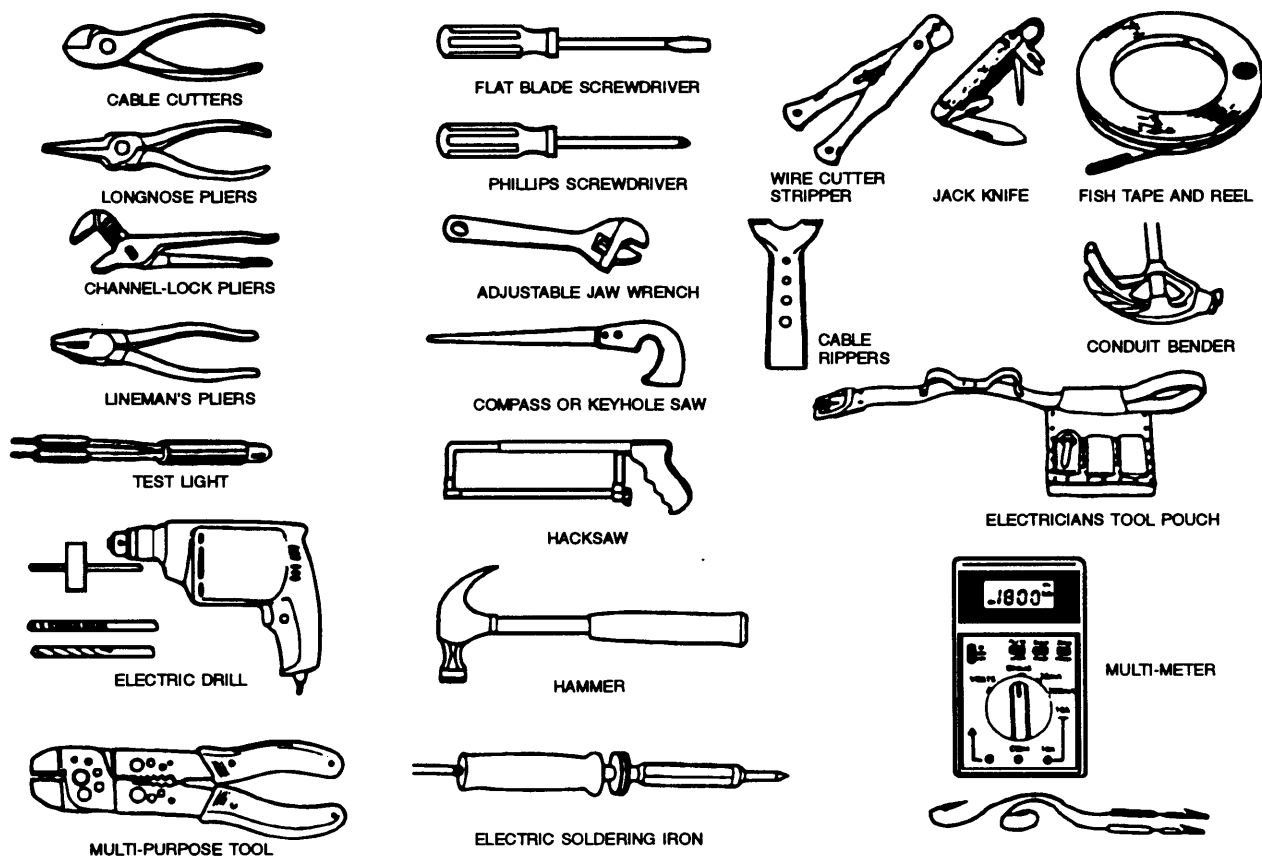
Electrical power is a modern convenience often taken for granted. It is hard to imagine life without it. An electrical system can be as safe or as dangerous as we make it. Electricity does not respect time, location, false economics, or excuses. It is capable of causing destruction of property, bodily injury, and/or death at any time or place when an unsafe condition exists.



Even if an electrical system is not subject to official inspection, it is recommended that it be installed and/or repaired according to the latest National Electrical Code (NEC). The NEC lists the **minimum recommended electrical standards**, not the maximum. These standards are offered in the interest of protecting lives and property. Anything less may create unsafe conditions. The NEC is updated every three years as technology changes and the use of electrical power in society broadens.

ELECTRICIAN'S TOOLS, EQUIPMENT AND SAFETY

It only takes a split second for an electrical shock to occur. The proper repair and installation of electrical circuits begins with the selection and safe use of the correct tools and equipment. The tools and equipment needed will vary from simple test probes, screwdrivers, claw hammers, jackknives, needle nose pliers, lineman's pliers, and adjustable wrenches; to conduit cutters and benders, multimeters, special purpose crimpers, wire strippers, multipurpose electrician's pliers, power tools, soldering equipment, fish tape, etc. It is recommended that student topic #s 8147-A, B, & C, and 8154-E, which discuss the selection and safe use of hand and power tools, be reviewed before proceeding with this topic.

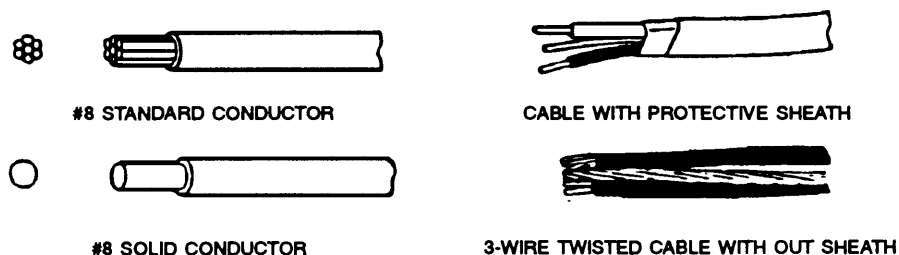


The rubber and plastic covered handles on most electrician's hand tools are not designed to allow a person to work on electrical circuits while the power is on. The specific adjustment and operating procedures for tools, electrical meters, etc., vary with the brand and/or model used. It is beyond the scope of this topic to cover the correct operation and use of each. Always consult the appropriate operator's manual and/or receive proper instruction from a knowledgeable person before attempting to use any tool or equipment.

A mistake some people make is to think the "hot wire is hot and the system ground/neutral is not." They think they can work with the white or gray wire at any time. This is incorrect. The white or gray system ground/neutral wire **is** a current carrying conductor. It is carrying current any time the circuit is complete. Use a circuit tester or multimeter to verify that the appropriate circuit breakers, fuses and/or disconnect switches are opened **before** attempting any repair or installation procedures.

TYPES OF ELECTRICAL CONDUCTORS OR WIRING

Individual electrical conductors may be **solid** or **stranded**. A solid conductor is made of one solid wire. A stranded conductor is made of several smaller solid wires stranded or wrapped together. A given size solid wire will have the same total cross-sectional surface area as the same given size stranded wire. Stranded wire is generally more flexible than the same size solid wire and is easier to bend and position. AWG # 10 is the largest size solid wire normally recommended for interior wiring.



A **cable** is generally considered an electrical wiring assembly that contains two or more individually insulated conductors wrapped together. The individual conductors within the cable may be solid or stranded. The cable may or may not have an additional protective covering or sheath over the outside of all the conductors.

Electrical conductors or wiring may be made of **aluminum** or **copper**. Aluminum wire is lighter in weight and is usually less expensive than copper. However, problems with using aluminum wiring include 1) heat buildup, 2) oxide formation, and 3) expansion and contraction, which causes loose connections.

Aluminum oxide forms on the outside of the wire creating a heat insulating barrier. This can allow heat generated from current flow to build-up internally within the wire. Aluminum expands approximately 40 percent faster than copper. Heat build-up causes the aluminum wire to expand. It can squeeze out from under the terminal screw or stretch the connector. When current flow stops or is reduced, the aluminum wire cools and shrinks. This can result in a loose connection. The loose connection may then arc when current flow is resumed or increased.

The use of #12, 10, or 8 AWG aluminum wire for interior circuits in enclosed areas is discouraged. Larger AWG aluminum wire is normally used only for outdoor overhead and/or underground service entrance or feeder circuits. This is because the heat can be more easily given off to the air or soil. Because aluminum is a poorer conductor of electrical current than copper, aluminum wiring must be one AWG size larger than copper to carry the same amperage load.

Newer **UL** approved **copper-clad aluminum wire** has a coating of copper on the outside of the aluminum wire. This minimizes the problem of the oxide formation. However, the problem of thermal expansion still exists. Copper-clad aluminum wiring is increasing in use for some home and agricultural branch circuits because it costs less.

When aluminum wiring is used, all terminals, fixtures, receptacles rated at 20 A or less must be marked "**CO/ALR**." CO/ALR indicates the device is approved for use with aluminum wires. All wiring devices and equipment rated at 20 A or less which are not marked CO/ALR are designed for use with copper or copper-clad aluminum wiring only.

All electrical equipment rated at 30 A or more that are marked "**AL-CU**" is designed for use with aluminum, copper, or copper-clad aluminum wiring. All exposed aluminum wire ends and terminals must be coated with a special oxide inhibitor to help reduce corrosion.

Electrical conductors or wires are also classified by the type of insulation and/or protective covering used. **Ampacity** is the current in amps a conductor can continuously carry under normal operating conditions without causing excessive voltage drop, overheating problems, or exceeding its temperature rating.

One of the factors that determines the ampacity rating of a particular wire is the type of insulation used and the temperature it can withstand. Insulation materials used for individual wires include rubber, thermo-plastics, and specially treated cloth or other fibers. Different insulation types are needed for the different operating environments.

Common types of individual insulated wire are **RH**, **RHW**, **THW**, and **THWN**. **Type RH** has a rubber insulation (R) that is heat-resistant (H) and is suitable for dry locations. **Type RHW** has rubber (R) insulation that is suitable for moist or wet conditions (W), in addition to being heat resistant (H). **Type THW** has thermoplastic insulation (T) and is moisture- (W) and heat-resistant (H). **Type THWN** has thermoplastic insulation (T) with a nylon jacket (N) and is moisture- (W) and heat-resistant (H). It is suitable for both dry or wet operating environments.

Aerial triplex is a cable with two individually insulated wires twisted around a bare wire. Aerial triplex is usually made of aluminum for outdoor overhead feeder circuits and service drops. The bare stranded aluminum wire in aerial triplex is called the **messenger** and is used for the system ground/neutral. The messenger usually contains one steel strand in the middle of the aluminum strands. The steel strand provides strength to support the cable overhead. When suspended from the proper insulators the required distance above ground, the messenger wire is not required to be covered with insulation. The other wires in aerial triplex cable are covered with **Type XHHW** insulation. It is a heat-, moisture-, and sunlight-resistant synthetic polymer plastic. **Quadruplex** cable contains three insulated wires and a bare messenger wire.

Service-entrance cable is a special purpose assembly with #12 or larger insulated wires. It is available with or without an additional outside protective sheathing. **Type SE** cable is designed primarily for use in service entrances. It has flame- and moisture-resistant insulation and sheathing. **Type USE triplex cable** has a moisture-resistant sheathing designed and identified for underground use. The wire inside the Type USE triplex cable designated as the system ground/neutral must be insulated. It must be white or gray, or have white markings along its entire length.

Underground feeder cable or Type UF has two or more insulated wires with an additional bare or green colored wire for the equipment safety ground. The outside sheathing is flame, moisture, fungus, and corrosion resistant. It is suitable for direct burial in the earth for feeder and branch circuits.



TYPE THWN SINGLE CONDUCTOR



TYPE SJO FLEXIBLE POWER CORD



TYPE NM "ROMEX" CABLE



TYPE SE SERVICE ENTRANCE CABLE



TYPE UF UNDER GROUND FEEDER CABLE



AERIAL ALUMINUM TRIPLEX CABLE

Nonmetallic-sheathed cable is often known by a common name **Romex**. It has two or more insulated wires wrapped together with an outer sheath of nonmetallic material. It may also contain a bare or green colored wire for use as the equipment safety ground. **Type NM** has a flame-retardant, moisture-resistant nonmetallic-sheathing. **Type NMC** is also fungus- and corrosion-resistant in addition to being flame and moisture-resistant.

Type NM "Romex" is an inexpensive cable used extensively for wiring branch circuits in residential homes and in other normally dry buildings. It is used for both exposed and concealed wiring. However, many people incorrectly use it in agricultural wiring. For agricultural use, Type NM is permitted only in indoor locations where there is always very low humidity. The NEC only recognizes **Types UF, NMC, SNM** and copper **SE** cables for use in agricultural buildings where dusty, damp, wet, and/or corrosive environments exist. Since most agricultural buildings will fall into at least one of these types of environments, Type NM cable can be correctly used in only very limited areas.

Flexible cord is a stranded cable with multiple wires. It is used as a power cord to connect appliances, lamps, portable equipment, etc., to receptacle outlets and to make extension cords. Flexible cord should not be used for permanent wiring in branch circuits. The type of insulation used on the individual conductors and for the outside protective sheathing varies with the intended use of the flexible cord.

Type C is a light-duty lamp cord that has a treated cotton braid around each wire with a thermoset plastic insulation covering. Its use is limited to small lamps installed in dry places. **Type STO** is a heavy flexible cord designed for use in "extra hard use" areas. It has a heavy thermoplastic covering that is oil-resistant.

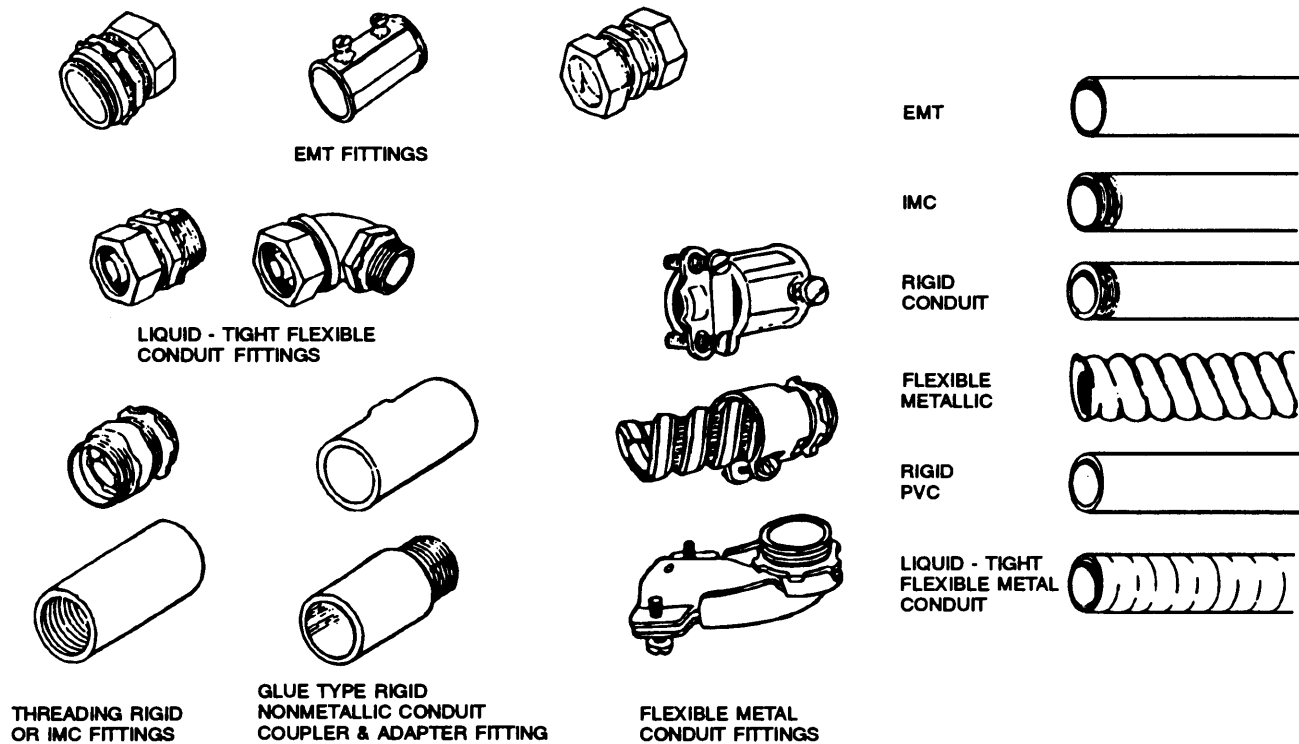
Individual wires, cables, and flexible cords are required to have the type code, voltage rating, and AWG size legibly shown along their entire length. Each wire in a cable or flexible cord assembly should have different colored insulation and/or other marks for identification purposes. On some types of cables and flexible cords, the insulation on each individual wire is the same color. The insulation for each wire is molded together to form one complete jacket. To identify the wire to use as the neutral/grounded conductor, small ridges or grooves are molded into the insulation on one of the wires.

Many types of wires, cables, and flexible cords are available for different applications. Some are manufactured to meet or exceed the requirements for several different codes. Always consult the latest NEC or electrical wiring handbooks for specific information on the types of wiring and the approved operating conditions of each.

TYPES OF CONDUIT

Different electrical codes may require individual wires or cables to be enclosed in conduit to provide physical protection and additional protection from moisture, dust, and/or corrosion. **Rigid metal conduit** is a thick-walled galvanized metal pipe with threaded ends and fittings. It is used to provide protection where severe physical damage may occur. It may be buried underground in noncorrosive soils or conditions. **Intermediate metallic conduit** or **IMC** is also a galvanized metal pipe with threaded ends and fittings. IMC has a slightly thinner wall than rigid metal conduit. Because of the lower cost, it is now used as a replacement for rigid metal conduit except where codes require protection from severe physical damage.

Electrical metallic tubing is even thinner walled than IMC. It is often called **EMT or thin-wall conduit**. It provides general physical protection for electrical wiring. Although galvanized, it is not permitted to be installed in extremely wet locations, or in corrosive environments. EMT is not threaded. It is connected with set-screw, indent, or compression type fittings. When used with compression type fittings, EMT may be water-resistant, but is not considered waterproof.



Flexible metal conduit is used to make flexible connections less than 6 feet long between stationary junction boxes and equipment that may vibrate or move slightly during operation. It is not permitted in damp or corrosive locations. Flexible metal conduit is jointed with compression fittings, but is not waterproof or dust-tight.

Rigid Nonmetallic Conduit is made of polyvinyl chloride (PVC). It is the ideal conduit for electrical wiring in many agricultural applications except where severe physical protection is required. When properly installed, it is corrosion-resistant, and waterproof and dust-tight. Schedule 40 PVC is thin-walled while schedule 80 is thicker and provides more physical protection. PVC conduit is not threaded. It is connected with special compression or glue-type fittings. **Note!** Electrical rated PVC conduit is not the same as the PVC pipe designed for plumbing. They are not interchangeable.

Liquid-tight flexible conduit may be metallic or nonmetallic. It has a liquid- and dust-tight outer protective covering. It provides general physical protection in high-moisture, dusty, and/or corrosive conditions when special compression type fittings are used.

The type and size of conduit to use is determined by 1) the size of wires to be installed, 2) the type of insulation on the wires, 3) the number of wires to be installed in the conduit, 4) whether or not all the wires are the same size and type, and 5) the operating environment. Consult the NEC or other wiring handbooks for specific recommendations. When cutting and installing conduit, always remove any burrs or sharp edges from the inside that may cut or nick the insulation of individual wires as they are pulled through.

In some residential and industrial wiring applications, continuous metallic conduit that runs from the service entrance panel to the last outlet box can serve as the equipment safety grounding conductor. This is provided each joint is properly bonded and only metallic boxes are used. However, according to recent NEC changes, this is not permitted in agricultural applications. Even if continuous metal conduit is used for physical protection, an equipment safety grounding wire must still be provided.

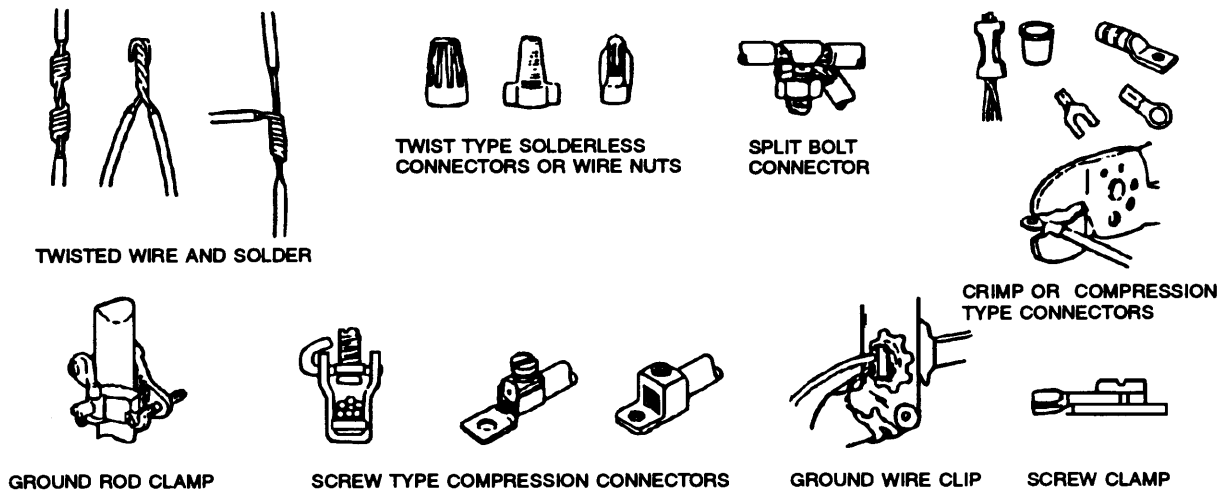
WIRING CONNECTION AND SPLICING PROCEDURES

Many electrical system failures can be traced to a faulty wiring connection or splice. A proper connection must secure the wire both **mechanically** and **electrically**. A connection must physically hold the wire to prevent it from coming loose. It must also provide a low resistance path between the wires or the wire and terminal.

Soldering can provide an excellent low-resistance connection electrically. However, heat buildup from normal or abnormal current flow may cause the solder to soften and/or melt. This can allow the connection to come apart if the wire ends are not also mechanically attached. On the other hand, some screws, clips, or clamps may physically grip the wires and prevent them from being pulled loose. However, because of corrosion and/or the lack of surface contact, the connection or splice may have a high resistance to current flow.

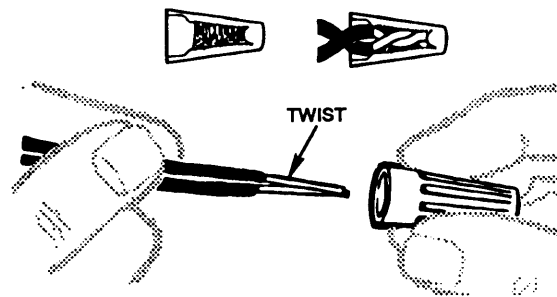
For many years, a common method of splicing wires on branch circuits was to twist them together to form the mechanical connection. Solder was then applied for the electrical connection. Because of the time involved to properly solder each connection, this method is decreasing in popularity. Some people may still attempt to use the twisting method to splice wires, but they do not take time to solder the joint. This **is not** a recommended procedure. It is difficult to twist the wires tight enough to provide a good electrical connection.

Approved methods or devices to splice or connect electrical wiring include 1) twisting wires and soldering, 2) twist type solderless connectors, 3) crimp type connectors, 4) split-bolt connectors, 5) screws, 6) clips, and 7) compression clamps.



Today, a popular method of splicing electrical wires in branch circuits is to use **twist type solderless connectors**, or **wire nuts** as they are commonly called. They are available in several sizes and types. The specific size and type of wire nut to use depends upon the size and number of wires to be connected. The largest wire nuts can be used to splice up to two-#8 AWG wires.

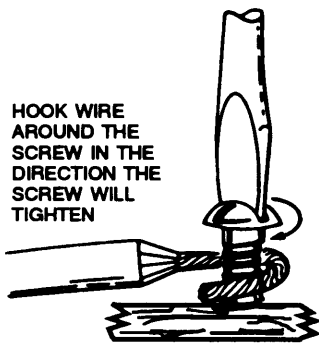
A wire nut has a cone-shaped spiral coil of metal inside a plastic or ceramic insulator. Before a wire nut can be installed, the wire ends must be stripped of their insulation. The amount of insulation to strip will vary with the size of wires and the size and type of wire nut used. After the wire ends are stripped, some instructions recommend that the wires be held side-by-side with their ends even, and the wire nut twisted on. Others recommend that the wire ends be twisted together slightly; excessive tips cut off; and then the wire nut twisted on.



As the wire nut is twisted, the cone-shaped coil should thread its way onto the wire ends pressing them together. The more the wire nut is twisted, the tighter the ends are pressed together. Some wire nuts will stop turning when tight. Others will slip or click. After the wire nut is installed, gently pull on each wire to make sure it is secure. When properly installed, the wire nut should cover and insulate all exposed bare wires.

The use of **crimp type compression connectors** are also increasing in popularity. Wire ends are stripped and placed inside a metal alloy sleeve or tube. A special tool is used to crimp the sleeve around the wire ends. Various sizes are available for use on small #22 AWG copper wire up to large aluminium triplex cable. Some crimp type compression connectors have forks, rings, blades, and sockets on the end so that conductors can be easily connected to terminal screws, etc.

Solderless split-bolt connectors are used on large solid and stranded wires. The split-bolt connectors can be used to make tap connections in the middle of a continuous length of wire. The split-bolt connector is placed over the wires and the nut tightened. **Grounding wire clips** and **bonding screws** are used to attach the equipment safety ground wire to many types of outlet and junction boxes.

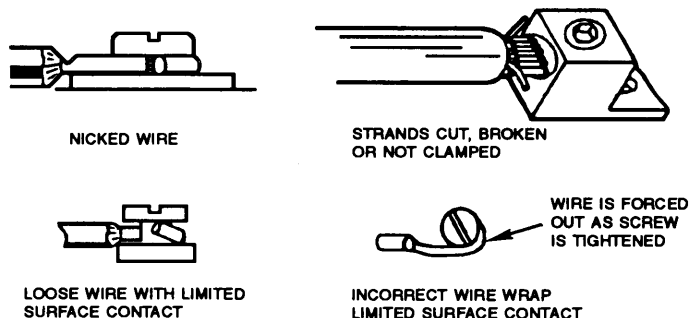


Various other types of **compression screws, clamps, and clips** are used to connect wires to special purpose locations, switch terminals, etc. Many are built directly into the electrical device. When attaching a wire end under a compression screw, hook the wire around the screw in the direction the screw turns to tighten. This tends to draw the wire in tightly under the screw as the screw is tightened.

An electrical system is no better than the condition of the terminal connections or wire splices. The proper size and type of wiring may have been selected and installed. However, as the resistance increases because of corroded, loose, or improperly made connections, the safe current carrying capacity of the circuit decreases.

Wire size is measured by the cross-sectional surface area of the wire. The smaller the wire size, the lower its ampacity. The **effective cross-sectional surface area** of a wire or connection and thus the safe ampacity of the circuit can be greatly reduced

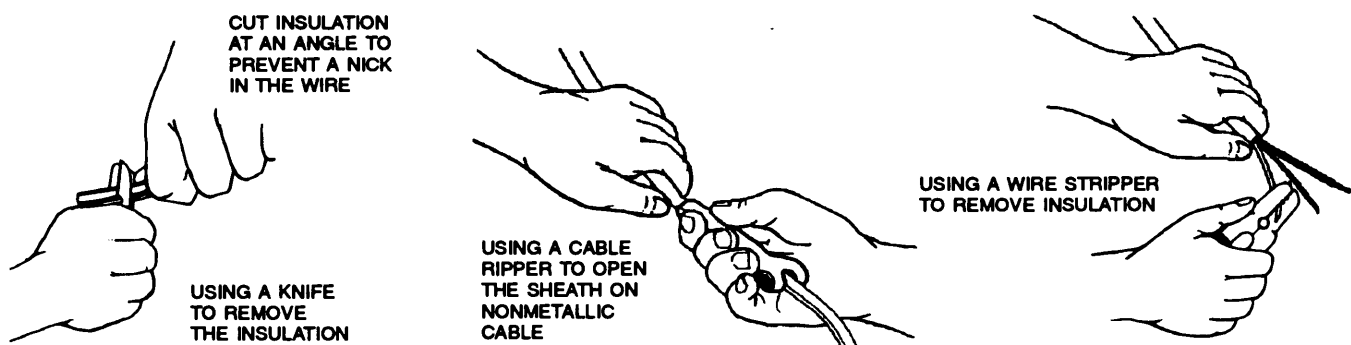
by 1) broken or cut strands, 2) individual strands or part of a solid wire not crimped or clamped in the connection, 3) nicks and cuts in the wire caused by a knife or stripping device, and/or 4) loose or corroded terminals.



For example: Suppose #10 AWG stranded copper wire with an ampacity rating of 25 amps is used to connect an electrical motor. The motor has a full-load rating of up to 24 amps. Suppose several outside strands on one wire end were accidentally cut off during the stripping process. Several strands on another wire end were folded back and not crimped because an undersized compression terminal was used. Thus, the effective wire size in the circuit was reduced to slightly less than a #12 AWG even though #10 AWG was installed. Number 12 AWG wire has a 20 amp capacity at normal operating temperatures. This means approximately 20 amps of current can safely flow through the poor connections. If the motor is operated at full load for any length of time, a current overload would occur. Heat would begin to buildup at the poor connections. As current flow continued, one problem would lead to others.

When stripping the outside sheathing from cables, be careful not to damage the insulation on the individual inside wires. Also, when stripping insulation, avoid cutting off any of the smaller strands or nicking the wires. If using a knife, cut away from your body. To reduce the chances of nicking the wires, cut through insulation at an angle as if you are sharpening a pencil.

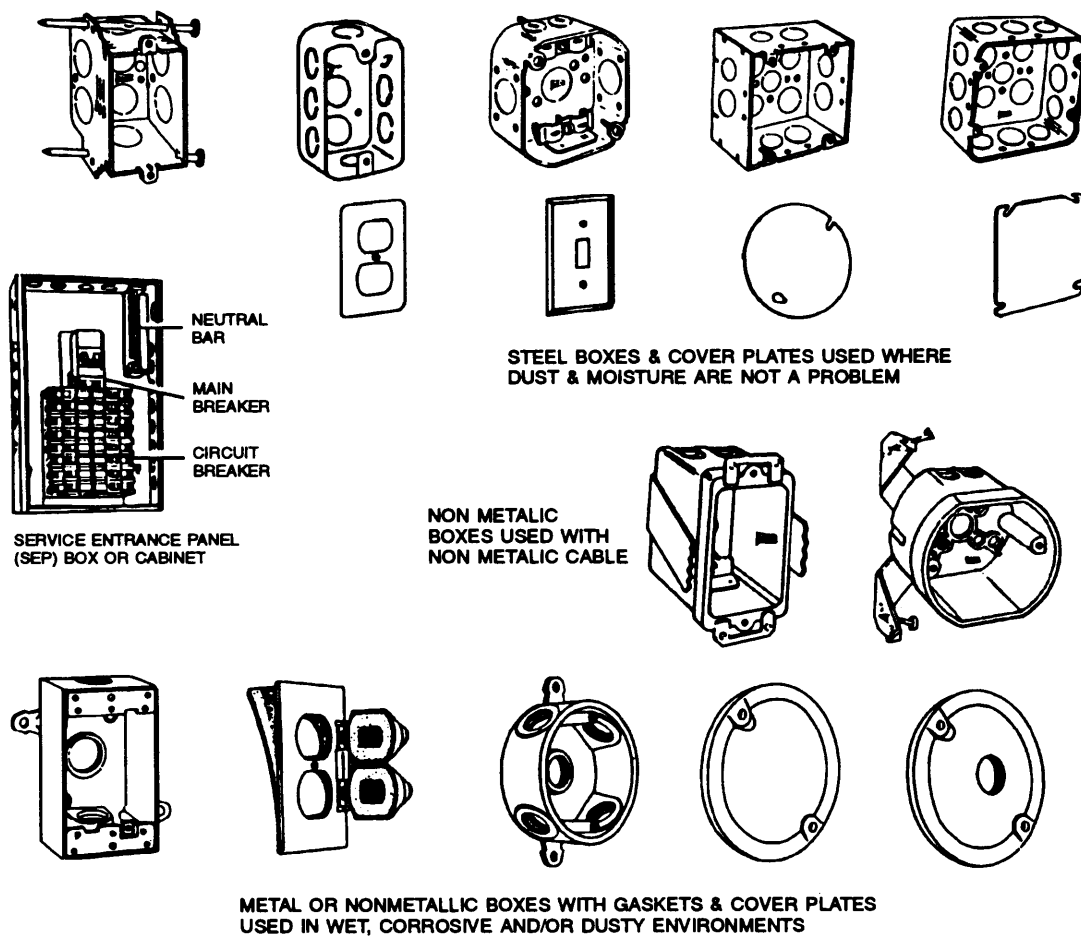
Special tools are available to make the task of stripping sheathing and insulation quicker and easier while minimizing with the chances of damaging the wires. Do not strip more insulation that is necessary. Many electrical devices will have a stripping gauge that indicates the length of bare wire needed.



After a splice or connection is made, make sure the electrical tape or other material used to cover the area is **UL** approved and has the appropriate temperature operating range. It should provide the same total insulating value and other protective qualities as the original insulation. Underground service entrance, feeder, or branch circuit cables must be spliced with special waterproof splicing kits. Any time aluminum wire is spliced or connected to terminals, the ends must first be coated with an oxide inhibitor to help prevent corrosion.

TYPES OF ELECTRICAL SUPPLIES AND EQUIPMENT

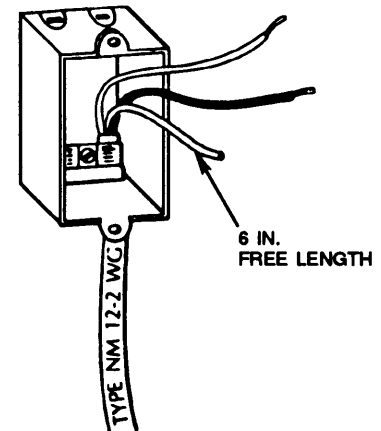
NEC specifies that wire splices, switches, receptacles, circuit breakers, fuses, etc., be housed inside an approved box or cabinet. Many electrical fixtures such as lights must be mounted to some type of junction box for support and to provide protection for the wiring terminals. Electrical boxes are made of steel, aluminum alloy, and non-metallic materials. They are available in many sizes and shapes for a wide variety of uses and operating environments. Depending upon design, some are corrosive-resistant, moisture-proof, and/or dust-proof. It is recommended that only **UL** approved electrical boxes, fixtures, equipment, etc., be used.



Some electrical boxes are designed to be **surface mounted** for use when installing exposed wiring. Others can be **recess mounted** for use with concealed wiring. A variety of cover plates and gaskets are available depending upon needs. Some electrical boxes are designed with built-in cable clamps for use with non-metallic sheathed cable. Others have pre-drilled holes and/or pre-cut knockouts so that conduit or cable connectors can be installed where needed.

Different size and shaped electrical boxes are known by various trade names depending upon where and how they are used. Generally, **switch, device, or handy boxes** are used to hold switches and duplex receptacles. **Outlet boxes** are used to mount or hold electrical equipment such as light fixtures and to protect wiring terminals. Outlet boxes may be round, square, or octagonal shaped. **Junction boxes** usually contain only wire splices. Larger boxes or **special purpose cabinets** are designed to enclose service entrance panels, circuit breakers, fuse holders, etc.

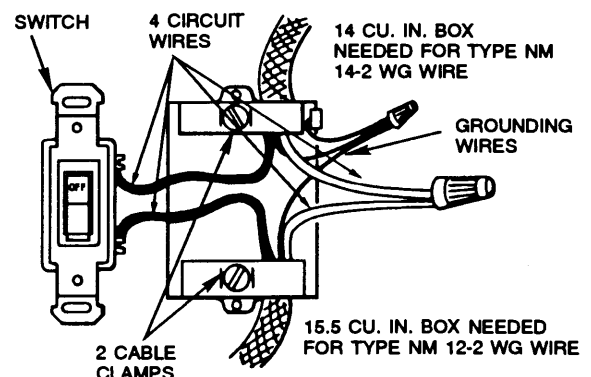
NEC recommends that each wire that enters a device, outlet, or junction box have at least six inches of **free length**. This is to allow enough wire to make splices and connections.



The more wires and/or the larger the size of the wires that enter or pass through a box, the larger the box must be. This ensures adequate room for the electrical device, terminal connections, wire splices, and to be able to safely position all the wires ends. It also allows sufficient air space inside the enclosed box to minimize heat buildup. Section 370 of the NEC provides procedures for determining the recommended type and size of box needed.

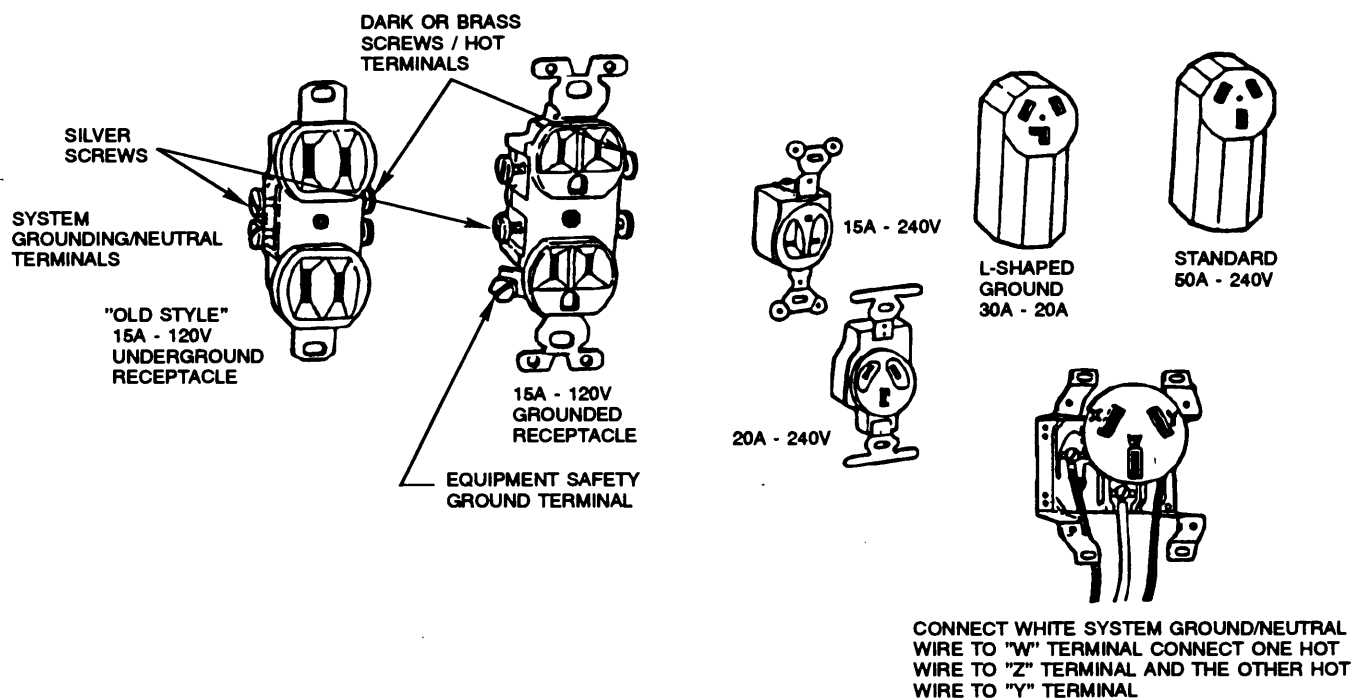
For example: When installing a common single-pole light switch wired with Type NM 14-2 WG cable, 14 cubic inches of room is needed for the switch, the four circuit wires, the grounding wires and wire nut, and the 2 cable clamps. In this case, a standard 3" x 2" x 2 ¾" device box, which has 14.0 cubic inches of capacity, would be adequate.

However, if Type NM 12-2 WG cable is installed in a similar situation, a minimum of 15.75 cubic inches of room is needed. Therefore, a larger 3" x 2" x 3 ½" device box, which has up to 18.0 cubic inches of capacity, should be used. Consult the latest NEC and/or wiring handbooks for the procedures to calculate the type and size of box needed in different applications.



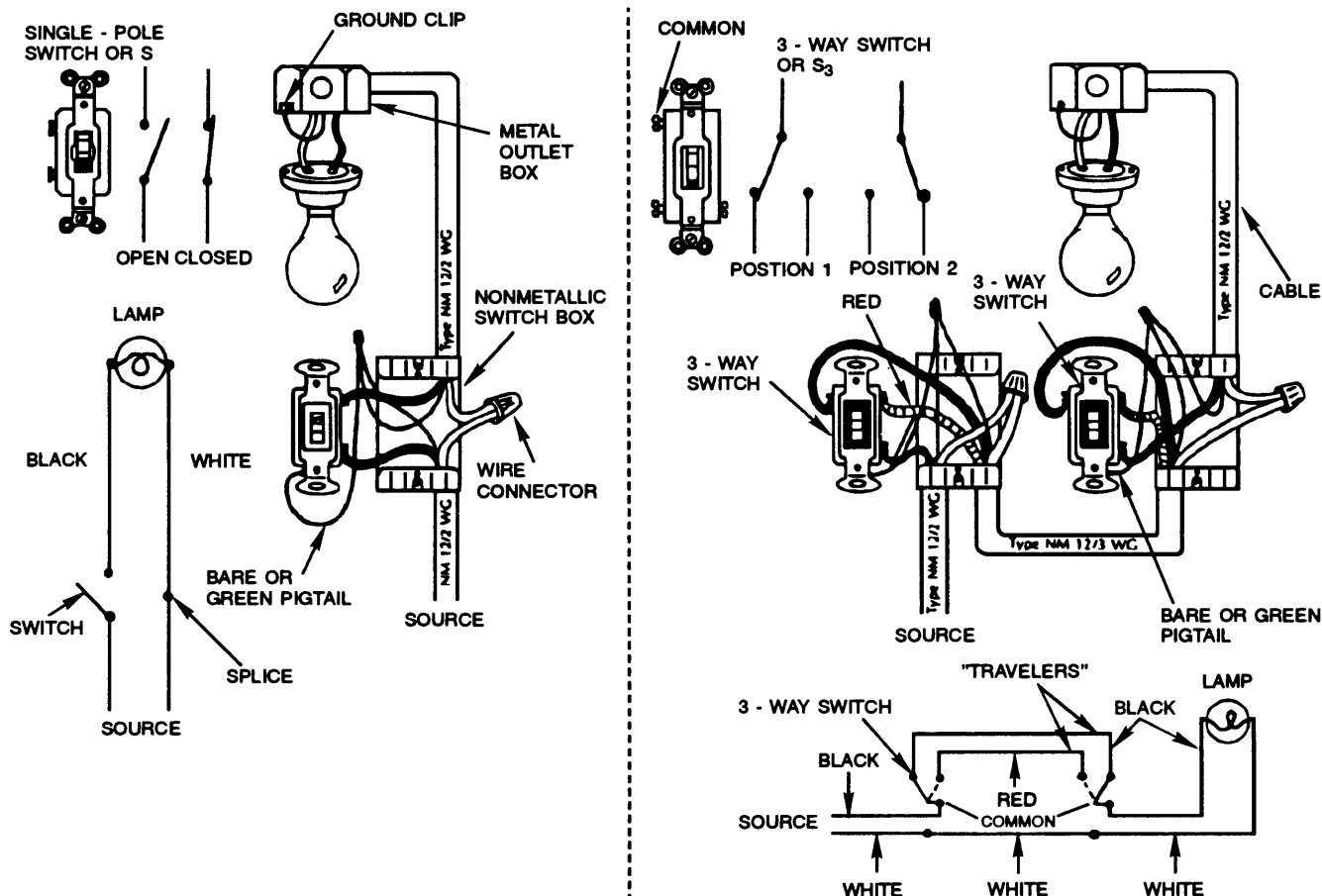
Receptacles and plugs are used to provide a safe and convenient way to connect the power cords of portable electrical equipment to a power source. They are sized by their voltage and amperage ratings. Different voltage and amperage receptacles and the corresponding plugs have different sized and shaped blades and sockets. This prevents the wrong voltage and/or amperage power cord from being plugged into the wrong receptacle.

Shown are common receptacles used in residential and agricultural applications. An old style **15 A-120 V ungrounded receptacle** is now permitted to be used only as a replacement receptacle in older 120 V two-wire circuits that are not equipped with an equipment safety grounding wire. Refer to student topic #8152-B for additional information on replacing ungrounded receptacles.

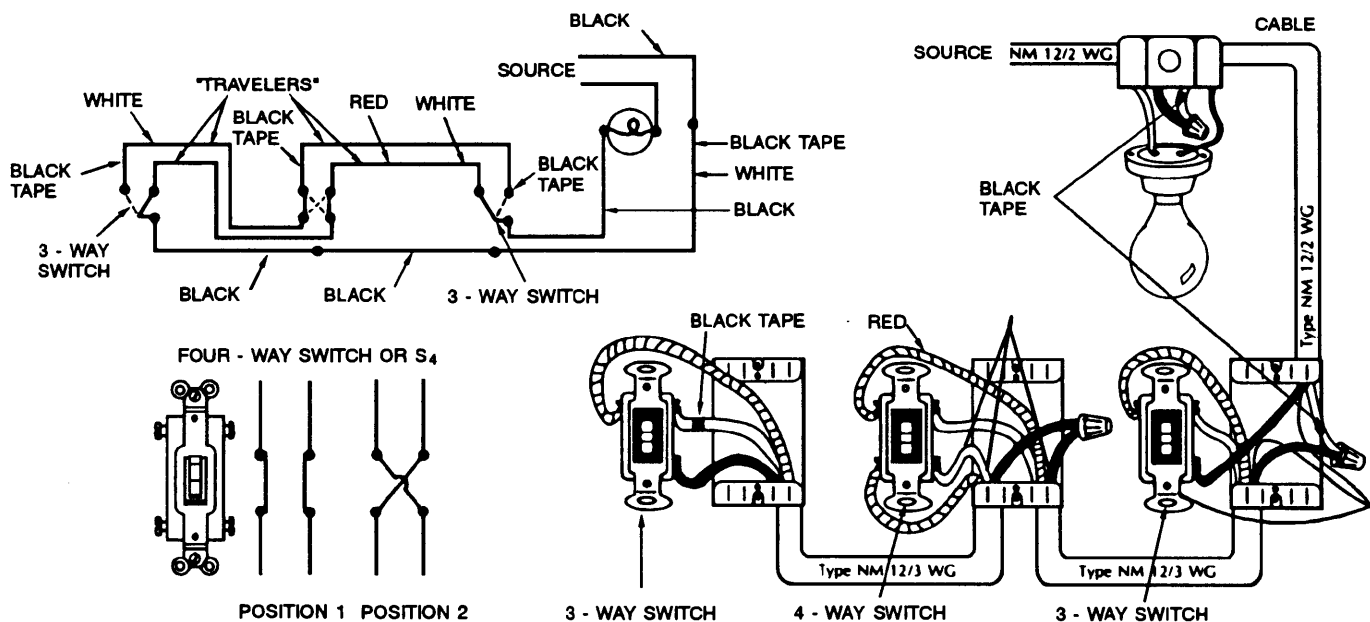


The 15 A through 30 A-240 V receptacles are used for lower amperage electrical motors and portable equipment, such as table saws, clothes dryers, grain augers, etc. The 50 A-240 V receptacles are used with larger horsepower electrical motors, arc welders, electric cooking ranges, etc.

Switches provide a safe and convenient way to start and stop the flow of electrical current. Switches are always installed in the hot wires of the circuits, not in the system ground/neutral or the equipment safety grounding wire. Single-pole or **S**, three-way or **S₃**, and four-way or **S₄** switches commonly used in lighting circuits are shown on the following page.



Three- and four-way switches allow a light to be controlled from more than one location. **Note!** For clarity, the equipment safety grounding wires, which are the green colored or bare copper wires, are not shown in all the illustrations. Always include them in all new circuits and bond them to all fixtures and metallic boxes. Other types of special purpose switches and control devices are discussed in student topic # 8152-D.



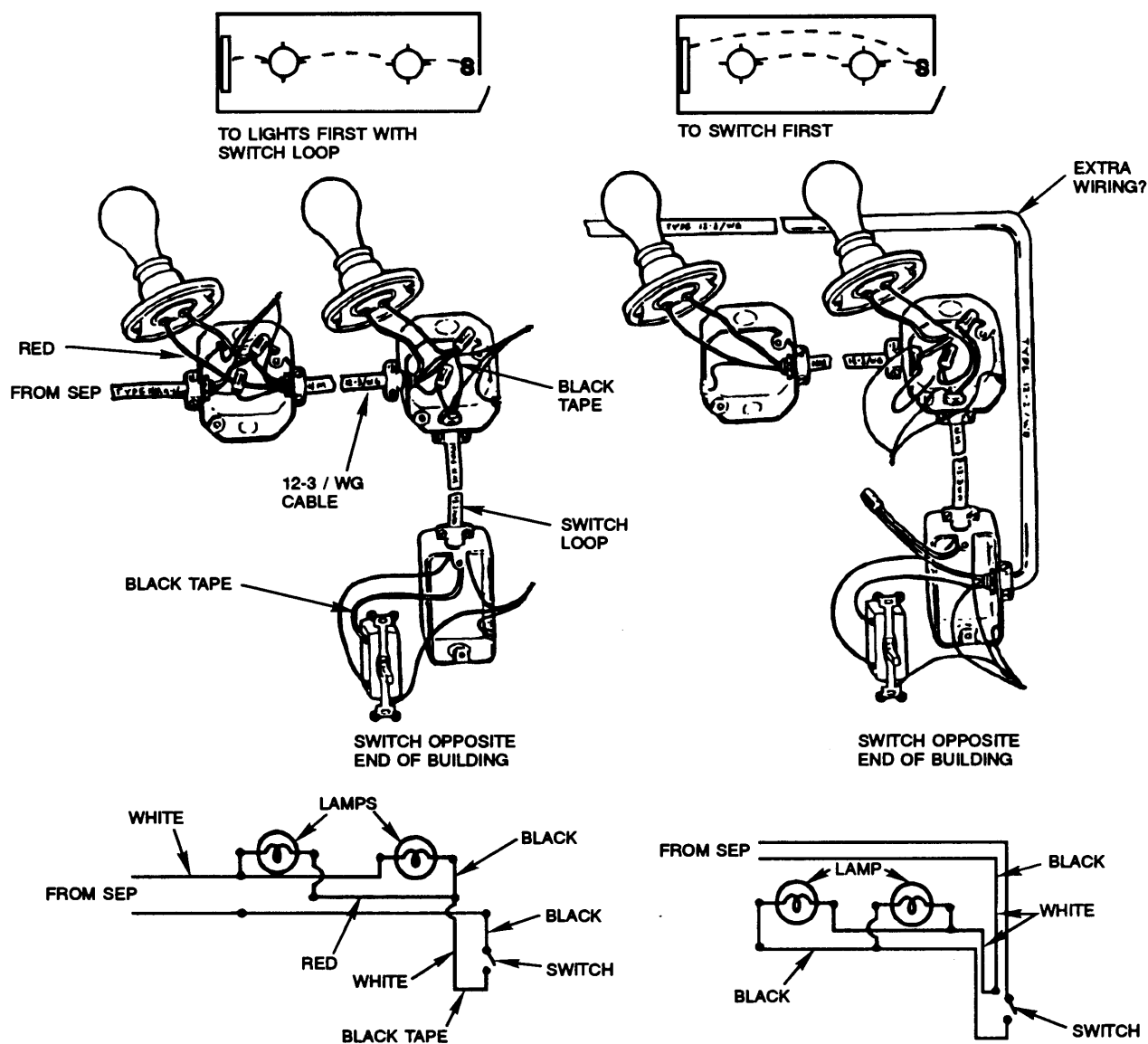
GENERAL ELECTRICAL CIRCUIT INSTALLATION PROCEDURES

Before installing any electrical equipment, study the building plans. Determine if the wiring will be surface mounted or concealed wiring. Remember, the type of wiring and other equipment installed must be suitable for the operating environment(s) in the building. Some plans may show where all the lights, switches, outlets, motors, equipment, etc., should be located and which circuits they are on. However, some may not show where the wires should be routed.

Before beginning to install any equipment or routing any wiring or conduit, it is often helpful to draw simple sketches or diagrams of individual branch circuits. Try to visualize the actual size of the building and the location of walls, ceilings, doors, etc., in relationship to where the electrical equipment is to be installed. This is particularly important for the circuits that have multiple receptacles, lights and switches. There are often several different ways to route the wires within a given circuit. Some may require more and/or different types of wiring or supplies. Some may require splices and connections to be made in different places.

For example: Consider a simple lighting circuit in a small building with 1) the service entrance panel located at one end, 2) two light fixtures equally spaced in the ceiling, and 3) a single-pole light switch located near the door at the opposite end. Shown on the following page are simple wiring plans and schematic drawings for two possible ways of routing the wiring in this circuit. **Note!** Also shown for comparison are drawings of the actual wiring layouts, fixtures, and boxes. In actual practice, it would not be necessary to draw them. This is what the electrician would visualize in his or her mind by using the simpler sketches.

Notice that by routing the wire to the switch first, approximately twice as much Type NM 12-2 WG cable is needed. By first routing the wire through the light fixtures and using a switch loop, less Type NM 12-2 WG cable is needed. However, a short section of Type NM 12-3 WG cable is needed between the light fixtures.



Even an experienced electrician will find simple wiring sketches of branch circuits helpful. Using simple sketches should not be considered a sign one does not know what he or she is doing, but rather he or she does. The electrician who sketches is only trying to complete the job quicker, safer, and more economically.

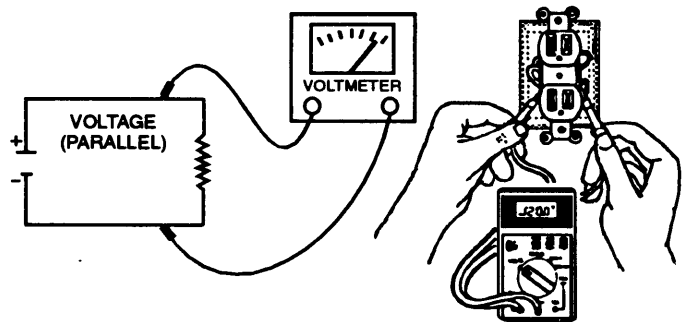
It is beyond the scope of this topic to show an example of all possible combinations of wiring multiple switches, duplex receptacle outlets, light fixtures, motors, circuit breaker panels, etc. Consult wiring handbooks for additional examples and procedures.

USING ELECTRICAL METERS AND TEST LIGHTS

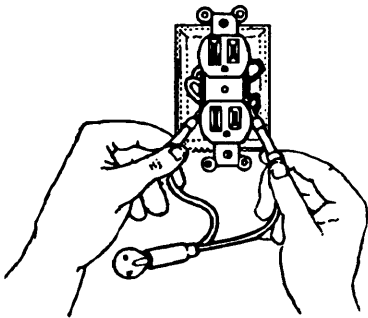
A complete electrical circuit is required for current to flow and equipment to operate properly. A typical electrical circuit consists of 1) a source of electrical pressure or voltage to force current to flow; 2) a planned path for the electrical current to follow; 3) a load that converts the electrical energy into heat, light, or power or to perform electronic functions; and 4) a switch to control the flow of current when needed. When an electrical system does not operate properly, an electrician must be able to apply the basic principles of electricity and electromagnetic induction and use test equipment.

A person should follow a **sequence of steps** in locating any problem. **Questions** must be asked. **How** should a **normal** system operate? **What** is the **problem** or **symptom** now? Based on the **basic principles**, what **cause and effect relationships** could have caused this type of problem? Of the **possible explanations**, which is the **simplest**, **easiest**, and **safest** to check first?

A **voltmeter** is used to measure the voltage in a circuit. It measures the voltage differential between two points in the circuit. A voltmeter is connected parallel to the circuit. A D.C. voltmeter is needed to measure direct-current voltage. An A.C. voltmeter is needed to measure alternating-current voltage. Most meters are designed to measure both A.C. and D.C. voltages.



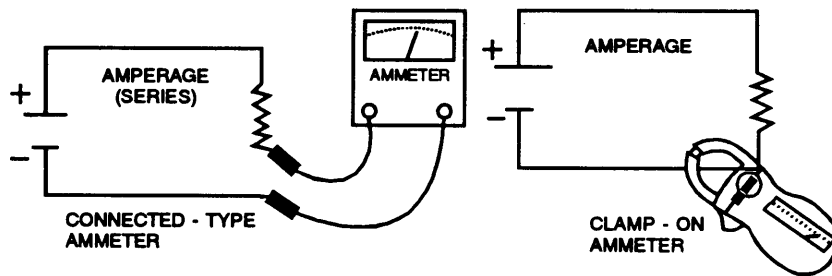
Using a Voltmeter



Using a Neon Circuit
Tester

A **neon voltage or circuit tester** can be used to determine if a circuit is hot. It is equipped with a small neon light bulb and two insulated test leads. Touch one probe to a hot wire or terminal and the other to the neutral wire or terminal. The neon bulb of the tester will light if the circuit is hot.

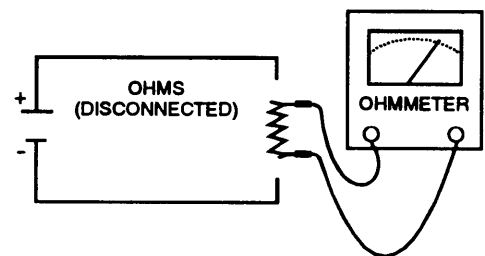
An **ammeter** is used to measure the current flowing in a circuit. An A.C. ammeter is needed to measure alternating current while a D.C. ammeter is needed for direct current. To measure electrical current with a **connected-type ammeter**, it is necessary for the current to flow through the ammeter. Therefore, the circuit must be turned off, one of the wires disconnected, the ammeter *connected* in series, and then the circuit turned back on to measure the current flow. It does not matter if the ammeter is installed in the hot wire or the neutral wire since the current flow should be the same. The ammeter, probe leads, and clamps must be rated to handle the anticipated amperage load or serious damage to the instrument will occur.



Using an Ammeter

When it is necessary to measure higher levels of electrical current flow, an **induction** or **clamp-on ammeter** is recommended. This type of ammeter is equipped with a movable iron jaw that can be clamped around one of the wires without disconnecting the circuit or removing any insulation. Current flowing through a wire produces a magnetic field. The clamp-on ammeter measures the strength of the magnetic field produced by the current flowing in the wire. The strength of the magnetic field is converted to an amperage reading.

An ohmmeter measures the ohms of resistance in a wire, motor, bulb, etc. To measure resistance, the electrical power in the circuit must be turned off. The component to be tested must be disconnected at both ends and the ohmmeter leads attached. An ohmmeter contains a battery, which then sends low voltage current through the component being tested. The ohmmeter measures the resistance to the given amount of current flow.



Using an Ohmmeter

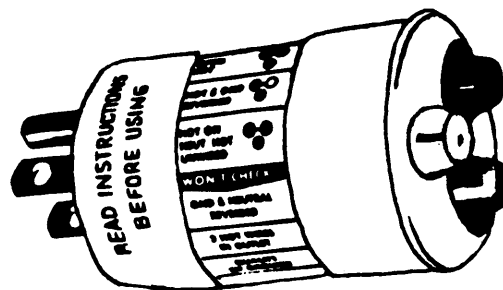
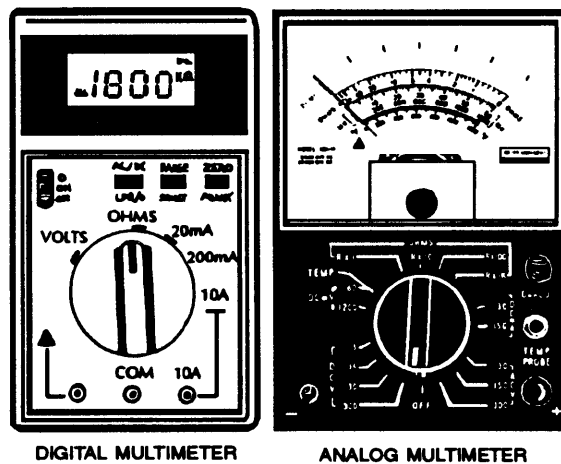
Many newer style electrical test meters combine the volt, amperage, and ohm meters into one unit. They are commonly called **multimeters**. **Analog multimeters** are equipped with graduated scales and a pointer. **Digital multimeters** provide a direct numerical readout.

When using a meter, always check to see if the selector switch is set to the function you are testing. **For example:** Suppose you want to measure high voltage alternating current and the meter selector switch is still set to measure amperage. If you connect the leads in parallel between a hot and neutral wire while the current is on, a dead short will occur and damage the meter.

Always start your measurements with a higher range scale setting than is necessary. This may protect the meter from damage in case the voltage and/or amperage in the circuit is higher than you are expecting. It is necessary to maintain proper polarity of the test probe leads to obtain a proper reading and to protect the meter from damage. The negative lead and probe are generally black. The probe should be touched or clamped to the neutral or grounded side of the circuit. The positive lead and probe are generally red. The red probe should be touched to the positive or hot side of the circuit.

A **receptacle circuit tester** can be used for testing three-wire, 115 V A.C. receptacle circuits. The small self-contained tester is plugged directly into a safety grounding-type receptacle. The circuit tester will test for proper connection of the neutral and equipment safety grounding wires. It will also test for correct polarity and for ground faults in any of the three wires.

When using any meter or tester, you are assuming some of the electrical wires are or may be hot. Be very careful. Do not hold the bare ends of the test probes. Be careful where you place the tips of the test probes. If a probe accidentally touches a hot and grounded object at the same time, a short circuit will occur. Do not touch uninsulated wires or metal parts with your hands until you are sure all electrical power is off.



Receptacle Circuit Tester

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Wiring Skills, Energy Concepts Inc., Chicago, IL.

National Electrical Code, 1993, National Fire Protection Association, Quincy, MA.

Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the information in this topic. Ms. Hannah Kerby, Graduate Assistant, Department of Agricultural Education, Texas A&M University, developed the student activities.

SUGGESTED STUDENT ACTIVITIES

TRUE OR FALSE: Circle "T" if the statement is true; circle "F" if the statement is false.

- T F 1. Only inexperienced electricians need to draw sketches of circuits or wiring routes.
- T F 2. The white or gray system ground/neutral wire is a current carrying conductor.
- T F 3. Aluminum wire used in a circuit must be two AWG sizes bigger than copper wire used in the same circuit.
- T F 4. Type NM cable should not be used in environments where damp, dusty, wet, or corrosive conditions exist.
- T F 5. For measurements of voltage, amperage or ohms of resistance to be taken in a circuit, the power must be turned off.
- T F 6. The rubber and plastic handles on most electrician's hand tools are designed to allow a person to work on electrical circuits while the power is on.

SHORT ANSWER: Answer the following items in a sentence, phrase or short paragraph. (Use additional paper when needed.)

7. Which types of wire are suitable for underground use?
8. What do the letters T, R, W, H and N mean in wire type codes?
9. What type of conduit would be most suitable for use in an agricultural application where severe physical protection is not required?

FILL IN THE BLANK: Complete the following statements by inserting the correct word(s) in the blanks.

- _____ 10. The National Electrical Code lists the _____ recommended safety standards for electrical installations.
- _____ 11. A(n) _____ is an electrical wiring assembly that contains two or more individually insulated wires wrapped together.
- _____ 12. _____ forms on the outside of aluminum wire, creating a heat insulating barrier.
- _____ 13. The bare stranded aluminum wire in aerial triplex or quadriplex cable is called the _____.
- _____ 14. A proper connection between two wires must secure them both _____ and _____.
- _____ 15. Switches are always installed in the _____ wire of the circuit.
- _____ 16. An _____ is used to measure the current flowing in a circuit.
- _____ 17. _____ is the current in amps a conductor can continuously carry under normal conditions without causing excessive voltage drop or exceeding its temperature rating.

MATCHING: Match the letter of the term with the description it best matches.

- _____ 16. Measures resistance in a component
 - _____ 17. Measures the magnetic field produced by current flowing through a wire and converts it to an amperage reading
 - _____ 18. Can be used to test three wire, 115 V A.C. circuits
 - _____ 19. Can indicate whether current is flowing through a circuit
 - _____ 20. Measures voltage, amperage, and ohms
-
- a. Receptacle circuit tester
 - b. Multimeter
 - c. Ohmmeter
 - d. Clamp-on ammeter
 - e. Neon voltage tester

ADDITIONAL SKILLS AND ENHANCEMENT ACTIVITIES: Perform the following activities or skills as assigned by your instructor.

1. Make a display of different types of electrical wire, conduit, and wire splices and connectors that are approved for use in different agricultural applications.
2. Study electrical wiring handbooks for examples of lighting, general purpose, and special purpose branch circuits.
3. Demonstrate ability to draw sketches of different wiring routes for branch circuits.
4. Demonstrate ability to install electrical equipment in basic branch circuits.
5. Demonstrate ability to use multimeters and circuit testers to check the condition of a circuit.

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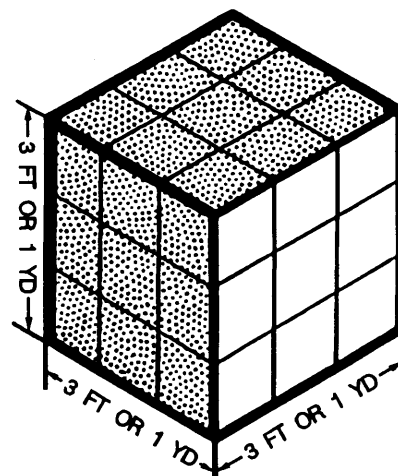
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PLANNING CONCRETE CONSTRUCTION

CALCULATING QUANTITY OF CONCRETE NEEDED

Before mixing concrete or ordering it from a ready-mix concrete supplier, you must determine how much you will need. The most common unit of measurement for concrete is the **cubic yard**. A cubic yard is a cube three feet square and three feet high. The question is, "How much area can I cover, or how big of an area can I fill with one cubic yard of concrete?"

The first step is to measure the area to be filled. The task is easy. Simply multiply the width of the area in feet, times the length of the area in feet, times the thickness of the area in inches. Divide the answer by 12 to determine the number of cubic feet. There are 27 cubic feet in a cubic yard. Divide the number of cubic feet by 27 to determine the number of cubic yards needed.



1 cu yd (27 cu ft) of
Concrete

$$\text{Cubic feet} = \frac{\text{width in feet} \times \text{length in feet} \times \text{thickness in inches}}{12}$$

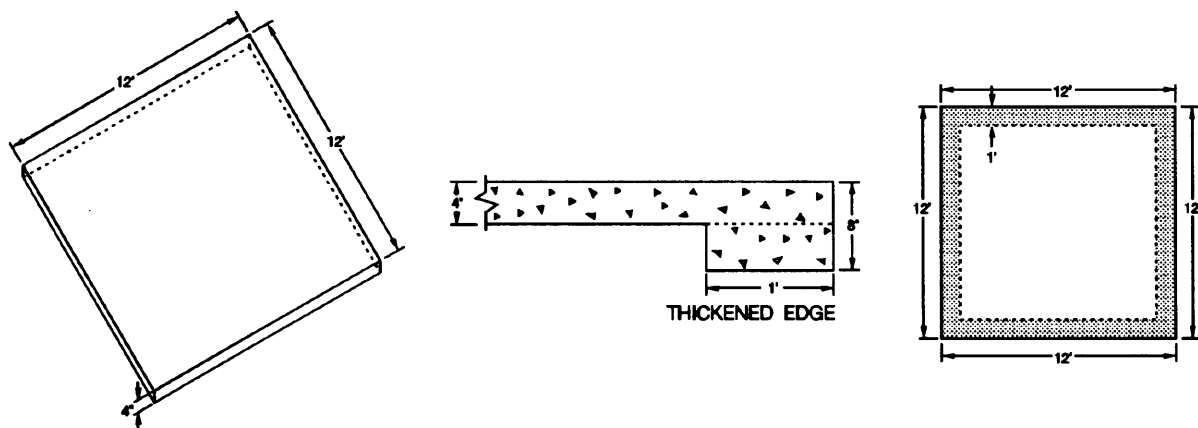
$$\text{then} \quad \text{Cubic yards} = \frac{\text{cubic feet}}{27}$$

Suppose you are going to pour a concrete slab for a small building that is 12 feet wide x 12 feet long. The floor will be four inches thick.

$$\frac{12 \text{ ft} \quad 12 \text{ ft} \quad 4 \text{ in.}}{\text{width in feet x length in feet x thickness in inches}} = 48 \text{ cu ft}$$

then $\frac{48 \text{ cu ft}}{27} = 1.78 \text{ or } 1.8 \text{ cu yd}$

Suppose the building also has a "mini-footing or thickened edge" under the slab. It will be poured at the same time as the slab. The thickened edge is one foot wide, four inches thick, and extends around the outside of the building. Think of it as one long narrow slab and calculate it as a separate area.



$$\frac{1 \text{ ft} \quad 48 \text{ ft} \quad 4 \text{ in.}}{\text{width in feet x length in feet x thickness in inches}} = 16 \text{ cu ft}$$

then $\frac{16 \text{ cu ft}}{27} = .59 \text{ or } .6 \text{ cu yd}$

1.8 cu yd for main slab

.6 cu yd for mini-footing

2.4 cu yd would be needed + any extra

An extra 5 to 10 percent is often ordered from the ready-mix concrete plant to allow for uneven subgrade, waste, spillage, etc.

CALCULATING THE QUANTITY OF INGREDIENTS NEEDED

When small quantities of concrete are mixed in a small mixer or wheelbarrow, it is necessary to know how much of each ingredient is needed. Shown is a chart which lists the amount of cement, sand, gravel, and water needed for three common water-cement ratio mixes. The .44 water-cement ratio will produce a high strength mix that is resistant to severe abrasion and wear. The .53 water-cement ratio mix is a general purpose, average strength mix suitable for most agricultural applications. The .61 water-cement ratio mix will produce a lower strength concrete.

RECOMMENDED SMALL OR TRIAL BATCH MIXES							
WATER-CEMENT RATIO	CEMENT (SACK)	SAND (Cu Ft)	GRAVEL (Cu Ft)	GALLONS OF WATER NEEDED FOR:			
				DRY SAND	DAMP SAND	WET SAND	VERY WET SAND
.44	1	2	2 1/4	5	4 1/2	4	3 1/2
.53	1	2	3	6	5 1/2	5	4 1/2
.61	1	3	4	7	6 1/4	5 1/2	4 3/4

Depending upon the size of the mix, the chart can be used in several ways. Suppose a portable mixer is large enough to mix one full batch. If a "1:2:3 6" or .53 water cement-ratio batch is to be made, the following ingredients would be needed.

- * 1 sack of cement (1 sack = 1 cu ft and weighs 94 lbs)
- * 2 cu ft or 200 lbs sand (dry sand weighs approximately 100 lbs per cu ft)
- * 3 cu ft or 300 lbs gravel (gravel and crushed rock also weighs approximately 100 lbs per cu ft)
- * 6 gallons of water when dry sand is used (Since most sand has some moisture in it, the amount of water may need to be adjusted as shown.)

A shovel is often used to add sand, gravel, and cement to the mixer. It may be convenient to convert the cubic feet to "number of shovels." An easy way to do this is to build a small box one foot square (one cubic foot). Count the average number of shovels necessary to fill it with each ingredient. The number will vary with the size of the shovel used.

The same chart and formula can also be used for smaller batches. **For example:** A one-half batch of the "1:2:3 6" mixture can be measured as: 1/2 cu ft cement (1/2 sack), 1 cu ft dry sand (100 lbs), 1.5 cu ft gravel (150 lbs), and 3 gallons of water.

For an even smaller wheelbarrow mix, the "1:2:3 6" formula can be used as: **one part** cement, **two parts** sand, and **three parts** gravel. The "parts" can be measured with a shovel, bucket, or other suitable container.

It is difficult to determine the exact amount of water needed when mixing small batches. The water needed will vary with the amount of moisture in the sand being used. **Damp sand** feels moist when squeezed and contains approximately one quart of water per cubic foot. **Wet sand** leaves water in the palm of one's hand when squeezed. It contains approximately two quarts of water per cubic foot.

It is necessary to estimate the amount of water in the sand being used and adjust the mixture accordingly. Do not add the water all at once. The water should be added to the cement, sand, and gravel a little at a time until the desired slump is obtained. Remember, a soupy mix will increase the water-cement ratio and decrease the strength of the mix.

Consider the one sack mixture example used above. The 1 cubic foot of cement, plus 2 cubic feet of sand, plus 3 cubic feet of sand, plus 6 gallons of water would equal **6.8 cu ft total volume of ingredients** (6 gal ÷ 7.5 gal per cu ft = .8 cu ft water). The water mixes with the cement, and the sand and smaller rocks fill the spaces between the larger rocks. The 6.8 cu ft of ingredients would thus only yield approximately 4.1 cu ft of actual concrete. As a rule of thumb, the yield of a concrete mix is generally 60 percent of the total volume of the ingredients.

In this example, 6.8 cu ft of ingredients x 60 percent equals 4.08 or approximately 4.1 cu ft of concrete. If one cu yd of actual concrete is needed, seven one-sack batches would have to be hand mixed.

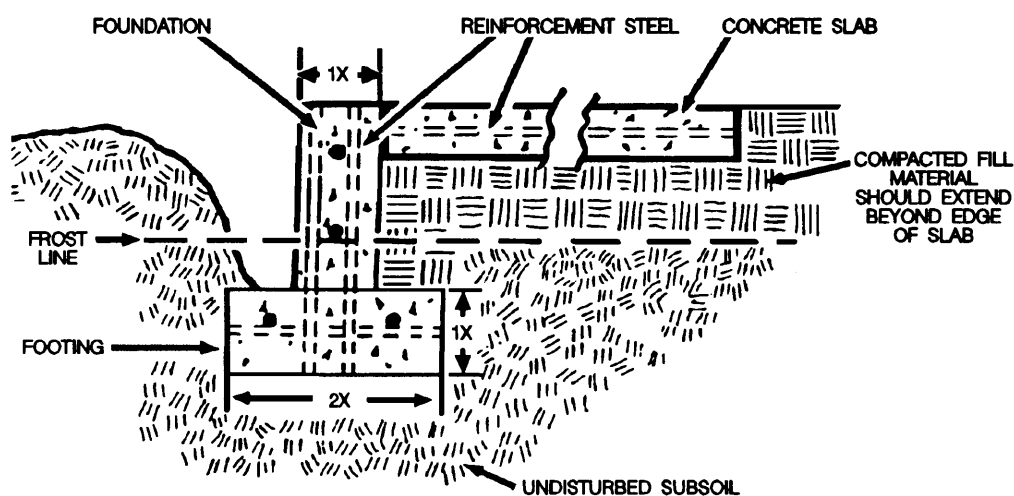
$$1 \text{ cu yd or } 27 \text{ cu ft} \div 4.1 \text{ cu ft per batch} = 6.58 \text{ or } 7 \text{ batches}$$

However, when ordering from ready-mix concrete suppliers, order the actual volume of concrete needed. Ready-mix concrete is sold by the actual volume of concrete *after* it is mixed. Ready-mix concrete suppliers automatically adjust for the amount of moisture in the sand. They also calculate the volume of concrete in the mix based on the size of the rocks or gravel used.

SITE, SUBGRADE, AND FOOTING PREPARATION

Proper site and subgrade preparation is as important as the proper mixing, placing, finishing, and curing of concrete. **Subgrade** is considered the subsoil, sand, rock, gravel, or other material the concrete structure is supported by or rests on.

Site and subgrade preparation should start with the removal of the top soil, and any grass, weeds, roots, etc. Top soil and organic matter do not pack easily and will remain spongy when they become wet. This will allow a concrete structure to shift and crack. The amount of top soil to be removed is determined by the size of the concrete structure and the weight that it will support. The design for a larger, heavy structure may require several feet of top soil to be removed down to firm undisturbed subsoil. A footing and foundation is then poured around the edges to spread the weight over a larger surface.



Typical Footing, Foundation, and Subgrade

Flat slabs should be placed over a layer of compacted fill material. Sand, granular gravel, or crushed rock are the most common types of fill material used because they can be packed. Fill material should be placed in layers three to six inches thick. Each layer should be thoroughly moistened and compacted before another layer is added.

The compacted subgrade should be extended out past the concrete slab to prevent settling around the edges. Avoid using smooth, round, pea-gravel or river rock as fill material. It will roll or shift and does not pack easily.

The size of the footing, and the fill material required will vary with the type of building, type of subsoil, and the climate. Local building codes and the building plans will usually specify the type and design of the foundation and footing.

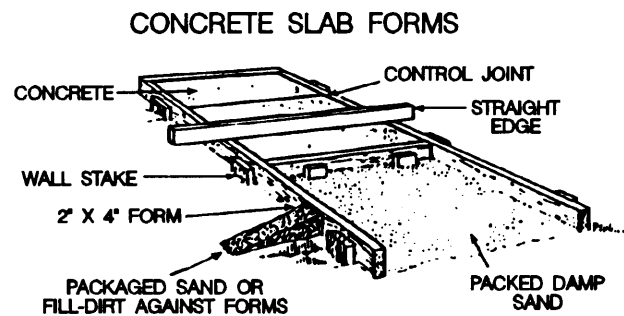
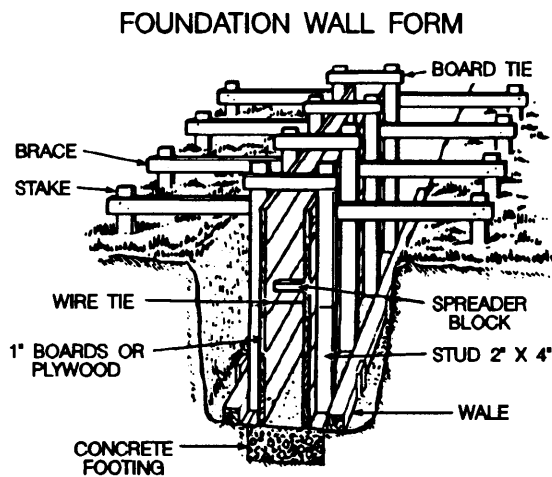
CONCRETE FORM CONSTRUCTION

The purpose of the **concrete forms** is to hold the wet concrete in the desired shape or position until it hardens. Forms must be strong enough to support the weight of the concrete without sagging or breaking. The final appearance and shape of the concrete structure will be the same as the inside of the forms.

Forms for walls and foundations are usually made with one-inch lumber or thick exterior grade plywood. The lumber or plywood is attached to 2"x4" studs and bracing. Additional bracing attached back to a bank or the ground may be required. Forms are usually assembled with double headed nails or bolts for easy removal. For large projects, commercial prefabricated concrete forms can often be rented cheaper than they can be built.

Two-inch lumber is used to construct the forms for most flat slabs. Two by four-inch lumber is used as forms for slabs from three to four and one-half inches thick. The thickness of the slab is controlled by varying the amount of fill material used. Two by six-inch lumber can be used on slabs from five to six and one-half inches thick.

Form stakes and braces are commonly made of 2"x4" lumber. Damp sand or fill material gently packed on the back side of the forms can provide additional support. The outside corner of forms are the weakest because pressure is exerted in two directions.



Typical Foundation Wall and Slab or Sidewalk Forms

Always consider the following factors when building forms and placing concrete.

1. Concrete weighs approximately 150 lbs per cubic foot. Concrete can exert over 1,200 psi of force against the bottom of a wall form.
2. If possible, pour concrete slowly in even layers and consolidate. Concrete dumped or poured fast will exert greater force on the forms and bracing.
3. The lower the temperature, the slower the hydration process. The slower the hydration process, the more stress there will be on the forms. The slower the hydration process, the longer the forms must remain in place.
4. Higher slump or "soupier" concrete tends to run or spread out. This places more stress on the forms. Concrete consolidated with vibrators also tends to spread and places increased strain on forms.
5. A light lubricating oil or form oil should be applied to the inside of forms. This prevents the concrete from bonding to the forms. **Caution!** Do not get oil on the reinforcement steel or the concrete will not bond to it either.

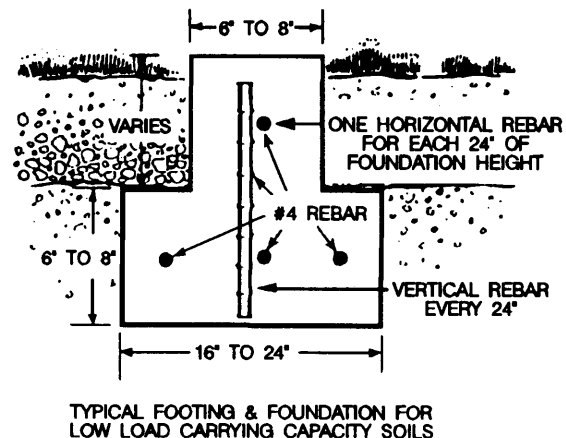
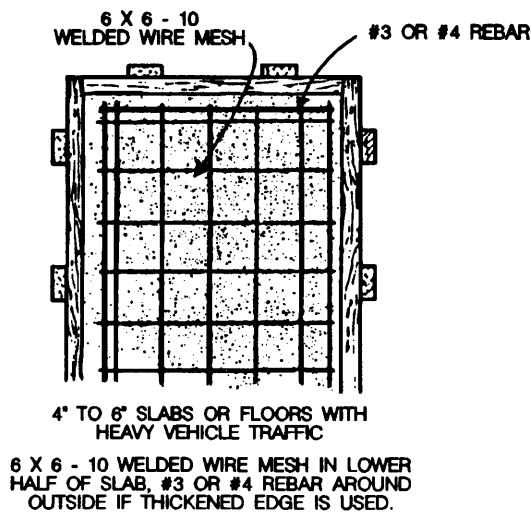
REINFORCING CONCRETE

Reinforcement steel is often added to concrete. Its primary purpose is to increase the tensile strength of the concrete. Reinforcement steel will not always eliminate cracking or breakage. It will reduce it to an acceptable level if properly used.

Two common types of reinforcement steel are **rebar** and **welded wire mesh**. "Deformed rebar" has lugs or ribs to allow for a better grip. Common sizes of rebar for agricultural construction range from one-fourth to five-eighths inch in diameter. Number 3 rebar is three-eighths inch in diameter. Number 4 is four-eighths or one-half inch, while number 5 is five-eighths inch in diameter.

Welded wire mesh is made with high strength wire spot welded at right angles. Common welded wire for flat slab construction is made with #10 gauge wire welded at 6-inch spacings. It is called "6x6-10 welded wire mesh."

Reinforcement steel can also help to control shifting or movement after a crack has occurred or along a construction joint. The amount of reinforcement steel needed, and where it should be located, is determined by an engineer when the structure is designed.

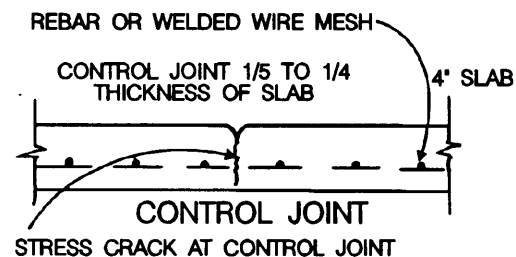
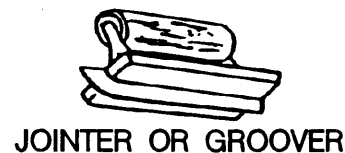
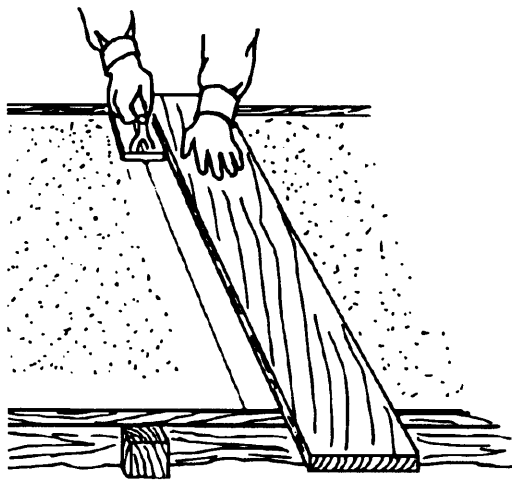


For most 4 to 6 inch thick slabs, 6x6-10 welded wire mesh is placed in the lower half of the concrete. One #3 or #4 rebar is positioned every 6 to 8 inches around the outside of thickened edges or in footing and foundations. The ends of rebar should be overlapped at least 12 inches and securely wired together. Welded wire mesh should be overlapped at least eight inches.

CONSTRUCTION JOINTS

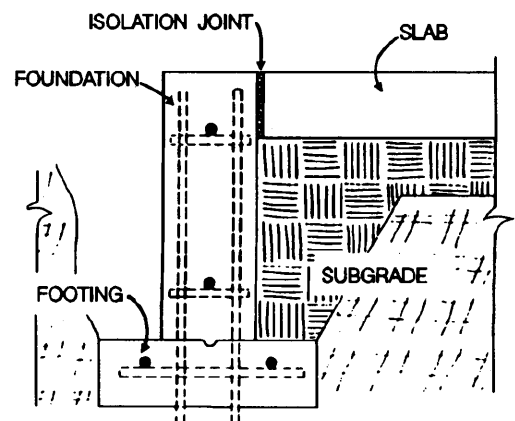
Concrete expands, contracts, and moves slightly during the hydration and curing process. Some cracking can occur naturally every 15 to 25 feet across a sidewalk or slab even if reinforcement steel is used. Slight movement also occurs: 1) due to changes in temperature and moisture conditions, 2) settling of the subgrade, and 3) changes in the force on or against the structure. Each change can cause additional stress cracks and breakage. There are three basic types of joints used in concrete construction to help control movement, relieve internal stress, and to control where natural cracks will occur.

Control joints are used to "control" cracking on large flat concrete slabs. Stress cracking will then occur along the planned control joint instead of in a random pattern. Control joints are pre-cut to a depth of one-fourth to one-fifth the thickness of the slab. They are placed at 10 to 15 feet intervals in each direction across a large slab. Control joints are placed at four to five feet intervals across narrow sidewalks.



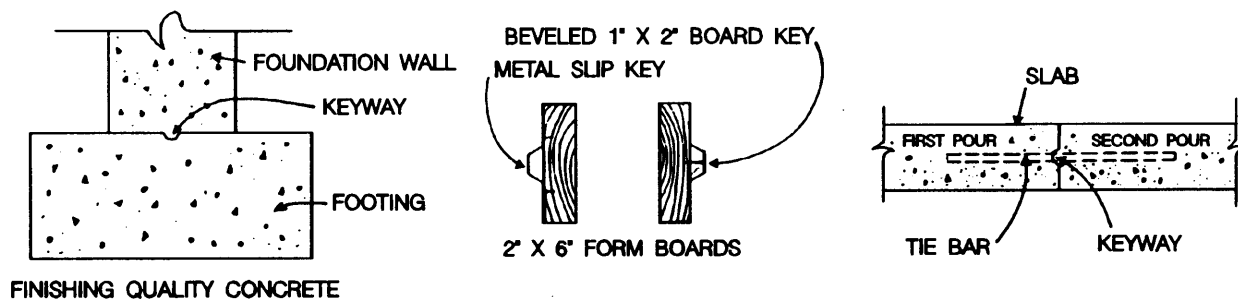
Cutting a Typical Control Joint in a Sidewalk

Isolation or expansion joints permit separate concrete sections to shift or move slightly. An isolation joint is required when two sections will move or expand at different rates. Isolation joints are often separated by a strip of asphalt insulation, tar paper, or a cedar board. This prevents the two sections from bonding and allows for expansion.



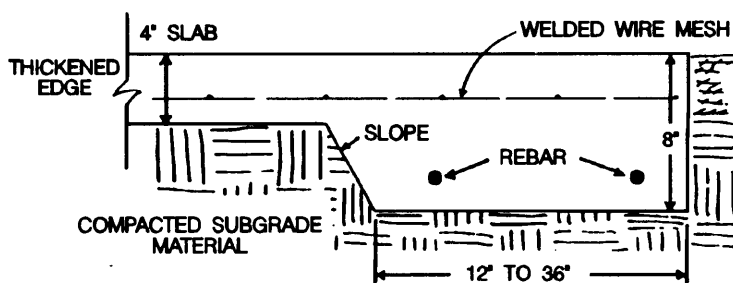
Isolation Joint

Construction joints are designed to tie two separate parts or pours together so there is little or no shifting or movement. Construction joints are sometimes called **keyways**. They are used when it is not practical to pour the complete structure at one time. All sections of the structure can still be bonded and connected together. Construction joints can be designed so they are waterproof.



Common Construction Joints

Thickened edges are used on some types of thin concrete slab work such as feedlots, floors, sidewalks, and driveways. The thickened edge is usually twice as thick as the slab and one- to three-feet wide. The thickened edge serves as a "mini-footing or foundation." This helps to prevent cracking or breaking around the edges. The thickened edge also helps to prevent the subgrade from being washed out from under the slab.



Thickened Edge

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Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the information in this topic. Mr. Bradley Green, Graduate Assistant, Department of Agricultural Education, Texas A&M University developed the student activities.

SUGGESTED STUDENT ACTIVITIES

TRUE OR FALSE: Circle "T" if the statement is true; circle "F" if the statement is false.

- T F 1. Concrete can be made stronger by increasing the amount of water used in the mix.
- T F 2. Wet sand requires that extra water be added to the mix.
- T F 3. Pea-gravel is a good fill material for the subgrade of a slab.
- T F 4. Reinforcement steel prevents concrete from cracking.
- T F 5. Soupy concrete places more pressure on forms.

PROBLEM SOLVING: Use the formulas found in the topic to solve the following problems. Show your work.

- 6. Calculate the cubic feet of concrete needed to construct a slab 10 feet wide, 14 feet long, and 4 inches thick.
- 7. How many cubic yards of concrete should be ordered to construct the slab in question #6?
- 8. Suppose the slab has a thickened edge which runs around the outside of the building. It is 2 feet wide and 6 inches thick. How much concrete would be needed to pour it?
- 9. What is the **total** amount of concrete which should be ordered to construct this slab and thickened edge allowing 5 percent extra for spillage and uneven subgrade?

SHORT ANSWER: Answer the following items in a sentence, phrase or short paragraph. (Use additional paper when needed.)

10. Describe the process of preparing a subgrade.
11. What are wall and foundation forms usually made of?
12. Why are smooth, rounded rocks not considered to be a good fill material?
13. What is the weakest part of a form?
14. Why is reinforcement steel added to concrete?
15. How far should rebar and welded wire mesh be overlapped?
16. What is the difference between a control joint and an isolation or expansion joint?
17. What is a thickened edge, and what purpose does it serve?

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PLACING, FINISHING, AND CURING QUALITY CONCRETE

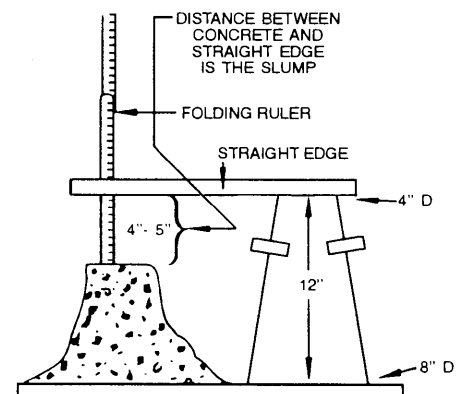
Quality concrete begins with the proper ingredients that are correctly measured and mixed. However, to ensure the quality of the finished product, the concrete mixture must be properly placed, finished, and cured. When shortcuts are taken at any step in the process, the strength and durability of the concrete decreases.

To mix, place, finish, and cure quality concrete, it is essential that enough help be available exactly when it is needed. Even with the use of power tools and equipment, the more concrete poured—the more help that will be needed. Tools and equipment should be obtained and moved to the job site before the concrete is mixed or delivered.

Once water is mixed with the cement and the concrete is placed, the hydration and hardening process is continuous. The construction foreman or boss can not just say, "time out, we're not ready" and expect the bleed water to stop forming or the concrete to stop hardening.

Even when adequate help is available, the placing, finishing, and curing procedures are often "hurry up and then wait." It is hurry and finish one procedure, then wait until the concrete is ready for the next. Trying to slow down or speed up the procedures can decrease the quality of the concrete.

Consistency is a measure of how wet or dry fresh concrete is after it has been thoroughly mixed. It is controlled by 1) the water-cement ratio of the cement paste, and 2) the amount of sand and gravel (aggregate) added to the cement paste. The consistency or **slump** of the concrete is an indication of how **workable** the wet concrete will be, or how easy it will be to place in the forms and finish.

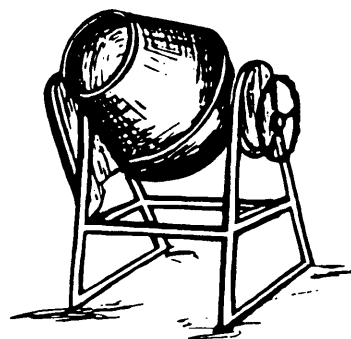


Conducting a Slump Test

The consistency or slump of freshly mixed concrete can be measured by a **slump test**. To conduct a slump test, a special cone is filled with freshly mixed concrete. The cone is 12 inches tall, 4 inches in diameter at the top, and 12 inches in diameter at the bottom. The concrete must be rodded or consolidated as the cone is filled to eliminate any voids. The cone is then slowly lifted off of the concrete and placed beside the pile. A straightedge is placed across the top of the cone.

The distance the concrete settles or "slumps" is measured from the top of the cone. The more the concrete slumps, the wetter the mix and the more workable it is. Unless the customer orders a different specification, most ready-mix concrete is delivered with an average consistency or a slump of approximately four inches. Concrete with a four-inch slump is normally workable enough for most situations.

For many jobs, small batches of concrete can be easily mixed in small portable mixers or in wheelbarrows to save time and money. However, a common mistake is to add all the sand, gravel, and cement at one time. Water is then added until "it looks about right." If the mixture ends up being too soupy, extra sand is added. When the mixture is too dry, more water is added. Little attention is given to the water-cement ratio and the strength of the concrete when it is cured.



To properly mix concrete in a small portable mixer, the following procedures are recommended:

- 1) Determine the capacity of the mixer and the proper amount of each ingredient needed per batch. Remember to adjust for any moisture in the sand. (Procedures for determining the amount of ingredients needed to mix small batches of concrete are discussed in student topic #s 8153-A and 8230-B.)
- 2) Add approximately 10 percent of the water to the mixer and start it turning.
- 3) Add approximately 95 percent of the gravel.
- 4) Add the remaining water.
- 5) Slowly add all of the cement. At this point, all of the cement and water have been added and the water-cement ratio should not be changed.
- 6) Slowly add approximately 95 percent of the sand.

- 7) Allow the concrete mixture to mix for several minutes until a uniform color and consistency is obtained. At this point, the mixture will probably be "soupy and wet." It may slosh as the mixer turns.
- 8) Slowly add small amounts of sand and gravel in the proper ratio to "decrease the slump." Always allow the concrete to mix thoroughly each time additional sand and gravel is added.

For an average slump or consistency, the concrete mixture should tumble and roll as the mixer turns. If the concrete continues to stick to the sides and is carried to the top before it drops, it is beginning to dry out. If the mixture becomes too dry, add water and cement in the proper ratio. Adding just water changes the water-cement ratio. This results in a weaker cement paste, which reduces the final strength of the concrete.

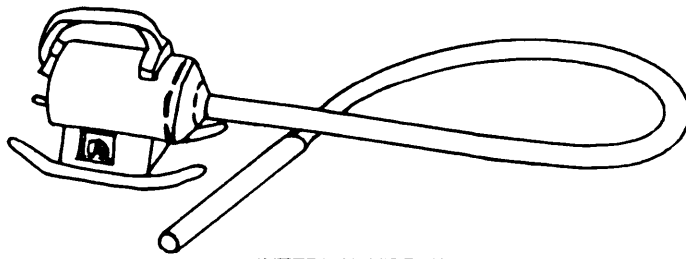
PLACING CONCRETE

Segregation of wet concrete is the excessive settling of the large aggregate to the bottom, which causes the smaller aggregate, rich cement paste, and excess water to rise. This can greatly reduce the quality and strength of the concrete. Segregation may be caused by: 1) allowing wet concrete to "free fall" more than two to three feet, 2) excessive consolidation or overworking the fresh concrete when it is first placed, and 3) using concrete with a very high slump.

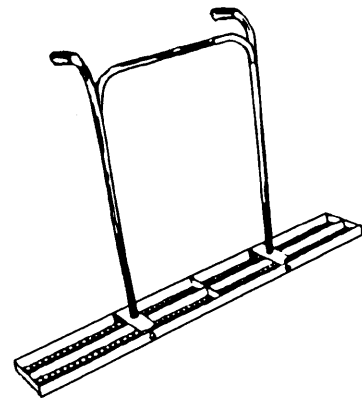
Concrete should be placed as close as possible to its final position. The further fresh concrete must be pushed, pulled, or dropped into position, the more segregation occurs. If concrete must be moved, use shovels, spades, or special concrete rakes. Avoid garden rakes. The wide teeth spacings will pull only the large aggregate allowing the smaller aggregate and cement paste to pass through.

Rods, shovels, pointed trowels, internal and surface vibrators, and jitterbugs are used to consolidate concrete as it is placed in forms. **Consolidation** is the settling of the wet concrete around and under the reinforcement steel and the gentle compaction of it to eliminate internal air bubbles or voids.

The less the slump (stiffer the consistency) and the larger the coarse aggregate used, the more difficult it is to place concrete and the more consolidation that may be required. **Caution!** Excessive consolidation can also lead to excessive segregation. Never consolidate concrete with a vibrator long enough for water to rise to the surface regardless of slump.



INTERNAL VIBRATOR



JITTER BUG

A jitter bug is used to hand consolidate large, flat surfaces such as sidewalks, slabs, and floors. As soon as the surface has been stuck off, a jitterbug may be gently tamped along the surface. This allows concrete with a lower slump to be used, which can be finished much quicker.

The small holes in the jitterbug allow some of the cement paste and finer aggregate to pass through. The coarsest aggregate is pressed down approximately one-half inch below the surface. Caution must be taken not to push the coarse aggregate too far down. Do not use a jitterbug on concrete with a slump of more than three inches. Overuse of the jitterbug can also cause excess surface bleed water.

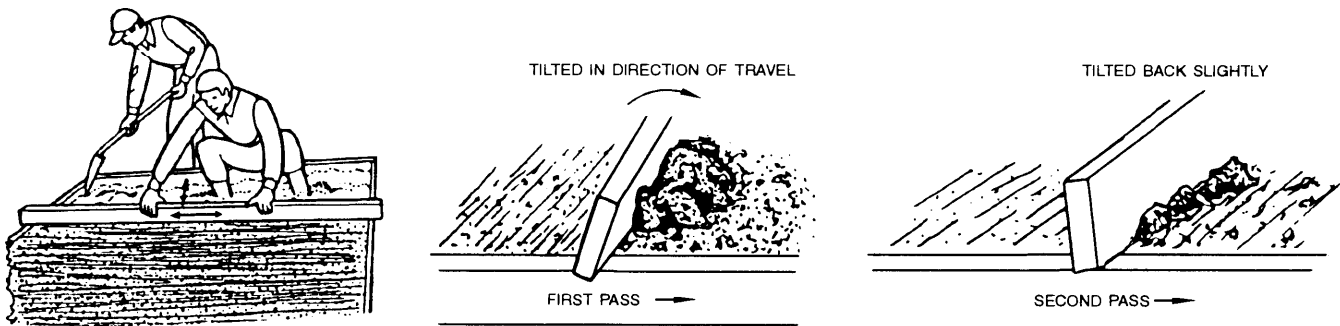
Only approximately one-half of the water added with the cement during mixing is immediately needed to start the chemical reaction. The additional water is added to increase workability of the concrete mixture. **Bleed water** is part of this extra water that rises (bleeds) to the surface as the concrete settles during placing and finishing procedures. The lower the slump or the more workable the concrete mixture, the more bleed water that will rise. Any finishing operation performed on the surface of a concrete slab while bleed water is present can cause serious dusting and scaling problems.

The initial bonding of the cement paste to the aggregate, rebar, and wire mesh begins within 30 minutes after concrete is placed. If any shifting of the forms or re-positioning of the reinforcement steel is required, it should be done while the concrete is being placed and consolidated. Any movement of the forms or reinforcement from this time until the concrete has hardened can cause the bond to break and seriously reduce the strength.

CONCRETE FINISHING PROCEDURES

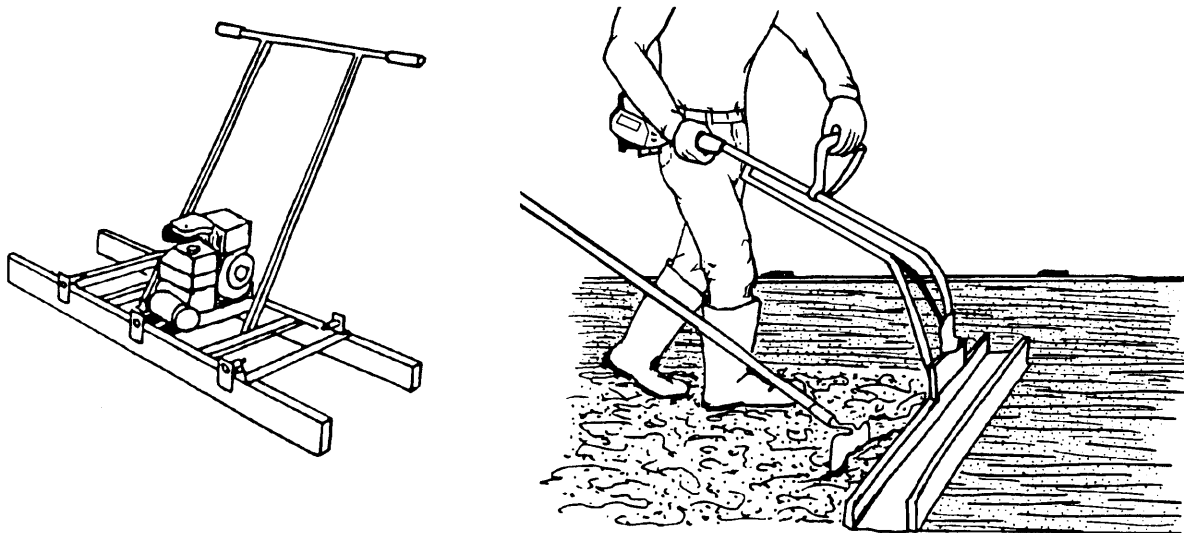
Concrete finishing procedures should start immediately after concrete is placed in the forms and consolidated before bleed water begins to rise. The first finishing procedure is **screeding** or **striking off**. This step begins to smooth the surface and bring it to the proper grade.

A **hand screed** is a long straightedge made of a 2"x4" or 2"x6" board, or special aluminum or magnesium tubing. The screed is pulled back and forth across the concrete surface in a sawing motion. A small amount of concrete should be kept in front of the screed as it is moved across to fill in any low spots. Two passes are usually made. The first is made with the screed tilted slightly in the direction of travel. The second is made with the screed tilted slightly to the back as it is moved forward.



Screeding the Surface

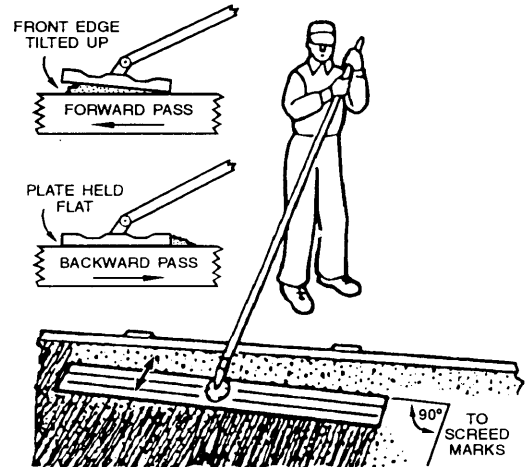
When large flat concrete surfaces are poured, consolidating and screeding are often combined into one operation by the use of vibratory or roller screeds. Surface vibrator/screeds such as those shown can be used to save time and labor.



Engine Powered Surface Vibrator/Screeds

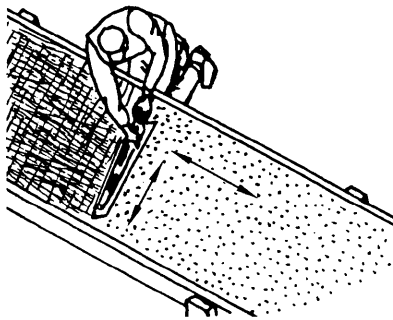
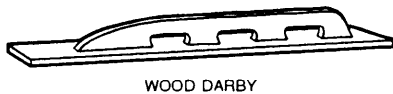
The second step in finishing is **bullfloating** or **darbying**. This step is performed to 1) smooth small ridges left by the screed, 2) embed the coarse aggregate slightly below the surface, and 3) bring just enough cement paste to the surface for final finishing procedures. Bullfloating and darbying are actually the same procedure, but can be performed with two different tools.

Bullfloats are made of wood, aluminum, or magnesium plates 8" wide and 36" to 60" long. They are equipped with screw-on handle sections, which allow a person to reach 20 feet or more across large slabs. The bullfloat is pushed away with the plate tilted so that the front edge is held off the surface slightly. It is then pulled back in the flat position following the same path. One forward pass and one backward pass is normally all that is required.



Bullfloating Concrete

A **darby** is a wood or light metal float 3" to 5" wide and 3' to 8' long. A darby is hand operated in a flat sawing motion while it is moved across the slab from side to side or in a long sweeping arc. A darby is used on smaller slabs or where the long handle of a bullfloat will not allow it to be used.

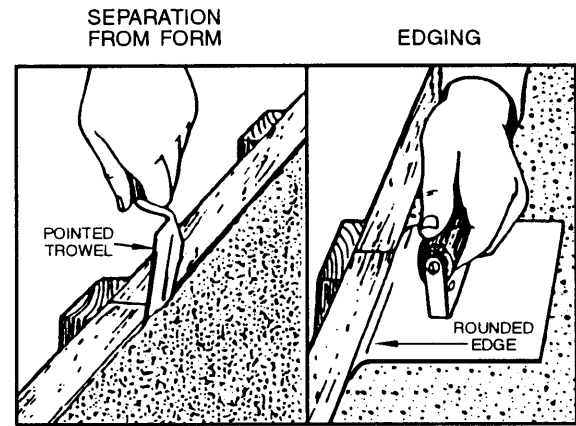


Darbying Concrete

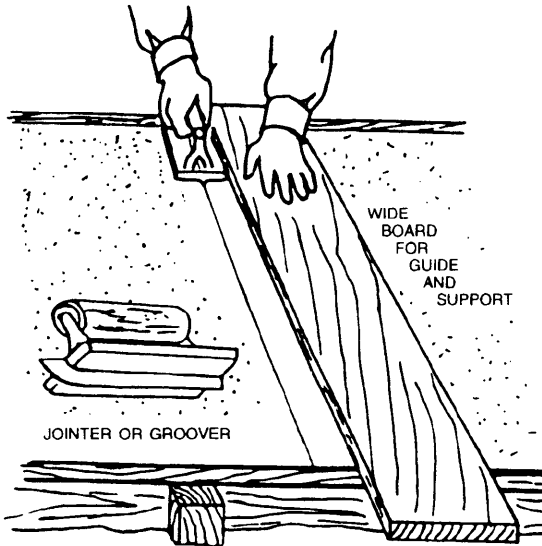
It is of utmost importance that bullfloating or darbying be performed immediately after screeding before any bleed water has bled to the surface. If possible, bullfloat or darby at right angles to the direction of the screeding to help remove small ridges. A smaller hand float can be used on irregular shaped surfaces and around obstructions.

Do not be tempted to make multiple passes with the darby or bullfloat to try to get the surface perfectly smooth. "Overworking" the concrete at this time can mix any rising bleed water with the cement paste on the surface. This can reduce the water-cement ratio of the cement paste on the surface. Overworking at this time can also pack and seal the surface. This can trap additional bleed water right under the surface as it rises. Both conditions can cause serious dusting and scaling problems later.

The next step in finishing concrete is **edging** and **cutting control joints**. A pointed trowel is used to separate the concrete from the forms. An **edging tool** is then pulled back and forth along the edge to produce a slightly rounded edge.



Edging a Concrete Slab



Cutting a Typical Control Joint

A simple method of cutting control joints is to lay a wide board across the fresh concrete. A person can crawl on the board and use it to guide the groover. Once bullfloating, edging, and the cutting of control joints are completed, the concrete should set undisturbed until all bleed water has risen to the top and evaporated.

Final Finishing Procedures

Final finishing procedures should not start until the "shiny water sheen or glossy appearance" has disappeared. The surface will have hardened enough so that the weight of a person standing on it leaves only a slight imprint. The length of time for this to occur will vary with the temperature, humidity, wind, and the admixtures used in the concrete.

Final finishing procedures begin with final floating. **Final floating** is not to be confused with bullfloating that follows the screeding. Final floating is done 1) to further embed coarse aggregate, 2) to smooth any ridges or tool marks from the darby, bullfloat, or edging and control joint tools, and 3) to begin to compact the cement paste for the final finish.

Final floating can usually start around the outer edges first. This is because concrete hardens around the outer edges next to the forms first. By stepping and/or kneeling on **kneeboards**, (2' x 2' pieces of plywood) a concrete finisher can work on across the slab to hand float without making impressions in the surface.

Again, do not overwork the surface or begin hand floating too soon. A slight water sheen or glossy appearance will usually reappear as hand floating continues. If bleed water begins to come to the surface, wait a few minutes and allow it to evaporate before proceeding.

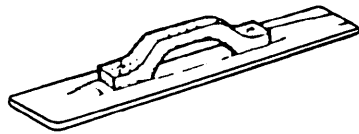
Air entraining agent is an admixture commonly added to concrete to increase its quality and durability. When an air entraining agent is used, the amount of water that must be added to a given mixture and maintain the same slump or workability is also reduced. This decreases the amount of bleed water that will come to the surface.

Because there is less bleed water with air entrained concrete, the shiny water sheen or glossy appearance may appear quicker, may appear for a shorter period of time, or may not appear at all. This is especially true when finishing air entrained concrete in hot, dry, or windy weather. Any bleed water that rises will usually evaporate immediately. If air entraining agents are used, carefully monitor the surface hardening along with surface bleeding to determine when to continue finishing procedures.

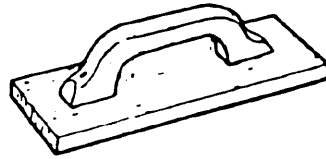
Air entrained concrete may seem "stickier" than regular concrete because less water is used. When finishing air entrained concrete, aluminum or magnesium tools are recommended because they will slide over the sticky surface more easily. The fibers of a wooden darby, bullfloat, or hand float will have a tendency to drag and produce a rougher surface.

Hand floats are made of wood, magnesium, or aluminum. They are usually 3½" to 4½" wide and 12" to 18" long. A hand float is held in a flat position and moved in a slight sawing action in large sweeping arcs. Magnesium or aluminum hand floats will produce a fairly smooth surface, while a wood float will produce a slightly rough, skid-resistant texture.

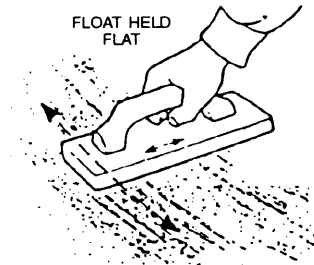
For some purposes, a hand float finish is the final desired finish. It may be necessary to reshape the control joints and edges during final finishing procedures.



MAGNESIUM FLOAT



WOOD FLOAT

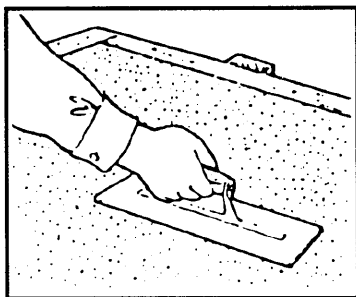


FLOAT HELD
FLAT

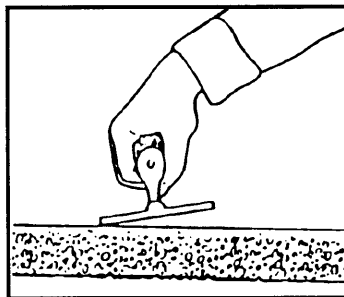
HAND FLOAT
WITH SLIGHT
SAWING-SWEEPING ARC

If a smoother, hard dense finish is required, **troweling** should follow the final hand floating. Hand trowels are made of thin steel blades 3" to 4¾" wide and 12" to 20" long. The short narrow trowels are used by experienced finishers for an extremely smooth finish.

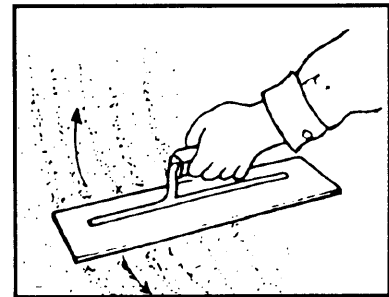
Troweling should be delayed as long as possible without letting the surface completely harden. **Scaling** and/or **dusting** of the concrete surface can be caused by troweling concrete when it is too wet. Hand troweling is done with long sweeping arcs with each pass overlapping by approximately one-half the length of the trowel. On the first passes, the trowel is held in a flat position to prevent "washboarding." As troweling progresses and the cement paste packs and hardens, the trowel can be tilted slightly. The final passes should produce a sharp ringing sound in the steel trowel.



FIRST TROWELING -- FLAT

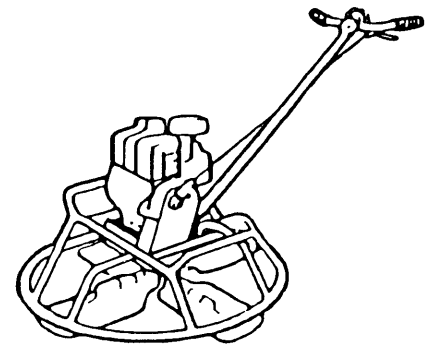


FINAL TROWELING -- TILTED



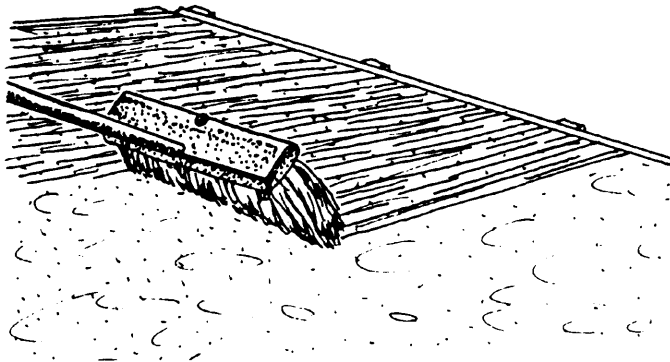
MAKING ARC SWING WITH TROWEL

Power floats and **trowels** are often used to speed the finishing process on large slabs. Again, do not begin the floating and troweling procedures too quickly or overwork the surface. Many flaking, scaling, and dusting problems can be traced to improper finishing procedures.



Power Trowel

Smooth floated or troweled finishes are extremely durable and easy to clean. However, they may be too slick for many agricultural applications especially when they become wet. A nonslip surface can be obtained by **brooming** the surface after it has been hand floated and troweled.



Applying a Broom Finish After Troweling

A broom or brush can be pulled across the surface to "roughen" the cement paste. By varying the bristle size and stiffness, and the amount of pressure applied on the broom, different textures can be obtained. Care should be taken not to pull the aggregate loose.

CONCRETE CURING PROCEDURES

The hardening of concrete is not a drying process as many people may believe. Rather, it is a chemical reaction between the cement and the water called **hydration**. The cement and water bonds or "glues" the sand, gravel particles, and any reinforcement steel together to form the concrete structure. The hydration and hardening process begins approximately 30 minutes after the mixture is placed.

Research has shown that the longer the hydration process continues, the stronger the concrete will be. However, the hydration process can continue only as long as there is adequate moisture to complete the chemical reaction and the proper temperature is maintained. The most desirable temperature for the hydration of concrete is between 50 and 75°F.

At lower temperatures, the hydration process is slow and incomplete. Below freezing (32°F), hydration all but stops. Concrete that is allowed to freeze during the first 24 hours after it is placed will be permanently damaged. It will gradually crumble and flake away.

If concrete must be poured during cold or freezing temperatures, it must be protected from freezing with some type of heat. Chemicals called accelerators and special high early-strength cement can be added at the ready-mix plant. However, these chemicals and the special cement only speed up the initial set. They do not keep the concrete from freezing.

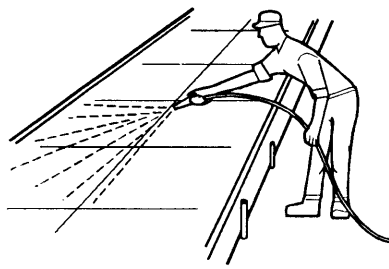
At higher temperatures, concrete can set too fast. This can stop the hydration process on the outer surface while it continues in the middle. All of the "gel or glue" that should be created does not have time to form and harden. Concrete contracts slightly as it dries. High winds and high air temperatures cause rapid evaporation of surface moisture. Tiny **craze cracks** are caused by rapid drying and shrinkage of the rich cement paste on the top surface of the slab.

Curing is the process of controlling the rate of hydration of concrete. Curing not only increases the strength, but the durability, watertightness, and wearability of concrete as well.

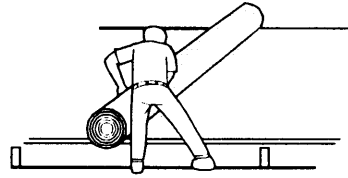
The first step in curing should actually be completed before the concrete is placed. The subgrade should be thoroughly moistened with water before the concrete is placed. This will prevent the dry sand and/or gravel subgrade from absorbing moisture from the wet concrete.

Moist curing is the practice of adding additional water back to the surface of green concrete and/or controlling surface evaporation. **Green concrete** is concrete that has gone through the initial surface hardening and is still in the hydration process. Various methods of moist curing concrete include:

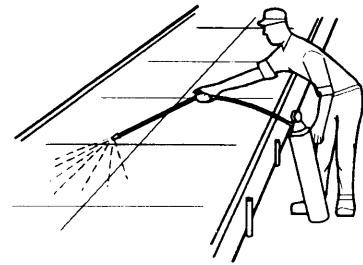
- * continuously spraying the concrete surface with a fine mist of water,
- * covering the concrete surfaces with plastic sheets; water proof paper; or wet burlap, straw or sand, and
- * spraying concrete surfaces with a chemical curing compound, which provides a thin waterproof membrane.



SPRAYING FINE MIST OF WATER



COVER WITH PLASTIC, WET BURLAP,
OR WATER PROOF PAPER



SPRAYING CHEMICAL CURING COMPOUND

Methods of Moist Curing Concrete

A common question is, "If water is to be applied to the green concrete surface, will it wash off the cement paste and/or raise the water-cement ratio?" The answer is no if the extra water is not applied until after the surface of the concrete has gone through the initial set and hardening.

Water, covering, or curing compounds can usually be applied just after the final finishing procedures have been completed. Time should be allowed for any "water sheen or glossy appearance" that may have developed during final troweling or finishing to disappear. The length of time will vary with 1) temperature, 2) wind conditions, and 3) the slump of the concrete when it was placed. Concrete that is moist cured for 7 days can be up to 50 percent stronger than concrete that is allowed to dry rapidly during hot dry weather.

FORM REMOVAL

Concrete will normally harden so that forms can be removed within two to three days. Although it may seem hard, the concrete mixture has only reached approximately 50 percent of its potential strength in the first three days. Care should be taken not to chip or break the corners or edges. Do not try to pry against the green concrete to remove the forms.

Within reason, the longer forms are left in place, the longer the edges are protected and the longer the hydration process is likely to continue. In cold weather, the forms may help hold in part of the natural heat generated by the hydration process and prolong curing. In hot, windy weather, leaving forms in place may prevent rapid evaporation of moisture around the edges.

SAFETY WHILE WORKING WITH WET CONCRETE

Extreme caution must be exercised while mixing, placing, and finishing concrete. Wet cement paste and bleed water are caustic. **Caustic** means capable of corroding, burning, or dissolving. Wet cement paste and bleed water can cause severe skin irritation and burns in some people. Second- and third-degree skin burns have been reported even when people have had skin contact with wet concrete for only a short period of time.

Exposure can occur when someone has direct contact with bleed water and wet cement paste with their hands. It can also occur when gloves, trousers, and/or shoes and socks become wet and saturated. The clothing holds the caustic cement paste or bleed water in constant contact with the skin. The caustic juices slowly penetrate and destroy the skin. Unfortunately, the skin burn occurs gradually without warning. Pain may not be felt for several hours and may not become severe for days.

For years, most cement sacks have shown precaution statements such as: "May cause skin irritation." Many people do wear gloves and boots while working with wet concrete. However, they may not realize the danger of allowing clothing to become wet and saturated. Perhaps they forget to protect their knees and legs from bleed water and cement paste when kneeling to screed, float, or trowel fresh concrete.

Some people in the concrete industry now suggest a bold more appropriate statement such as: **"WARNING: FRESH CONCRETE CAN CAUSE SEVERE, LIFETIME THIRD-DEGREE BURNS. PROTECT SKIN FROM EXPOSURE BY USE OF WATERPROOF CLOTHING!"**

REFERENCES

- White, George, *Concrete Technology*, Delmar Publishers, Inc., Albany, NY.
Ahrens, Donald, *Concrete and Concrete Masonry*, Hobar Publications Inc., St. Paul, MN.
Hine, William, *Concrete Construction*, The Aberdeen Group, Addison, IL.
Cement Mason's Guide to Building Concrete Walks, Drives, Patios, and Steps, Portland Cement Association, Skokie, IL.

Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

Fill-In-The-Blank: Complete the following statements by inserting the correct word(s) in the blanks.

- _____ 1. _____ is the water that rises to the surface as the concrete settles during placing and finishing procedures.
- _____ 2. _____ or _____ is a measure of how wet or dry fresh concrete is after it has been thoroughly mixed.
- _____ 3. The consistency or slump of wet concrete is an indication of how _____ it will be.
- _____ 4. _____ of wet concrete is the excessive settling of the large aggregate to the bottom causing smaller aggregate, rich cement paste, and excess water to rise.
- _____ 5. _____ is the settling of the wet concrete around and under reinforcement steel and the gentle compaction of it to eliminate internal air bubbles or voids.

SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph. (Use additional paper when needed.)

6. Briefly explain two methods of how the consistency of fresh concrete is controlled.
 - a.
 - b.

7. Briefly discuss three common causes of segregation in wet concrete.
 - a.
 - b.
 - c.
8. When should final floating procedures be started?
9. Explain why direct skin contact with wet concrete and bleed water can be harmful.

TRUE OR FALSE: Circle "T" if the statement is more true than false. Circle "F" if the statement is more false than true.

- T F 10. When properly mixed in a small portable mixer, concrete should tumble and roll to obtain an average slump or consistency.
- T F 11. When finishing air entrained concrete, it is recommended that aluminum or magnesium finishing tools be used.
- T F 12. The hardening of concrete is actually a chemical reaction called hydration rather than a drying process.
- T F 13. Moist curing concrete will increase its strength, durability, watertightness, and wearability.
- T F 14. Scaling and/or dusting of the concrete surface can be caused by troweling concrete when it is too wet.

ARRANGE IN ORDER: Arrange the following procedures for mixing concrete in a small portable mixer in the proper order by inserting the correct number in the blanks provided.

- _____ 15. Add approximately 10 percent of the water to the mixer and start it turning.
- _____ 16. Add approximately 95 percent of the gravel.
- _____ 17. Determine the capacity of the mixer and the proper amount of each ingredient needed per batch.

- _____ 18. Slowly add all of the cement. At this point, all of the cement and water have been added and the water-cement ratio should not be changed.
- _____ 19. Allow the concrete mixture to mix for several minutes until a uniform color and consistency is obtained.
- _____ 20. Slowly add small amounts of sand and gravel in the proper ratio to "decrease the slump." Always allow the concrete to mix thoroughly each time additional sand and gravel is added.
- _____ 21. Add the remaining water.
- _____ 22. Slowly add approximately 95 percent of the sand.

ADDITIONAL SKILLS AND ENHANCEMENT ACTIVITIES: Perform the following activities as assigned by your instructor.

1. Observe different types of concrete structures. Determine if any failures may have occurred because of improper placing, finishing, and curing procedures.
2. Visit the construction site of an agricultural structure in your community. Observe different procedures and equipment used to mix, place, finish, and cure concrete. **Note!** This activity will require prior approval by the property owner and construction supervisor.
3. Demonstrate the ability to mix concrete in a small portable mixer.
4. Demonstrate the ability to place, finish, and cure concrete.

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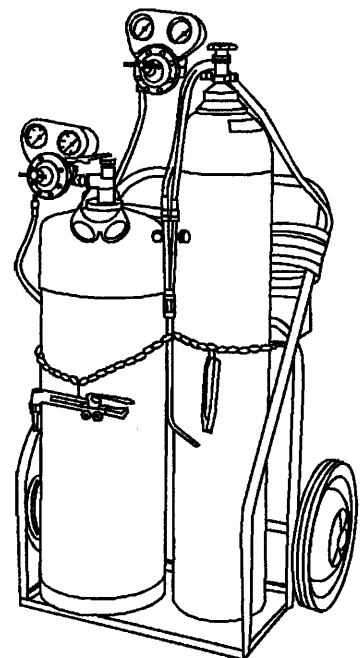
OXYFUEL CUTTING AND WELDING PRINCIPLES AND PROCEDURES

The term **oxyfuel** is a shortened name for the use of a mixture of pure industrial oxygen and one of the industrial fuel gases to produce a high temperature flame. **Oxyacetylene** is the common name for the use of the combination of industrial oxygen and industrial acetylene gas. Other industrial fuel gases used in the welding and cutting profession include Mapp® gas, liquefied petroleum, and natural gas. In this topic, industrial oxygen will be referred to as oxygen. Please see the section on Types of Oxygen and Fuel Gases for an explanation of the difference between oxygen and industrial oxygen.

In order to maintain safety and insure oxyfuel cutting and welding quality, it is necessary for the student to thoroughly understand the principles of operation. It is not enough to know the proper operating procedures, one must also know the fundamental physical and chemical relationships of the materials used in the cutting and welding processes.

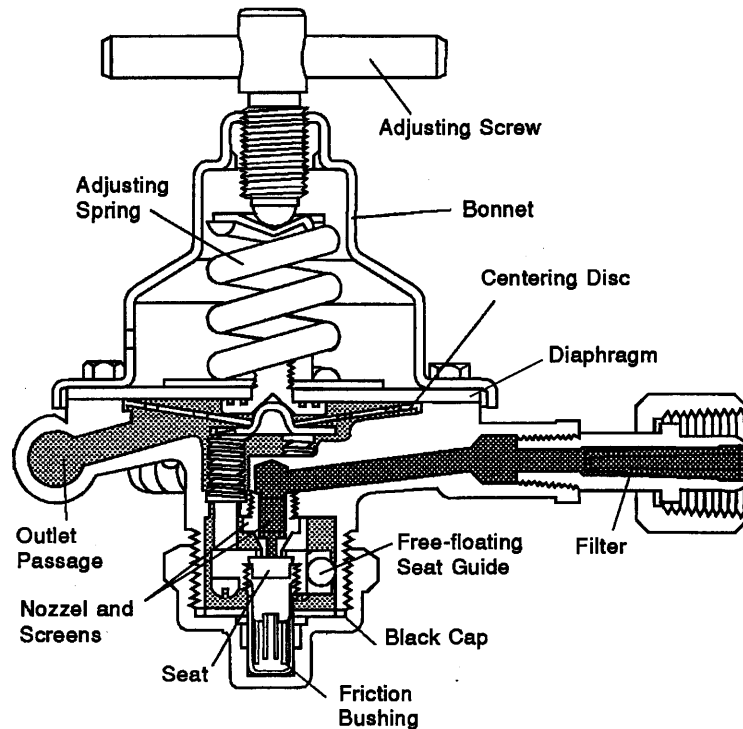
OXYFUEL CUTTING AND WELDING EQUIPMENT

Oxyfuel equipment is used as a heat source for the fusion, welding, brazing, cutting, and heating of metals. The major parts of a portable oxyfuel cutting and welding system include: a cylinder truck to secure and move cylinders, gas cylinders, regulators with gauges, hoses, reverse-flow check valves, and/or flash back arrestors, torch handle assembly, welding tips, and a cutting or welding head attachment.



Regulators

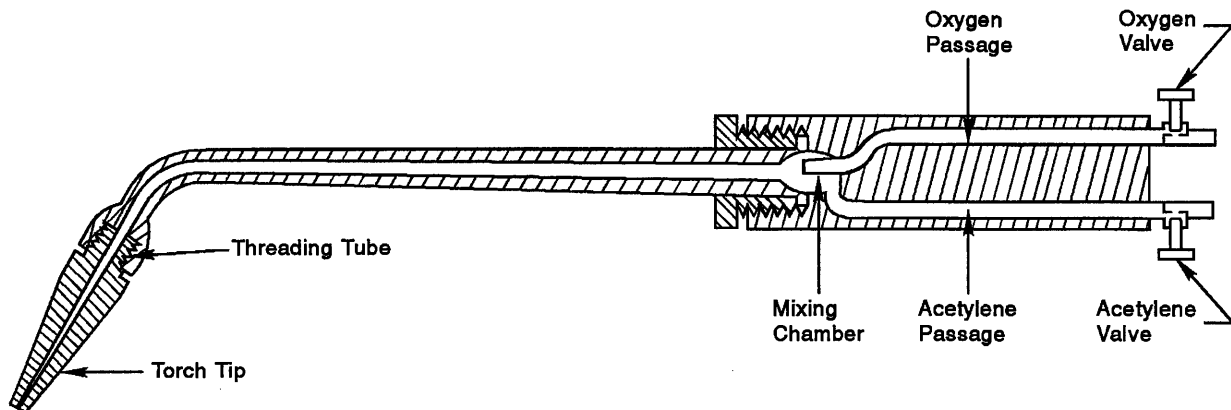
The **regulator** is a mechanical device which reduces the high pressure of the gas in the cylinder as it flows from the cylinder to the torch body during the welding or cutting process. The operator can rotate the **adjusting screw**, located on the regulator, to change the pressure at which the gas is delivered to the torch body. In addition to pressure reduction, the regulators provide a steady flow of gas at a constant pressure from the cylinder.



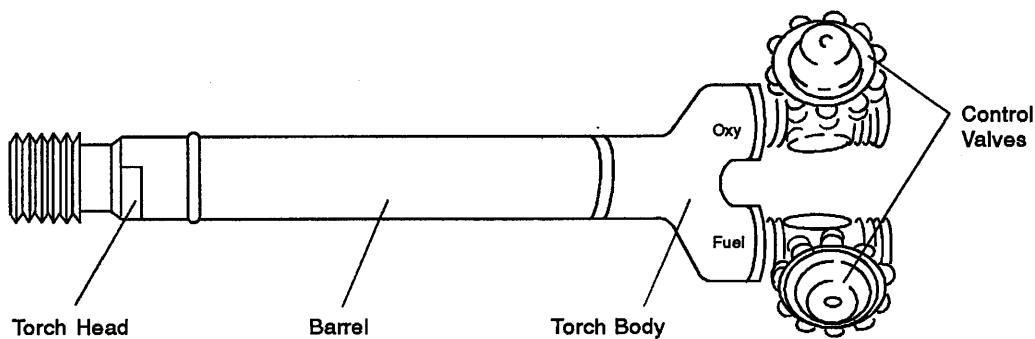
Single Stage Regulator

Regulators are equipped with two pressure gauges. The cylinder pressure gauge is connected to the regulator between the regulator nozzle and the cylinder valve. When the cylinder valve is open, the pressure gauge registers the cylinder pressure or **static pressure** of the gas inside the bottle. Another pressure gauge is connected between the diaphragm chamber of the regulator and the hose leading to the torch body. This gauge indicates **working pressure**, the dynamic pressure registered by the gauge during the use of the torch body. The gauge that shows the working pressure on the acetylene regulator should be marked in red above the **15 psi mark** on the dial face. This is a safety reminder to the operator that working pressure of acetylene should *never* be more than 15 psi. When installing a regulator, the gauges should face upward to prevent personal injury if the regulator or gauges burst and fly apart.

Torch Body

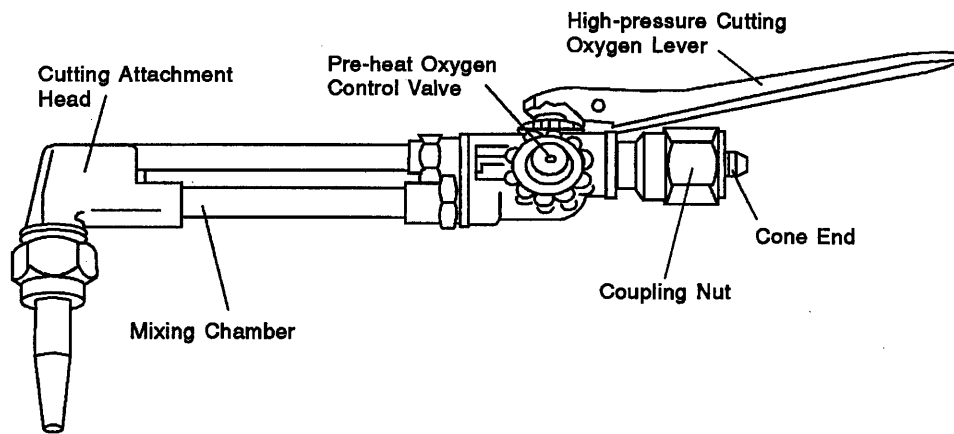


The **torch body system** has internal and external components. The internal components consist of a mixing chamber, oxygen and acetylene passages, and gas needle valves. The control valves on the torch body govern the volume of oxygen and fuel gas that is provided to the torch tip. All internal parts of oxyfuel cutting and welding equipment are precision units and should be serviced and repaired by trained personnel.



Typical Torch Body

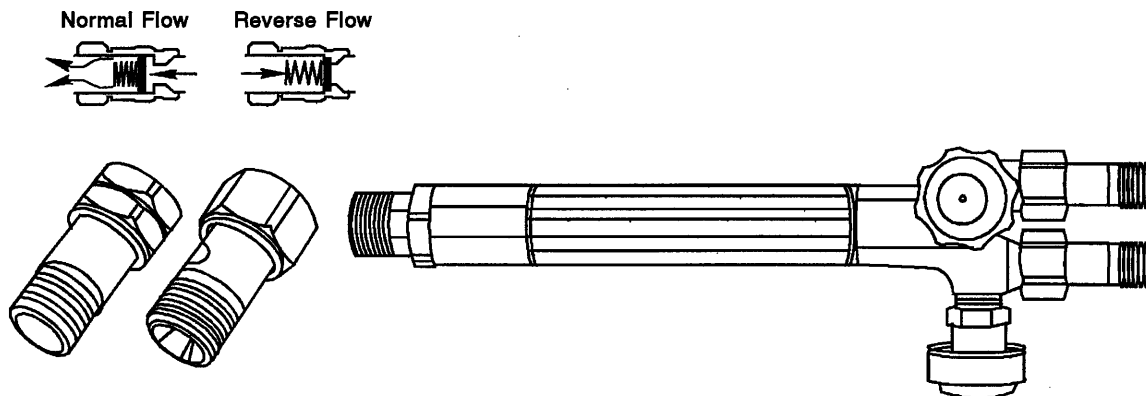
External components of the torch body consist of gas valve handles, threads for welding or cutting tip attachments, gas hose connections, and a hand hold for the operator. The type of tip attached to the body governs the mixing of the two gases in the mixing chamber. The cutting torch attachment allows some of the gas to mix while keeping a portion of the oxygen separate so it can be used for the oxygen jet stream. Unlike the cutting attachment, the welding tip mixes both gases equally. Tips are discussed in another section.



Welding and Cutting Attachments

Reverse Flow Prevention

A **reverse-flow check valve** prevents the reverse flow of gas through the torch, hose, and regulator. They are fairly inexpensive and consist of a spring-loaded ball or plate with a sealing surface. Check valves are available for both the oxygen and fuel gas systems, and can be installed at both the torch inlet fittings and the regulator outlet fittings. Gas pressure from the correct direction pushes the valve open, allowing gas flow. When gas flow stops or pressure develops from the opposite direction, a spring instantly pushes the valve onto its seat to stop the reverse-flow of gas. Reverse-flow check valves do not always prevent flashback fires from occurring, but they reduce the risk of such a malfunction. Some newer models of oxyfuel torch bodies have built-in reverse-flow check valves.



Flashback arrestors are more expensive check valves and are specifically designed to help eliminate the risk of an explosion in a hose, regulator, or cylinder. Newer styles of flashback arrestors are a combination of: 1) a heavy duty reverse-flow check valve; 2) a pressure sensitive cut-off valve that stops gas flow in the event of an explosion in the torch body or hoses; 3) a thermal cut-off valve that can instantly stop gas flow when the arrestor temperature rises above 220°F, and 4) a stainless steel filter that stops an internal flame.

Currently all agencies and businesses who operate under the Occupational Safety and Health Administration (OSHA) regulations are required to install flashback arrestors on all oxyfuel cutting and welding equipment. It is strongly recommended that reverse-flow check valves and flash back arrestors be installed on all oxyfuel equipment owned by individuals and other small businesses who do not fall under official jurisdiction of OSHA. Check with you local welding equipment supplier for current regulations.

Oxygen and Fuel Gas Storage Cylinders

All fuel gas, inert gas, and oxygen storage cylinders are manufactured to meet Interstate Commerce Commission (ICC) and Department of Transportation (DOT) specifications. Storage cylinders are made of thick, high-carbon armor-plate steel. For additional safety, gas suppliers are required to periodically inspect and pressure test all cylinders before they can be refilled. Oxygen cylinders are available in seven sizes, ranging from 20 to 300 cu ft. The most common size used is **244 cu ft**. Acetylene cylinders are available in sizes from 10 to 390 cubic feet and will be discussed in the next section.

A full oxygen cylinder will have from 2,000 to 2,600 psi of pressure. If an oxygen cylinder valve should become accidentally damaged or broken-off, the high pressure oxygen will escape rapidly, possibly injuring anyone nearby and damaging equipment. There is enough pressure in a cylinder to propel it, making it an uncontrollable missile. For safety, all high-pressure storage cylinders must be properly attached to a secure object *before* the protective caps are removed. If a portable cylinder truck is used, it must be designed to hold the cylinders securely and resist tipping.

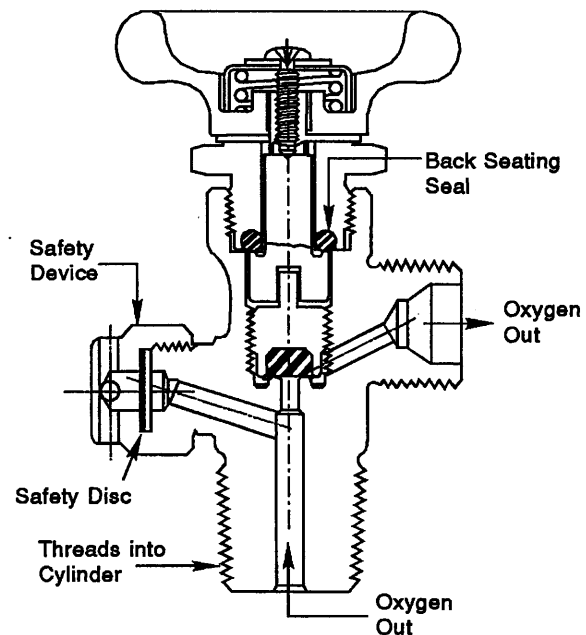
Cylinder Valves

Cylinder valves are made of forged brass to prevent the possibility of sparks. The upper body of oxygen and most other industrial gas cylinders are equipped with large external threads. A steel cap is screwed down over the cylinder valve to protect it during storage and shipment. Instead of a screw-on cap, some fuel gas cylinders are equipped with a steel collar that is permanently-attached around the cylinder valve to protect it from damage.

There are two types of handles used on fuel gas cylinder valves. The newer is a hand wheel that is permanently attached to the valve stem. An older type is a special 3/8" box-end wrench handle that must be placed over the square shank of the cylinder valve stem. *Always* leave the special wrench handle in place while the cylinder valve is open and the system is being used. When the valve is closed, remove the special wrench handle. Do not attempt to use an adjustable end wrench or pliers for opening and closing a 3/8" square-shank acetylene cylinder valve.

Back Seating Cylinder Valve

Oxygen cylinders are equipped with a special **double seating** or **back seating** valve. When the valve is opened completely, the upper end or "back side" of the valve stem seals. This prevents high pressure oxygen from leaking out around the valve stem while the valve is open. Thus, an oxygen cylinder valve should never be used in the partly opened position.



Cylinder Safety Valves

A high pressure **pop-off safety valve** is located on the side of the oxygen cylinder valve. If the cylinder pressure should start to increase above safe limits, a special disc inside the safety valve will burst. This allows the excess pressure to be released slowly, before an explosion can occur.

Acetylene cylinders are equipped with **safety plugs** that are filled with a special lead alloy. The center of the plug is designed to melt if heated above 212°F. This allows acetylene gas to escape slowly, thus preventing an explosion.

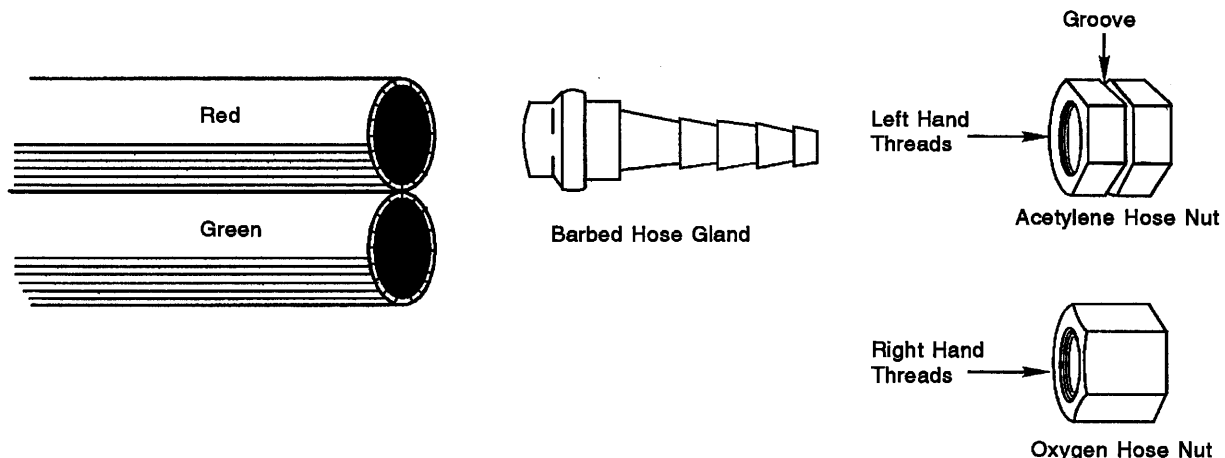
Cylinder Identification

All cylinders must be properly labeled as to their contents. Compressed gases are potentially dangerous if improperly mixed or incorrectly used. If a label is missing or is not readable, return it to your supplier for gas content identification. Presently, there is not a standardized color code for cylinders or their content.

Oxygen and Fuel Connections

To prevent an incorrect regulator from being attached to the outlet fitting, oxygen cylinders have right-handed male-threads while the outlet fitting on the fuel gas cylinders have left-handed female-threads. This difference helps operators distinguish between oxygen and fuel cylinders and prevents errors during hook-up. The outlet fitting on an inert gas cylinder has right-handed female-threads.

All regulator inlet connections, torch and hose fittings, and cylinder valves should conform to specifications and standards set by the Compressed Gas Association (CGA). Fuel gas connections and fittings with left-handed threads are easily identified by a “v” notch or groove machined on the outside of the fitting. All oxygen connections have right-hand threads. ***Do not*** attempt to replace or modify any connections or fittings on cylinders, regulators, torches, or hoses in order to use them for a different type of gas.



Oxygen and Fuel Gas Hose

Oxyfuel cutting and welding hoses are made of a special non-porous rubber. They are usually color coded for gas service identification. Oxygen hose is green or black while fuel gas hose is red. The two hoses are usually webbed together. The hoses are sized by the measure of their inside diameter (ID). Common sizes are 3/16", 1/4", and 5/16". As the velocity and volume of gas traveling inside the hose increases, so does the friction between the gas and the wall of the hose. Therefore, just as in water pipe sizing, one must use appropriately sized hose to insure the proper volume of gas is delivered to the torch body.

TYPES OF COMPRESSED OXYGEN AND FUEL GASES

Oxygen is a colorless, odorless, and tasteless gas. Oxygen itself is not flammable. However, because oxygen supports combustion, a small flame will transform into an intense fire if pure oxygen is added. Oxygen molecules are separated from other gases (purified) and compressed allowing manufacturers to place a significant amount into a bottle. There are two main types of compressed oxygen cylinders sold: 1) **industrial oxygen** for use in the oxyfuel cutting, heating, and welding processes and 2) **breathing oxygen** for medical purposes, passenger aircraft, and scuba diving. Never use industrial oxygen for breathing purposes or cylinders marked industrial oxygen for storing and transporting breathing oxygen.

Acetylene gas is a highly combustible industrial fuel gas and is the most commonly used. Acetylene produces the hottest flame, as the inner cones of a neutral flame average approximately 5,720°F. Acetylene is preferred for oxyfuel welding because it produces a cleaner weld and the flame is easier to control. Pure acetylene is colorless and odorless. However, for safety reasons, an additive that has a distinct pungent, garlic-like odor is mixed with acetone. Any time you smell this odor, you should suspect a leak in the system and assume there is unburned acetylene in the surrounding area. Acetylene is heavier than air, therefore upon escaping into the atmosphere, the molecules will settle to the floor or to the lowest possible area.

Acetylene gas becomes very unstable when compressed above 15 psi in an open cavity. For safety, it must be stored in specially designed cylinders that are filled with a porous, sponge-like material. The material decreases the size of the open space inside the cylinder and is saturated with liquid acetone.

The liquid acetone absorbs the acetylene gas as it is pumped into the cylinder. Thus, acetylene can be safely stored at pressures up to 250 psi. By theory, the acetylene molecules fit in between the acetone molecules and prevent large pockets of acetylene gas.

An acetylene cylinder *must always* be used in the upright position. If a cylinder is laying over on its side while the cylinder valve is open, liquid acetone will flow out with the acetylene gas into the regulator, hose, and torch assembly. This can create a potentially dangerous condition and cause damage to the equipment. If an acetylene cylinder has been stored or transported on its side, it must be allowed to stand upright for at least 30 minutes before use. This will allow time for the acetone to settle back to the bottom of the cylinder. An oxyacetylene flame that is burning acetone will exhibit a purplish tint.

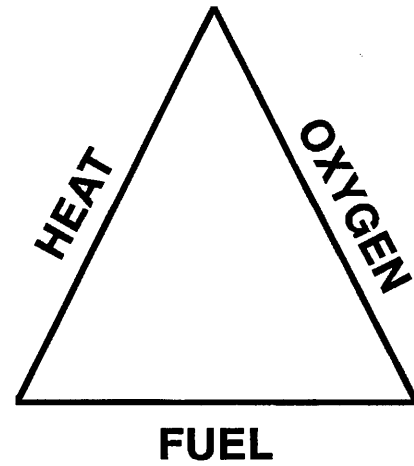
Mapp® gas is a trade name for stabilized methylacetylene-propadiene. The inner cones of an oxy-Mapp® gas flame average approximately 5300°F. In some industrial applications, such as underwater metal cutting processes, Mapp® gas is preferred over acetylene because it creates a very liquefied slag that blows away easily. Mapp® gas can be safely used at working pressures much greater than 15 psi. Except for different storage cylinders and cutting tips, the same regulator and other torch equipment used with acetylene can be used with Mapp® gas.

Liquefied Petroleum, LP, or Propane gas is stored in steel cylinders in a liquid form near 250 psi. Liquefied petroleum vaporizes into a gaseous state as the pressure is diminished when it flows through a pressure regulator and into the fuel gas hose. LP has a lower flame temperature, with the inner cone of a neutral flame averaging only 4,550°F. By installing a special cutting tip, LP gas can be used with most oxyfuel cutting torches. LP gas is rarely used for welding, but is more commonly used for cutting, soldering, and brazing. LP gas and Mapp® gas have less tendency to cause back fires because they have more stability as a fuel gas than acetylene.

Natural gas is not popular as a fuel gas for welding. The inner cone of a neutral flame averages 4,600°F. Supply of the gas is limited to buildings that are serviced by a gas pipeline from a public utility company. The pipeline must be protected with a special water-seal, back-flow valve. This helps prevent the possibility of oxygen and/or air from back firing or back flowing into the gas supply line. Natural gas is used for cutting, soldering, brazing, and preheating in some industrial applications.

THE OXYFUEL CUTTING PROCESS

Recall from your science courses the three parts of a fire triangle: 1) fuel, 2) oxygen, and 3) heat. To produce a fire, all three components must be present at the same time. Remember, oxygen is not flammable, but it is required to support the burning process. **Kindling temperature** is the temperature at which a combustible material must be heated before it will begin to burn.

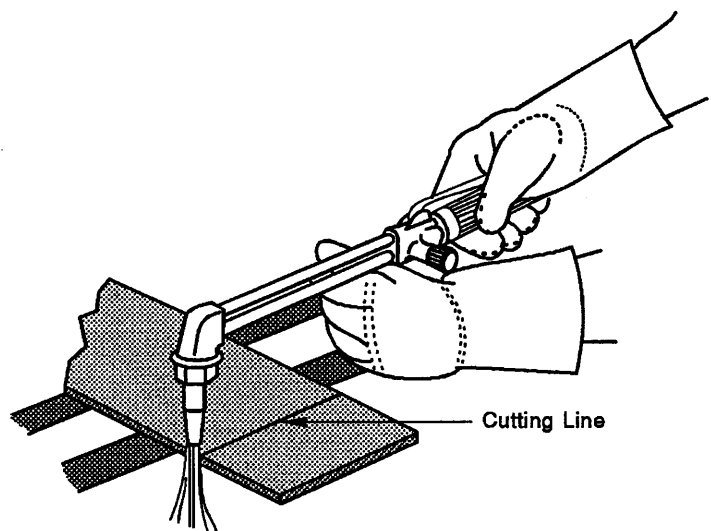


Fire Triangle

Different combustible materials have different kindling temperatures. If the temperature of a combustible material remains at or above its kindling temperature and adequate oxygen is supplied, the material will continue to burn. If the temperature drops below the kindling temperature *or* the supply of oxygen is removed, combustion will stop.

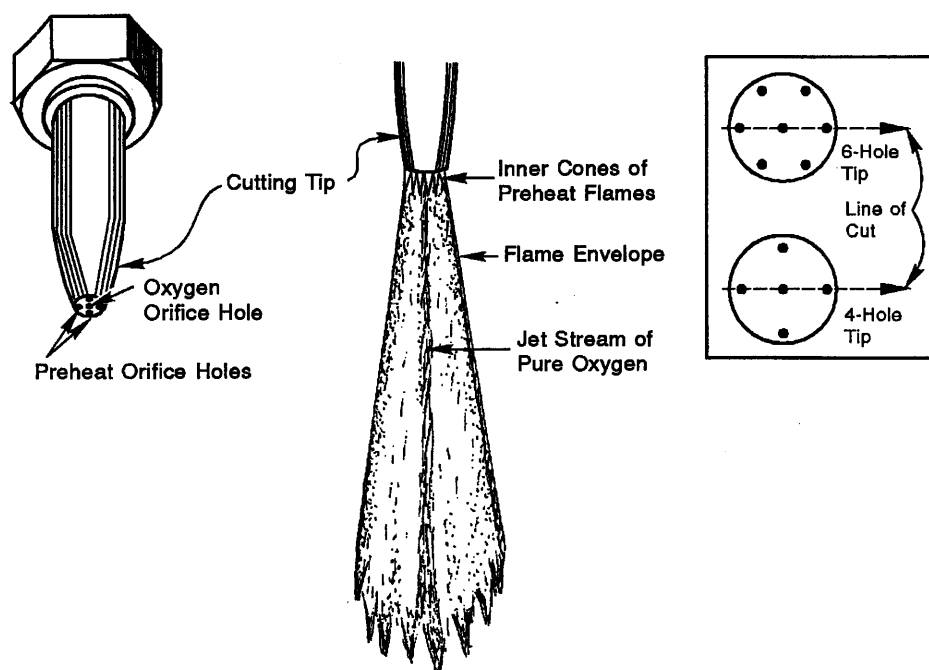
There is a crucial difference between something burning and something melting. The **melting temperature** is the temperature at which a solid begins to change to a liquid. There is a significant difference between the kindling temperature of a combustible material and its melting temperature. The melting temperature of mild steel is between 2,400° to 2,800°F.

Oxyfuel flame cutting is an oxidizing and burning process, *not* a melting process as many people may think. Oxyfuel cutting is used to separate metal by: 1) heating it to slightly above its kindling temperature of 1,500° to 1,800°F, 2) oxidizing and burning it with a stream of pure oxygen, and 3) using the force of the oxygen jet stream to blow the **slag** from the kerf.



Think of slag as the “ashes” or iron oxide that remains as the metal is burned. The **kerf** is the width and shape of the area cut away by the torch. Only **ferrous metals**, which oxidize rapidly, can be flame-cut with an oxyfuel torch. Ferrous metals are metals which contain large quantities of iron.

There are two distinctly different fires involved in the oxyfuel flame cutting process. The **preheating fire** is a mixture of the pure oxygen and the fuel gas. It consists of the tiny inner cones and the larger flame envelope that burn from the preheat orifice holes around the outside edge of the oxyfuel cutting tip. The preheating fire is used to heat the surface of the metal to its kindling temperature, *but not to its melting temperature*. The surface of mild steel has a dull to bright cherry red color as it reaches its kindling temperature. When the surface of the steel is preheated to its kindling temperature, the oxygen lever on the cutting torch attachment is then pressed. This allows a separate stream of pure oxygen to flow through internal passages to the orifice hole in the center of the cutting tip.



The top surface of the preheated metal quickly oxidizes and burns as the pure oxygen is supplied. The jet stream of pure oxygen creates the second fire called the **cutting fire**. As the surface of the preheated metal starts to burn, the cutting fire produces more heat known as heat of combustion. This additional heat causes the metal directly under the burning surface to become part of the combustion process.

Two main conditions are required to maintain the cutting fire and to make a smooth-continuous “cut” all the way through the metal. First, the surface of the metal must be maintained above its kindling temperature, but below its melting temperature. Second, the air in the kerf area must contain at least 87% oxygen for the mild steel to continue to burn.

Wood begins to burn when it is heated to its kindling temperature and is exposed to air. This is because atmospheric air, which contains approximately 21% oxygen, can supply enough oxygen for the wood to burn. Like wood and paper, steel is a combustible material. The kindling temperature of mild steel ranges from 1,472° to 1,832°F. However, for steel to burn at this temperature, a high concentration of oxygen is required.

The oxygen jet stream is approximately 100% pure as it comes from the cutting tip near the metal surface. As the metal burns from the surface down through the kerf, part of the oxygen from the jet stream is consumed. The jet stream is also “diluted” by the surrounding air that contains only 21% oxygen. Therefore, the jet stream must have adequate volume and speed to continuously maintain the oxygen level above 87% the entire depth of the kerf. It must also have enough volume and speed to blow the slag completely out of the kerf before it solidifies.

These conditions are controlled by the:

1. Forward travel speed of the torch
2. Working pressure of the fuel gas and oxygen
3. Angle the cutting torch is held against the surface
4. Size of the preheat and oxygen orifices in the cutting tip
5. Distance the cutting tip is held away from the metal surface

The oxygen working pressure determines the velocity of the oxygen jet stream. The size of orifice in the cutting tip determines the volume of oxygen delivered at that particular pressure. However, if too much oxygen is supplied, the kerf widens out as the jet stream penetrates the metal. This results in a bell-mouthed kerf with a lot of slag and reshaped metal residue.

Excessive preheating and/or moving the torch too slow allows the metal surface to overheat. The top of the kerf starts to melt instead of “burning” which causes the edges to be rough and rounded. Moving the torch too slowly and/or with a jerky motion can result in a rough kerf area with gouges.

When the torch travel speed is too fast, the metal surface will not reach its kindling temperature fast enough. This causes the burning and cutting to stop. In addition, all the slag may not be blown out of the kerf area.

SLAG

When the proper flame adjustment, tip size and clearance, travel speed, and working pressures are maintained, there should be a steady flow of sparks and **slag** emitted from the bottom side of the kerf. The slag will be blown out of the kerf in a fairly straight line. Very little slag, if any, should remain attached to the bottom corners of the kerf.

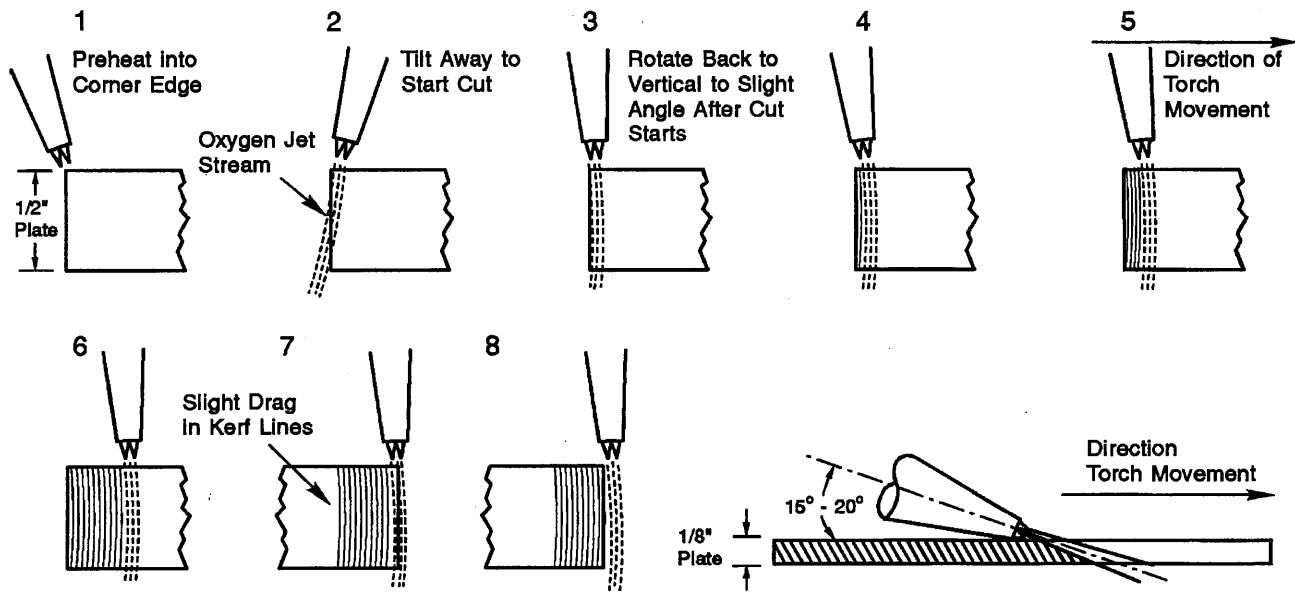
There are differences in the appearance and characteristics of “slag” versus “molten metal.” Slag that attaches to the bottom of the kerf can be chipped off easily with a chipping hammer. Improper adjustments and operation can cause part of the metal in the kerf to melt rather than burn. This molten metal can quickly solidify and fuse weld back to the base metal as it tries to flow from the kerf. This solidified, molten metal will be much more difficult to remove.

Set Up

As you learn to operate oxyfuel equipment, you should develop “a feel” for how to comfortably position your body and arms before you start to cut or weld. Plan the cut so that you can grip and stabilize the torch as you follow the cutting line across the metal. The cutting tip should be installed in the cutting head attachment so that the two opposite preheat orifice holes are in-line with the cutting line in the majority of applications. This allows one of the preheat flames to lead the kerf and the opposite to follow.

In some welding shops and school laboratories, multiple oxygen and fuel gas cylinders are connected to a **manifold system**. The manifold system allows several work stations to be used at one time. Before attempting to setup, adjust, or use a oxyfuel manifold system, you should receive special instructions from your instructor or supervisor.

Flame Cutting Plate Steel



When properly adjusted and operated, oxyfuel torches can cut a kerf that is nearly as straight and smooth as a cut made with a saw, and still have square top and bottom edges.

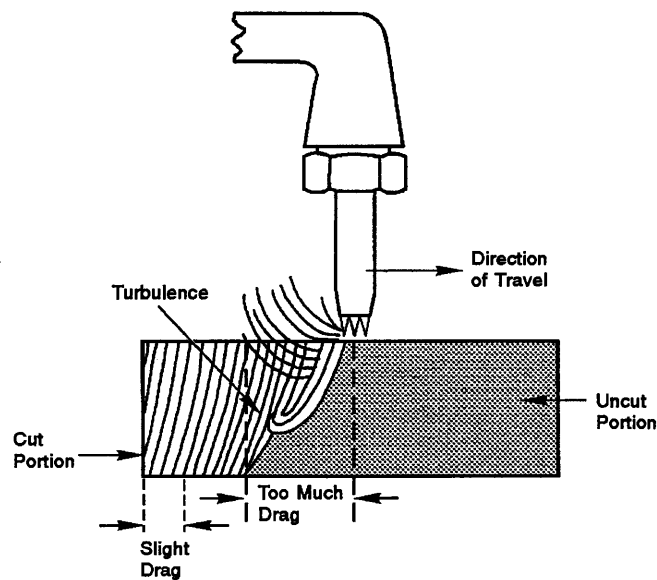
To cut flat plate or shaped steel, start by directing the tips of the preheat flames at a slight angle into a corner edge. The tips of the inner cones should be approximately 1/16" to 1/8" above the metal surface. Remember to align opposite preheat orifices with the line of cut.

As the edge of the metal surface reaches its kindling temperature (dull to bright cherry red), rotate the tip to a slight angle directed away from the corner edge of the plate. Slowly press the oxygen cutting lever until the valve is fully open. This allows the oxygen jet stream to start the cut. At the same time, rotate the tip back to a vertical to slight angle in the direction of the cut. While leaving the oxygen cutting valve lever pressed open, advance the cutting torch down the cutting line in a slow steady motion. Proceed only as quickly as good cutting action permits.

When cutting steel 1/2" thick or thicker, the cutting tip should be held near-vertical to the metal surface. For steel thicker than 1/8" but less than 1/2", the tip is held in a slight angle into the direction of travel. When cutting steel 1/8" thick or less, the tip is held at an angle up to 15° to 20° in the direction of the cut.

Remember to watch the slag and sparks emitted from the bottom of the kerf. If the cutting action stops, stop forward travel. Release the oxygen cutting lever and preheat the edge where the cutting action stopped. When the metal surface reaches its kindling temperature, slowly press the oxygen cutting lever again, tilt the tip to the proper angle, and proceed down the cut line.

As a rule of thumb, a cut should proceed just fast enough to provide a slight amount of **drag** in the kerf. Drag is the difference from where the oxygen cutting stream actually exits the bottom of the plate versus a straight line from where it enters on the top of the plate. The drag is shown by the lines in the kerf area as viewed from the side. If forward travel proceeds too fast, turbulence will start in the middle of the kerf. The cut will become incomplete and slag will be blown back to the top.

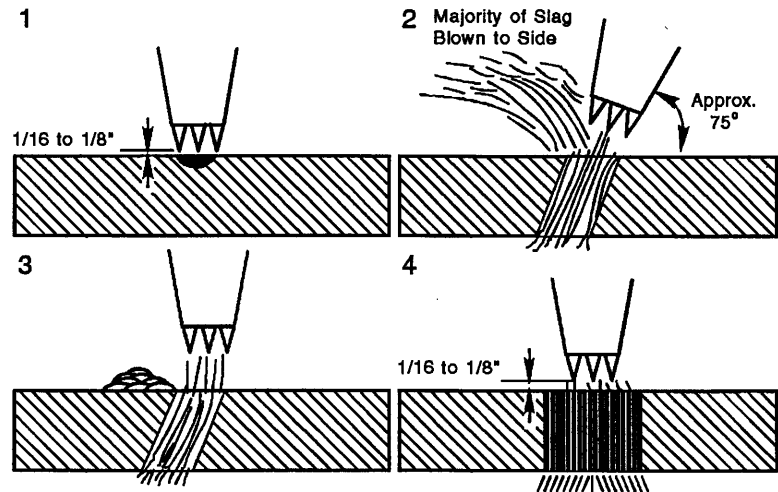


Cutting Holes in Metal

To pierce a hole in metal with an oxyfuel cutting torch, start the initial pierce in the middle of the hole away from the final cutting line. Hold the tips of the inner cone preheat flames approximately 1/16" to 1/8" above the metal surface. As the metal surface reaches its kindling temperature, raise the torch slightly while tilting the tip away from you at approximately a 75° angle. Slowly depress the oxygen lever until the valve is open all the way.

By raising and tilting the torch slightly until the initial pierce is made, the majority of the heat and slag can be blown away from you and the tip. Excess heat reflected back onto the torch can damage the tip and cause back fires. Slag blown back onto the tip can easily clog orifice holes. If the metal does not pierce all the way through, it probably indicates that not enough

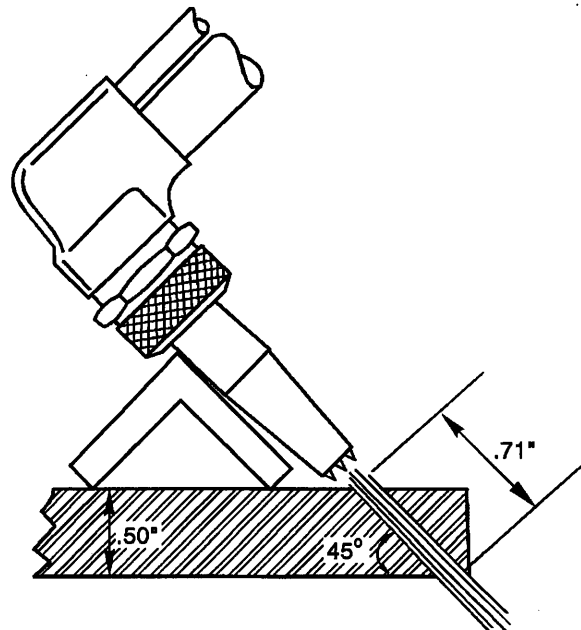
oxygen working pressure is being used and/or the oxygen lever is not being depressed far enough to allow full flow of the oxygen jet stream.



If necessary, release the oxygen cutting lever, preheat the metal surface, and start the process over. When the metal is initially pierced, immediately tilt the torch back to a 90° angle, position the torch about 1/16" to 1/8" away from the surface, and move the torch steadily in the direction of the cut line to complete the hole.

Cutting Bevels on Plate Steel

As shown in the illustration, a 45° bevel cut will be approximately 50% longer than a 90° cut for the same thickness metal. In addition, part of the heat from the preheat flames is reflected away due to the angle the torch must be held to make a bevel. Therefore, a one size larger cutting tip and/or higher oxygen working pressure is required when making a bevel cut versus a 90° cut on the same thickness metal. To make straight bevel cuts with a uniform angle, a piece of angle iron or other appropriate object can be used as a guide.



SETTING UP OXYFUEL CUTTING AND WELDING EQUIPMENT

Setting-up, turning-on, and turning-off oxyfuel cutting and welding equipment *requires you* to follow specific procedures to maintain safety for yourself and others in the vicinity. The procedures listed are primarily for oxy-acetylene equipment. If another fuel gas is to be used, follow specific instructions listed in the operators manual, or contact your welding equipment supplier. It is assumed that the system has been assembled and hoses are attached to the regulators and torch body. If setting up a new system, follow specific procedures listed in the operator's manual.

Procedures For Setting up Oxyfuel Cutting/Welding Equipment on Cylinders

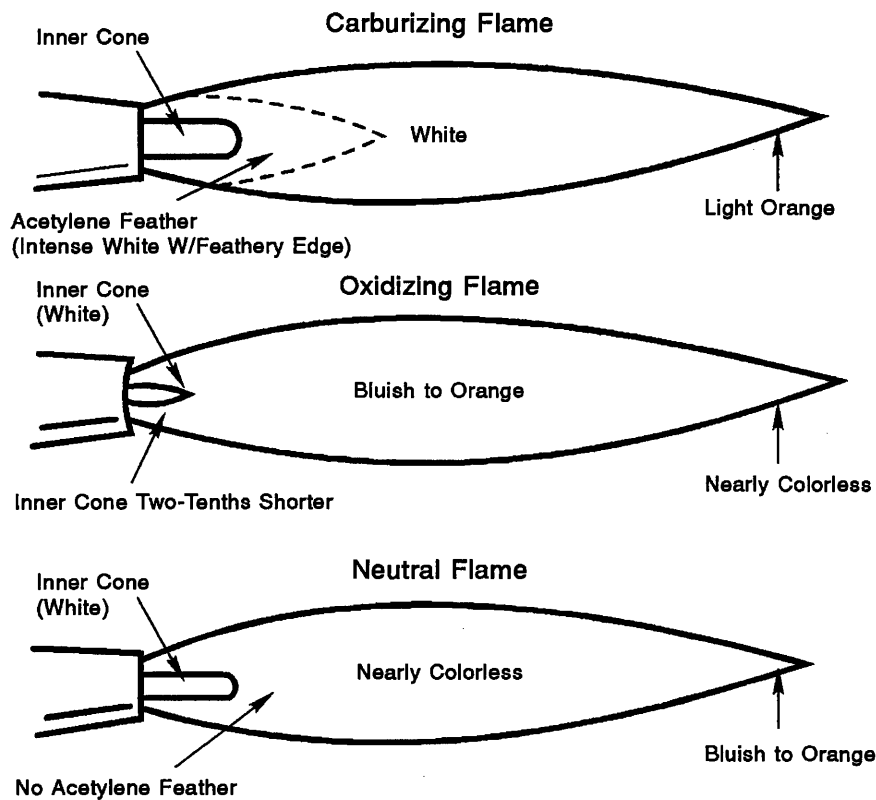
1. Secure the oxygen and fuel gas cylinders upright in a stationary shop rack, in a cylinder truck, or in a vehicle mounted bracket if the cylinders are to be transported.
2. Remove protective caps and keep them in an accessible location so they can be replaced whenever the cylinders are empty or anytime regulators are removed. Inspect the cylinder valve outlet fittings for dry dust and dirt. Wipe with a clean cloth if needed. Inspect for damaged threads or seats and the presence of oil or grease. Even a trace of oil and grease in the presence of pure oxygen can ignite and burn abruptly. Cylinders and oxyfuel equipment must be chemically cleaned and repaired by properly trained personnel, or by your welding equipment supplier.
3. Loose dirt and foreign material can be removed from the threads of the valve by quickly opening (**cracking**) and closing the oxygen cylinder valve.
4. Next, inspect the regulators, gauges, hoses, and torch body for visible signs of damage or any oil or grease. Do not use if damage is detected. Attach the regulators to the appropriate cylinders. Remember, the outlet fitting on the oxygen cylinder valve has right-handed male threads and the outlet fitting on the fuel gas cylinder has left-handed female threads. Position the regulators so that the gauges are facing upward and securely tighten the regulators with the properly sized open-ended wrench. Do not use a pipe wrench or pliers.

5. Make sure the spring tension is released on both the oxygen and fuel gas regulator adjusting screws (adjusted fully out in the counterclockwise direction). As you turn the screw in a counter-clockwise direction, you should feel a decrease in the resistance of the screw to turn.
6. For safety, stand so that the oxygen cylinder valve is between you and the regulator. Never stand directly in front or behind the regulators when opening cylinder valves. Wear eye protection and watch for those around you. Slowly, crack open the oxygen cylinder valve until maximum pressure is shown on the oxygen regulator high-pressure gauge. Then, open the oxygen cylinder valve completely to back-seat the valve stem in its fully open position.
7. Stand so that the fuel gas cylinder valve is between you and the regulator. Very slowly, open the fuel gas cylinder valve until maximum pressure is shown on the high pressure gauge. Then, open the fuel gas cylinder valve 1/2 to 3/4 turn, but never more than 1 to 1 1/2 turns. In case of an emergency, the fuel gas valve can be closed with one or two quick rotating motions of the hand. If the acetylene cylinder valve is equipped with a wrench handle instead of wheel handle, leave it in place when the cylinder valve is open.
8. Check all cylinder valves, safety plugs, and regulator fittings for leaks with an approved leak detector solution. Apply the fluid and observe the application area, escaping gas will produce bubbles in the solution. *Do Not* use a flame to check for leaks.

Set up and Lighting Procedures If Using An Oxyfuel Welding Torch

1. Determine the thickness of the metal to be welded. Check the appropriate charts to determine the correct size of welding tip and the oxygen and fuel gas working pressures needed.
2. Inspect the seats and seals on the welding tip and the torch handle for damage. Do not use if any damage, oil, or grease is found.

3. Install the welding tip on the torch handle. Position and securely hand tighten the welding tip so that it is pointing down when the fuel gas valve is easily accessible with your free hand. Do not over tighten with a wrench or you will damage the seats and sealing areas.
4. Make sure you are in a well ventilated area. Open the torch handle oxygen valve 1/4 to 1/2 turn. Turn the adjusting screw on the oxygen regulator in clockwise until the desired working pressure is shown on the working pressure gauge. Wait a couple of seconds to purge the hose and torch, then close the torch handle oxygen valve.
5. Open the fuel gas valve on the torch handle 1/4 to 1/2 turn. Turn the adjusting screw on the fuel gas regulator in clockwise until the desired working pressure is shown on the fuel gas working pressure gauge (If Acetylene is used as a fuel gas, *Never* adjust working pressure above 15 psi). Wait a couple of seconds to purge the hose and torch, then close the torch handle fuel gas valve.
6. Use the leak detector solution to check the regulator, hoses, and torch body connections for leaks.
7. To light the welding torch, hold the torch handle in one hand and the friction spark lighter in the other. Point the end of the tip away from the cylinders, persons, and flammable materials. Open the torch handle fuel gas valve approximately 1/8 to 1/4 turn. Immediately use the spark lighter to ignite the fuel gas. Continue to slowly open the torch handle fuel gas valve until the flame stops smoking excessively and the flame base separates from the end of the tip. Next, slowly close the torch handle fuel gas valve just enough to bring the base of the flame back into contact with the welding tip.
8. Slowly open the torch handle oxygen valve until a bright neutral flame is obtained. The torch is ready to be used for welding.



9. When the welding procedures are completed, First, close the torch handle oxygen valve, then immediately close the torch handle fuel gas valve. If the fuel valve is closed first, a backflash may occur, forcing soot into the tip and clogging the orifices or the gas passages. If you notice a pop sound when you shut-off the fuel valve, then the torch is leaking oxygen. If the flame continues to burn after you have shut down the fuel valve, then the torch is leaking fuel. Close both cylinder valves, remove torch body from the hoses, and have the entire torch body, including cutting attachment, serviced by a qualified technician.

If the oxyfuel welding torch is to be used again within a short period of time, the equipment can be left in this condition. If you have completed all welding procedures for the day, or if the system will not be used within the hour, it is recommended that the equipment be completely shut-down.

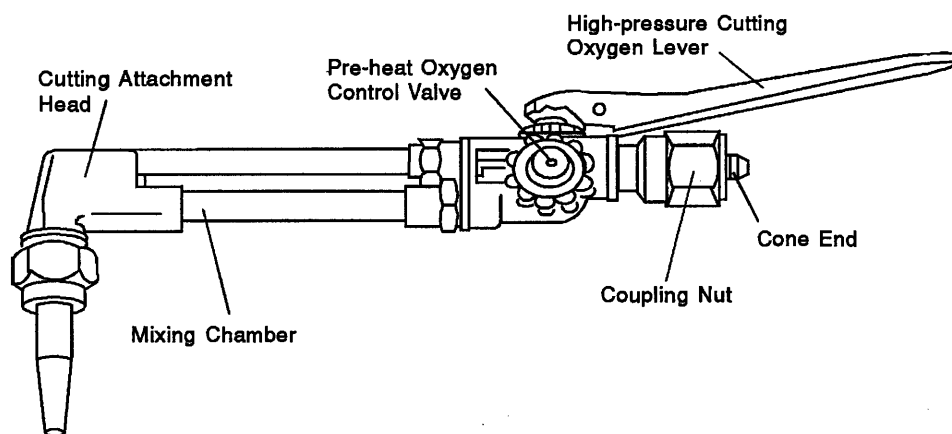
Complete Shut-down Procedures If Using An Oxyfuel Welding Torch

1. Close the oxygen cylinder valve. Open the torch handle oxygen valve 1/4 turn and leave it open until pressure drops to zero on both the oxygen working pressure and the cylinder pressure gauges. Screw the oxygen regulator adjusting screw counterclockwise (out) until the spring tension on the diaphragm is released. Close the torch handle oxygen valve.
2. Close the fuel gas cylinder valve. Open the torch handle fuel gas valve 1/4 turn and leave it open until pressure drops to zero on both the fuel gas working pressure and cylinder pressure gauges. Screw the fuel gas regulator adjusting screw counterclockwise (out) until the spring tension on the diaphragm is released. Close the torch handle fuel gas value.
3. Roll-up the hoses and place the torch in a safe and secure position.

Set-up and Lighting Procedures If Using An Oxyfuel Cutting Torch

1. Determine the thickness of the metal to be cut. Check the appropriate charts to determine the correct cutting tip size and the oxygen and fuel gas working pressures. (This step may have already been performed.)
2. Inspect the hoses for cuts, burnt areas, or other damage. Inspect the cutting tip, cutting head attachment, and torch handle fittings for damage, oil, or grease.
3. Install the correct size cutting tip in the cutting head attachment and tighten with a wrench. There are some models of cutting head attachments equipped with special "quick-change" cutting tips that are hand-tightened only. If you are unsure which model you are using, consult your instructor, supervisor, or the operators manual for further instructions.
4. Depending on whether you are right-handed or left-handed, position the cutting head attachment on the torch handle so that you will have easy access to the preheat oxygen valve and the torch handle fuel gas valve with your free hand. Hand tighten the cutting head attachment to the torch handle. Do not over tighten with a wrench or you will damage the seats and sealing areas.

5. Make sure you are in a well ventilated area. Open the torch handle oxygen valve all the way. Open the oxygen preheat valve on the cutting head attachment a 1/4 to 1/2 turn. Turn the adjusting screw on the oxygen regulator clockwise (in) until the desired working pressure is shown on the oxygen low pressure gauge. Wait a couple of seconds to purge the hose and torch, then close the oxygen preheat valve on the cutting head attachment.
6. Open the torch handle fuel gas valve 1/4 to 1/2 turn. Turn the adjusting screw on the fuel gas regulator clockwise (in) until the desired working pressure is shown on the low pressure gauge. Wait a couple of seconds to purge the hose and torch, then close the torch handle fuel gas valve.
7. Momentarily depress the cutting oxygen lever to purge the high pressure cutting oxygen passages.
8. Use the leak detection solution to check the regulator, hoses, cutting attachment, and torch body connections for leaks.



9. To light the oxyfuel cutting torch, hold the torch handle in one hand and open the torch handle fuel gas valve approximately 1/4 to 1/2 turn. Immediately use the friction spark lighter to ignite the fuel gas. Continue to slowly open the torch handle fuel gas valve until the base of the flame leaves the end of the tip by approximately 1/8". Next, slowly close the torch handle fuel gas valve until the base of the flame just touches the end of the tip.

10. Slowly open the preheat oxygen control valve on the cutting head attachment until a neutral preheat flame with sharp inner cones is established.
11. Slowly depress the cutting oxygen control lever and observe as the preheat flame changes to a slightly carburizing flame. While holding the cutting oxygen control lever in the open-depressed position, continue to very slowly open the preheat oxygen control valve until the preheat flame changes back to a neutral state. Release the cutting oxygen control valve lever. The cutting torch is ready for use to cut metal.
12. When the cutting procedure has been completed, first close the preheat oxygen control valve on the torch handle, then immediately close the torch handle fuel gas valve. If you notice a pop sound when you shut-off the fuel valve, then the torch is leaking oxygen. If the flame continues to burn after you have shut down the fuel valve, then the torch is leaking fuel. Close both cylinder valves, remove torch body from the hoses, and have the entire torch body, including cutting attachment, serviced by a qualified technician.
13. Place the hoses and cutting torch in a safe position. If the cutting torch is to be used again within a short period of time, the equipment can be left in this condition. If you have completed all cutting for the day, or if the system will not be used within the hour, the equipment should be completely shut-down.

Complete Shut-down Procedures If Using An Oxyfuel Cutting Torch

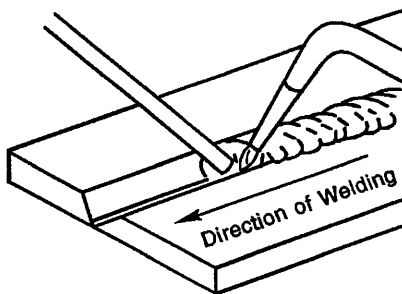
1. Close the oxygen cylinder valve. Open the preheat oxygen control valve on the cutting torch attachment approximately 1/4 turn. Leave it open until the pressure drops to zero on both the oxygen working pressure and the cylinder pressure gauges. Screw the oxygen regulator adjusting screw counterclockwise (out) until the spring tension on the diaphragm is released. Close the preheat oxygen control valve.
2. Close the fuel gas cylinder valve. Open the fuel gas valve on the torch handle approximately 1/4 turn. Leave it open until the pressure drops to zero on both the fuel gas working pressure and cylinder pressure gauges.

Screw the fuel gas regulator adjusting screw counterclockwise (out) until the spring tension on the diaphragm is released. Close the fuel gas torch valve.

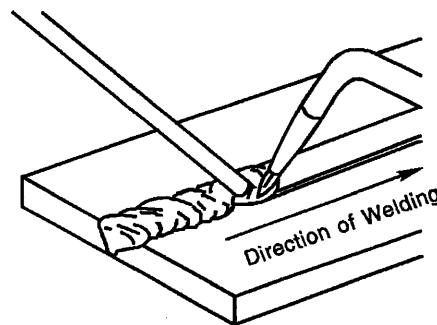
3. Roll-up the hoses and place the torch in a safe and secure position.

OXYFUEL WELDING PROCEDURE

After adjusting the gas valves to produce a neutral flame, move the torch into the weld area and preheat the workpiece. Create a puddle, holding the inner cone just above the metal surface at a 45° angle. Although filler rod is not necessary to fuse two pieces of metal, adding filler rod into a puddle reduces the surface tension of the puddle and facilitates the fusion process. The **forehand** and **backhand methods** are techniques used during oxyfuel welding.



Forehand Welding



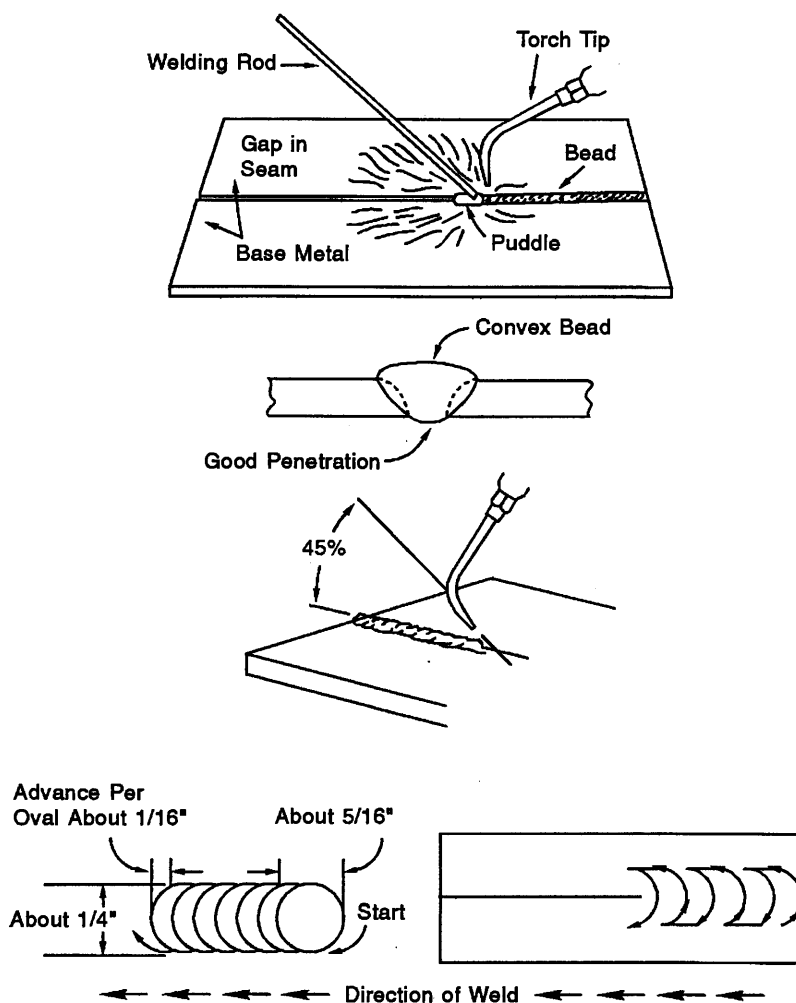
Backhand Welding

As the diagram indicates, using the forehand method consists of pointing the torch in the direction of travel. The forehand method is better when welding thin metals of 1/8" or less. When using the forehand method, an operator can control the puddle better, see the path to be traveled easier, and create smoother beads.

When using the backhand method, the operator can obtain better penetration into the base metal, thus allowing for the fusion of thicker metals. As the torch is aimed toward the welded bead, filler rod can be added to the puddle as necessary. The hand and rod motions used in the forehand and backhand welding methods is called the **oscillating** or **circular motion**.

Holding the torch at a 45° angle and the inner cone 1/16" to 1/8" above the surface of the puddle, push the puddle in the direction of the intended weld. Preheat the filler rod by placing it into the weld zone.

As more metal is needed, insert the rod into the puddle. As the puddle crowns, pull the rod slowly out of the puddle. In order to become proficient at this technique, practice on scrap metal. Finish a weld by slowly moving the torch away from the puddle. Remember, molten metal oxidizes when it is exposed to the oxygen in the atmosphere. Keep the outer cone of the flame in the weld zone to prevent oxygen from contaminating the base metal. Slowly pull the torch away from the workpiece as the metal solidifies. This action will prevent porosity, which are tiny holes formed on the surface and inside of the weld.



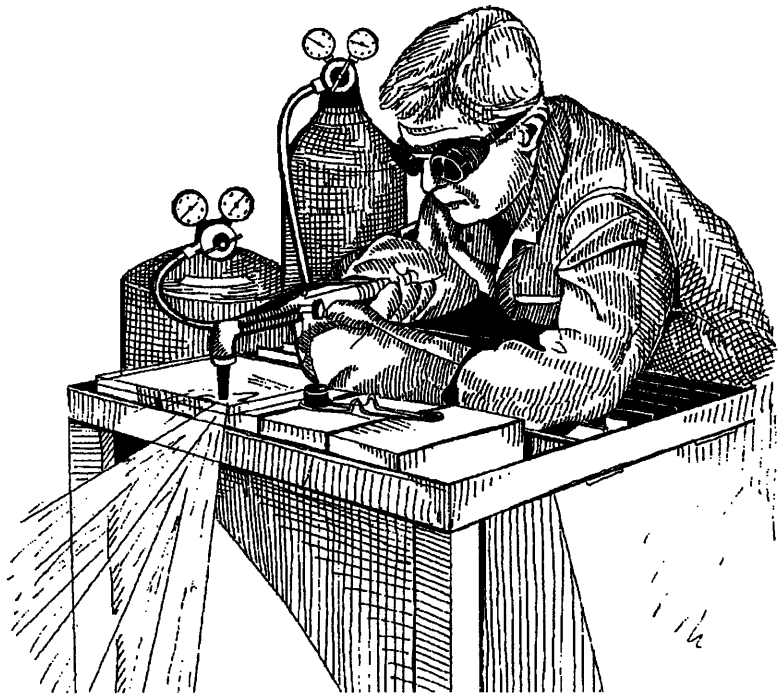
OXYFUEL CUTTING AND WELDING HAND POSITIONS

Oxyfuel cutting and welding requires eye-mind-hand coordination. Your ability to remain comfortable during the welding and cutting process will improve the quality of your workmanship. You need to develop a personal technique that is comfortable to you.

Visibility is a key factor in keeping your torch on a marked line or a weld in the proper place. Before you light the torch, practice the range of motion needed to perform the weld or cut and position your body so that you will be able to see the entire process, without being blocked by your hands or the work piece. While your practicing, figure out how you could brace your arms or the torch so you can follow the mark and maintain a constant speed. Right handed persons typically place their left forearm down on the table or the work piece itself. The right hand and the torch can then be laid across the left forearm and used to steady the torch.

Some operators prefer to hold the welding torch in their writing hand similar to the way one holds a pencil. This technique allows greater flexibility and fine tuning of the movement of the puddle. The fuel and oxygen hoses can limit your flexibility.

Before you start the process, check to see if you have enough hose to reach the entire weld area or cut. Possible solutions to hose problems are supporting the weight of the hose by slinging it over your shoulder, hanging it from the ceiling, or reducing the diameter of the hose within ten feet of the torch.

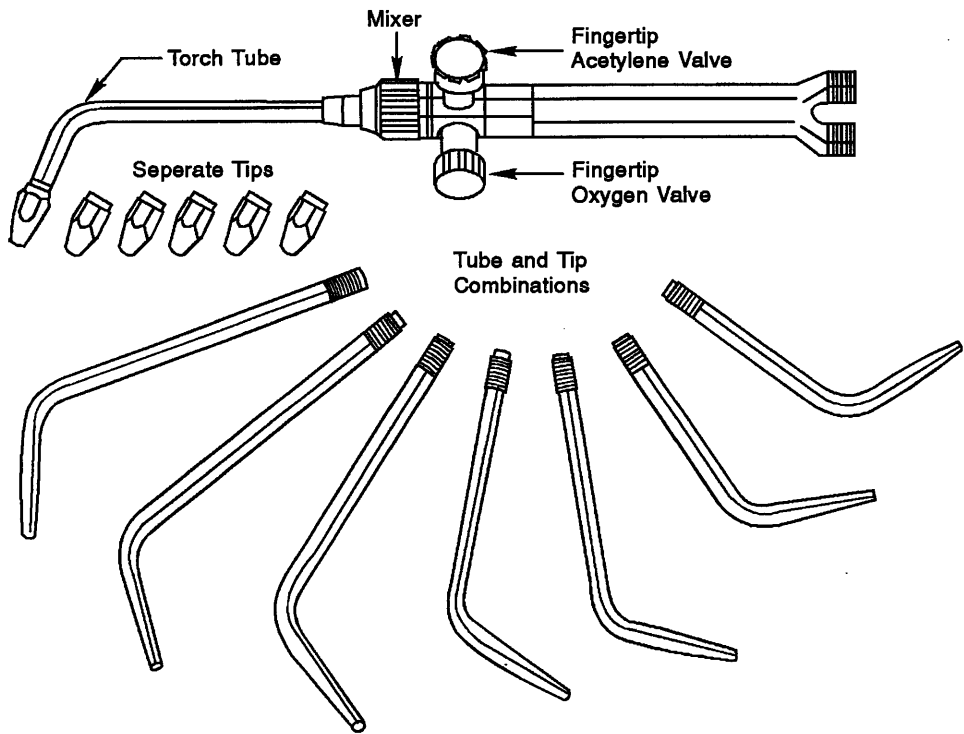


PROCEDURES FOR PREPARING METAL FOR OXYFUEL WELDING

Clean the metal thoroughly around the area to be welded with a wire brush, grinder, or wire wheel. Remember, rust will not melt or burn. Therefore, all rust must be removed if you want to maintain an acceptable level of quality. Joint preparation techniques similar to that for other types of welding processes should be used. Where needed, beveled edges and grooves increase the surface area for the fusion process.

SELECTION AND CLEANING OF CUTTING AND WELDING TIPS

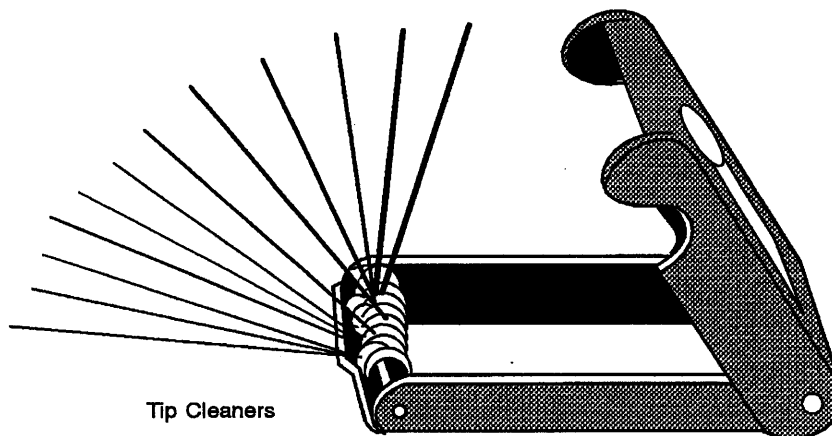
The size of the preheat orifices in the oxyfuel cutting tip are selected according to the *volume of heat* that is required to preheat the thickness of metal to be cut, *not* the temperature of the flame. The actual temperature of the flame depends upon the type of fuel gas used and the proper flame adjustment, not the size of the orifices. Cutting and welding tips are usually made of hardened copper.



		Very Heavy	For General Cutting; Also for Cutting Cast and Stainless Steel
		Medium	For Grooving Gouging or Removing Imperfect Welds
		Light	For Straight Line and Shape Cutting Clean Plate

Very few oxyfuel equipment operators will use the correct size tip for every cutting or welding operation. For example, after cutting a 1" thick piece of metal with a large tip, there is a tendency to cut a 1/16" piece of metal using the same tip, but using reduced pressures. This is dangerous because the lower gas velocity greatly increases the chances of a dangerous back flash.

Keeping the orifices clean and smooth is necessary to maintain a high standard of work quality. Carbon and slag deposits can be removed with a **tip cleaner** as shown in the figure. Do not enlarge the orifice size as you clean the tip, instead choose a wire cleaner that is smaller in diameter than the size of the orifice. Insert the wire and carefully push and pull the wire in and out of the tip. If the tip has been damaged by flying slag, gently file the end of the tip at a right angle to the flow of gases. Preserving smooth, clean, and open orifices is a key factor for a proper flame.



BASIC SAFETY PROCEDURES: OXYFUEL CUTTING AND WELDING

During the oxyfuel cutting and welding processes, you must protect yourself from radiation burns and high-temperature burns. Temperatures above 120°F will cause severe skin burns. Prevent bodily burns by wearing protective clothing. Gauntlet-type leather gloves should be worn to protect hands and wrists. To provide protection from hot sparks, slag, and spatter, wear a cotton cap or welding beanie. You should wear a heavy, long-sleeved, dark-colored cotton shirt and long cotton pants. Wear high-top shoes or boots with pants legs down over the tops.

Avoid cuffs, open pockets, and rolled up sleeves that can catch sparks. A heavy cotton apron treated with a fire-resistant chemical or a leather jacket, cape, or sleeves provides added protection when cutting or welding at a higher temperature or out-of-position. Cotton may smolder, but it will not usually flame up and burn as synthetic fiber can. Synthetic fibers such as nylons and polyesters are highly flammable and if they burn, hot melted patches can cling to the skin.

Sparks and spatter can easily start a fire if they fall on flammable material. Flying sparks can travel more than 35 feet. The small globules of molten metal and slag leaves the kerf area at temperatures in excess of 3,000°F. They can fly or bounce 50 to 60 feet or more, coming in contact with surrounding equipment, personnel, or flammable liquids. Keep approved fire extinguishers in the area where you are using oxyfuel equipment.

The oxyfuel cutting and welding flame produces bright rays of light. In addition to the flame, molten metal emits invisible ultraviolet and infrared rays. These are the same type of rays emitted during arc welding. Even though the rays from oxyfuel cutting or welding are not as concentrated as those from arc welding, they can still cause serious injury, permanent damage, and/or pain to the eyes if the flames and sparks are viewed without a properly darkened lens. The operator must protect his eyes from the bright light with goggles or shatter proof glasses fitted with #5 or #6 colored filter or reflective lenses. As the lens number increases, the amount of protection from harmful rays increases.

TEN RULES TO FOLLOW WHEN USING OXYFUEL EQUIPMENT

- 1) Do not cut or weld on galvanized, painted, or lead coated materials inside a shop without an adequate exhaust ventilation system. Fumes are toxic.
- 2) Keep hoses from coming in contact with hot metal or sharp edges.
- 3) Do not pick up hot metal with your gloved hands. Heat can cause leather gloves to instantly shrink and harden around your fingers.
- 4) Do not use a match or cigarette lighter to ignite an oxyfuel torch.
- 5) Do not cut or weld on containers such as 55 gallon drums which have held combustible materials.
- 6) Never test for gas leaks with a flame.
- 7) Do not wear synthetic clothing.
- 8) Never use standard "air hoses" for oxyfuel systems.
- 9) Never use oxygen hose to splice a fuel gas hose or vice versa.
- 10) Use oxy-fuel equipment only with the industrial gases for which it was designed.

General agricultural mechanics safety information is covered in topics #8600 and 8147-A. Operating procedures vary slightly with different brands and models. Review the appropriate operators manual for the equipment you are using or consult an instructor. As with all new techniques you are learning, it is helpful to observe an experienced professional demonstrate the safe and correct procedures.

DANGEROUS SITUATIONS

A **backfire** is a loud snapping or popping sound produced when the fuel gas and oxygen mixture pre-ignites and the flame momentarily burns back just inside the end of the torch tip. A back fire may be caused by: 1) touching the torch tip against the metal surface which restricts the gas flow, 2) overheating the tip, 3) slag clogging or restricting the orifices, 4) operating the torch with improper gas pressures, and/or 5) operating the torch with a loose tip or cutting head fitting. A backfire may or may not cause the flame to go out. In some cases, the flame may go out, but be instantly re-ignited because of excess heat built up in the tip.

When a backfire occurs, close the oxygen torch valve immediately, then the torch fuel gas valve. Closing the oxygen torch valve first removes the oxygen supply. Allow the tip to cool, inspect the system, clean the tip, and tighten if needed. Ignite the torch following normal procedures.

If ignored, continuous backfiring can develop into a **flashback**. A flashback occurs whenever the flame disappears and actually continues to burn back inside the tip, mixing chamber, and torch body. A flashback indicates that something is definitely wrong with the torch, or that it is being operated improperly. The torch body will get hot and produce a high-pitched shrill, hissing, or squealing noise. A flashback causes damage to the internal seals and valve seats, thus creating a very dangerous condition. In extreme cases, the flashback can burn back inside the hoses and regulators.

If you suspect a flashback, *immediately* close the torch oxygen valve, then the torch fuel gas valve. Next, close the oxygen and fuel gas cylinder valves. Closing the oxygen torch handle valve first stops the flow of oxygen to the torch which should stop the flashback. Do not use the regulators, torch, and hoses after a flashback has occurred until they have been properly inspected. Only a qualified instructor or repair technician can determine if they are safe to reuse after a flashback.

OTHER OXYFUEL WELDING PROCESSES

Fusion welding occurs when the edges of two pieces of metal are heated so that they melt into liquid molten metal and flow together. When the liquid metal from both pieces is allowed to flow together and cool properly, a metallurgical bond results. The two pieces become one.

All fusion welding processes require a high temperature heat source to melt the metal. In arc welding, this heat is supplied by an electric arc. In the **oxyfuel fusion welding process**, the intense heat is supplied by burning a fuel gas in combination with pure oxygen.

It is important to recognize that during the oxyfuel fusion welding process, mild steel is heated *above* its kindling temperature to its melting temperature, 1,832°F. Even though it is heated above its kindling temperature, it will not burn as it did in the oxyfuel cutting process. This is because the atmospheric air alone can not supply enough oxygen to support rapid combustion of the molten steel.

Another welding process made with oxyfuel equipment is referred to as **adhesion welding**. In the adhesion welding process, the base metals *are not* melted, but only heated to a dull red color. A filler rod having a lower melting temperature than the base metal is added to the surface of the pieces of metal being joined. The filler rod melts and flows by capillary action over and between the surfaces of the joint. As the molten filler rod cools, it adheres to the microscopic pores of the base metals. Common adhesion welding processes include hard soldering, soft soldering, and brazing or brass welding. Soft and hard soldering are discussed in more detail in student topics # 8154-E.

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Acknowledgments

Mr. Douglas M. Kingman, Graduate Assistant, Agricultural Education Department, Texas A&M University and Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

TRUE OR FALSE: Circle "T" if the statement is true; Circle "F" if the statement is false.

- T F 1. Slag can be thought of as metal.
- T F 2. Assuming the torch is properly adjusted, steel does not actually burn during the combustion process.
- T F 3. Acetylene becomes very unstable when it is compressed above 15 psi in an open cavity.
- T F 4. Oxygen Cylinders are not equipped with a back seating valve.
- T F 5. The size of the preheat orifices in the oxyfuel cutting tip are selected according to the volume of heat required, not the temperature of the flame.
- T F 6. Trailing method results in deeper penetration than the leading method.
- T F 7. Working pressure is the pressure of the gas in the cylinder.
- T F 8. Synthetic clothing is safe to use around cutting torches because it resists heat and prevents slag burns.
- T F 9. A squealing noise may be an indication of a flashback.
- T F 10. When finished oxyfuel welding, close the oxygen valve on the torch body first.

SHORT ANSWER/LISTING: Respond to the following item in sentences, phrases, or short paragraphs in the spaces provided. (Use additional paper when needed.)

11. List the three components required to initiate combustion.

- a. _____ b. _____
c. _____

12. List four types of fuel gas discussed in this topic.

- a. _____ b. _____
c. _____ d. _____

13. Name two dangerous conditions that involve combustion inside the welding or cutting torch handle or hose assembly.

- a. _____ b. _____

14. Explain how to clean the orifice in a welding tip.

15. Describe the lighting procedure for a cutting torch.

16. Describe the inside of an acetylene bottle.

17. Explain why it is dangerous to cut or weld on an enclosed container, like a 55 gallon drum, that has held combustible liquids.

18. Briefly explain the difference in the melting and the kindling temperature of a material like steel.

19. Explain why fuel and oxygen hoses must be of proper size.

ADDITIONAL SKILLS & ENHANCEMENT ACTIVITIES: Perform the following activities or skills as assigned by your instructor.

1. Observe the inspection information stamped on the oxygen and fuel gas cylinders used in your school laboratory. Contact your school's local gas supplier and find out what happens to a bottle if it needs to be inspected. Discover the inspection process and the criteria that must be followed in order for a bottle to pass inspection. Submit your findings in an oral presentation to the class.
2. Go to the American Welding Society (AWS) Home Page and find the listing for the AWS Journal. Locate and read an article of your choice. Prepare a one page report describing the article and highlighting an interesting point. Also, investigate the college scholarship opportunities available from AWS.

3. Describe the combustion process. Explain how it works and what components are necessary to initiate and maintain this process. Discuss kindling and melting temperatures of steel. Ask your Science or Agricultural teacher to allow you to present this information to the class.
4. Invite a local business owner or manager that hires workers that use oxyfuel cutting and welding equipment to your classroom. Ask them to discuss the positive work behaviors of a good employee.

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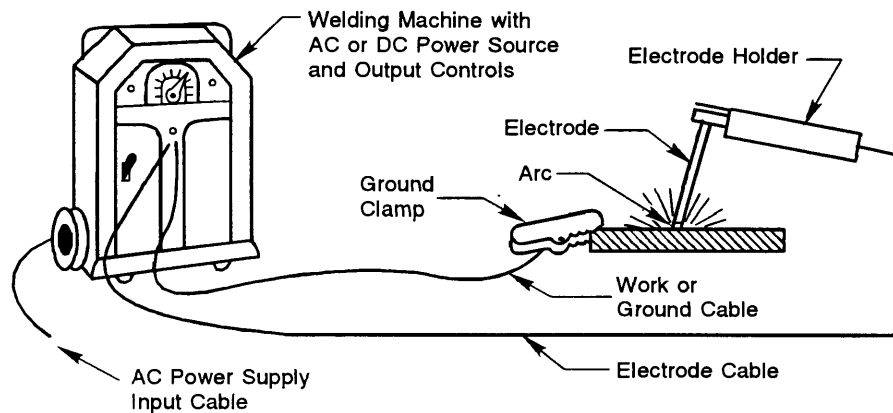
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ARC WELDING PRINCIPLES AND PROCEDURES

Fusion welding occurs when the edges of two pieces of metal are heated so that they melt into liquid molten metal and flow together. When the liquid metal is allowed to cool properly, a metallurgical bond results. The two pieces become one. The fusion weld joint has the potential for exhibiting the same strength properties as the base metal parts. **Shielded Metal Arc Welding**, or **SMAW**, is one of the fusion welding processes that uses heat from an electric arc. SMAW is also referred to as **stick welding**.

To understand the shielded metal arc welding process, it is necessary to understand the flow of electrical current in a complete circuit. Electrical current is the flow of electrons through a conductor. Electrical current always flows from its source through a completed circuit, and back to its source.



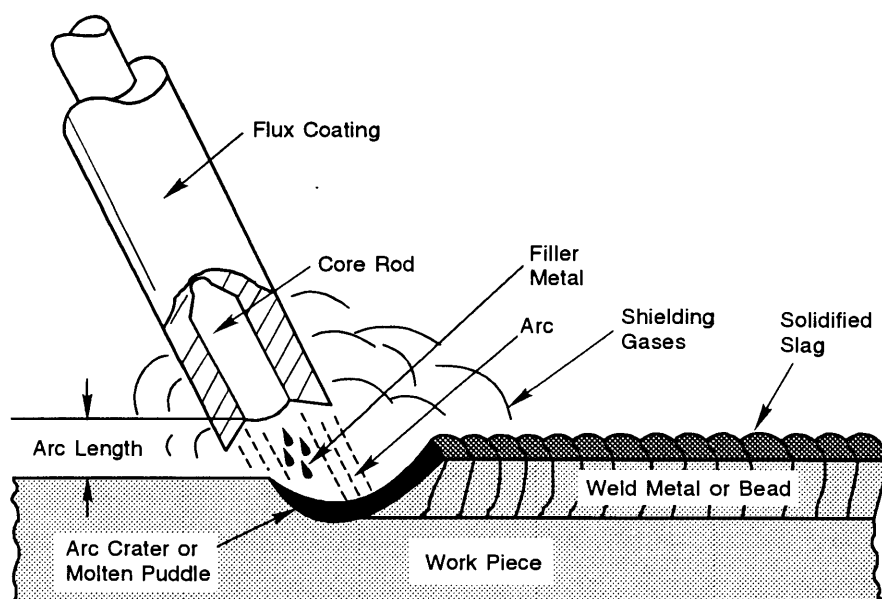
Shielded Metal Arc Welding Circuit

The welding circuit for SMAW consists of an electrical power source with controls, an electrode cable, an electrode holder, a consumable metal electrode, metal workpieces, a ground clamp, and a ground or work cable. Consumable means that the electrode is used up during the welding process. The electrical current from the power source is carried through the electrode cable to the electrode holder, and to the metal electrode. The metal workpiece is connected back to the power source by the ground clamp and ground cable. Most ground clamps are spring loaded for quick attachment.

The electrical current for the shielded metal arc welding process may be either **direct current (DC)** or **alternating current (AC)**. DC flows continuously in one direction. AC alternates the direction of flow at a rate of 60 cycles per second. **Voltage** is the measure of electrical pressure that causes current to flow. Voltage is similar to the pressure that causes a liquid to flow through a pipe. The rate at which current flows through the circuit is measured in **amperes**. This is similar to the volume of liquid flowing through a pipe.

The shielded metal arc welding process begins when the operator turns on the welding machine and momentarily touches the tip of the electrode against the base metal to complete the electrical circuit. (At this point, we will assume the operator has followed all safety precautions and has lowered his or her welding helmet.) By quickly raising the tip of the electrode slightly, an **air gap** is created in the completed electrical circuit. This is called “**striking an arc**.” The current jumps across the air gap to form an electrical arc as it continues to flow in the completed circuit. The “electrical arc” generates the extreme heat used to melt the base metal and electrode.

The width of the air gap is the distance between the tip of the electrode and the workpiece. It is called the **arc length**. As a rule of thumb, the arc length should be approximately the diameter of the bare end of the electrode. The proper arc length produces an even crackling sound similar to bacon frying. Too long of an arc length will give a loud blowing or hissing sound.

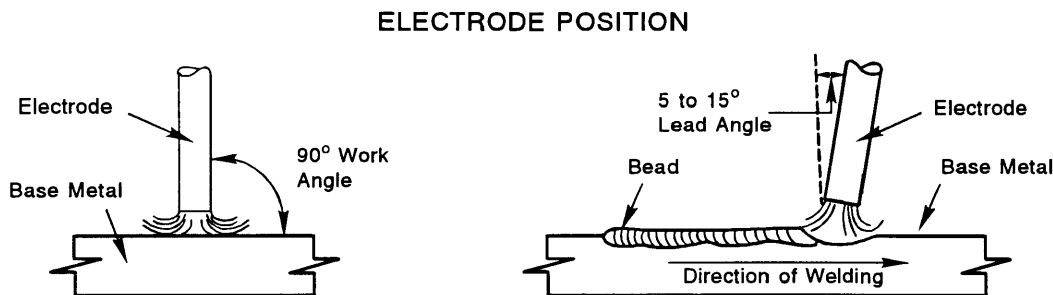


Shielded Metal Arc Welding

In arc welding, the term **amperage** is often used synonymously with the term current. Amperage is actually the amount of electrical current flowing in the circuit at a given time. Thus, amperage is also used to indicate approximately how much heat will be produced by the arc.

The current jumps the air gap producing an arc of between 6,000° to 11,000° F. The welding machine operator is able to control the amount of heat by controlling: 1) the amperage setting, 2) the arc length, and 3) the size of the electrode. The higher the amperage setting of the welder, the more heat produced by the arc.

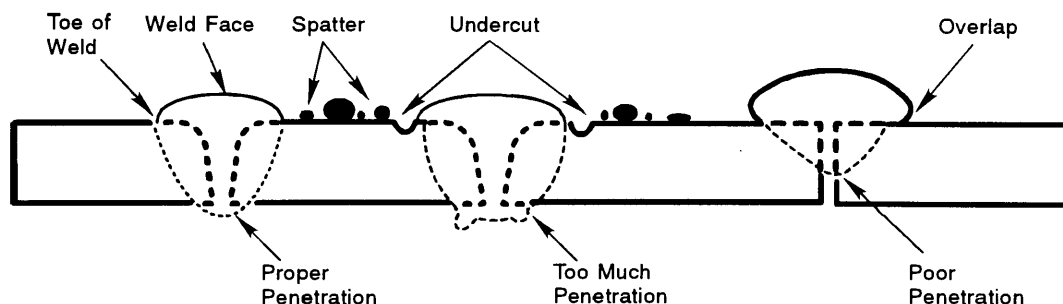
As the proper arc length is established and the arc is slowly moved along the joint, the base metal is melted to form a **molten puddle** or **arc crater**. At the same time, the tip of the electrode melts and flows across the arc. It is deposited into the middle of the molten puddle as **filler metal**.



As a beginning welder running a bead in the flat position, hold the electrode at approximately a 5 to 15 degree **lead angle** from vertical in the direction of travel. In this flat position, the **working angle** is 90° from side to side. The arc has a definite directional force as it melts the tip of the electrode and the base metal. The arc tends to force the molten metal puddle away from the end of the electrode. The back edge of the molten puddle cools and solidifies to form the ripples in the **bead** as the arc is moved along the weld joint. Controlling the lead and working angles help control where the arc force pushes the molten puddle.

Penetration is the depth the arc crater melts into the base metal and fusion occurs. Penetration is measured from the surface of the base metal. The **weld toe** is the junction where the face of the weld bead and the base metal fuse together. An **undercut** is an unfilled groove adjacent to the weld bead that was melted into the base metal by the arc. Undercutting is caused by: 1) excessive arc force because of too high of welding amperage, 2) improper electrode angles, 3) improper travel speed, and/or 4) improper electrode motion.

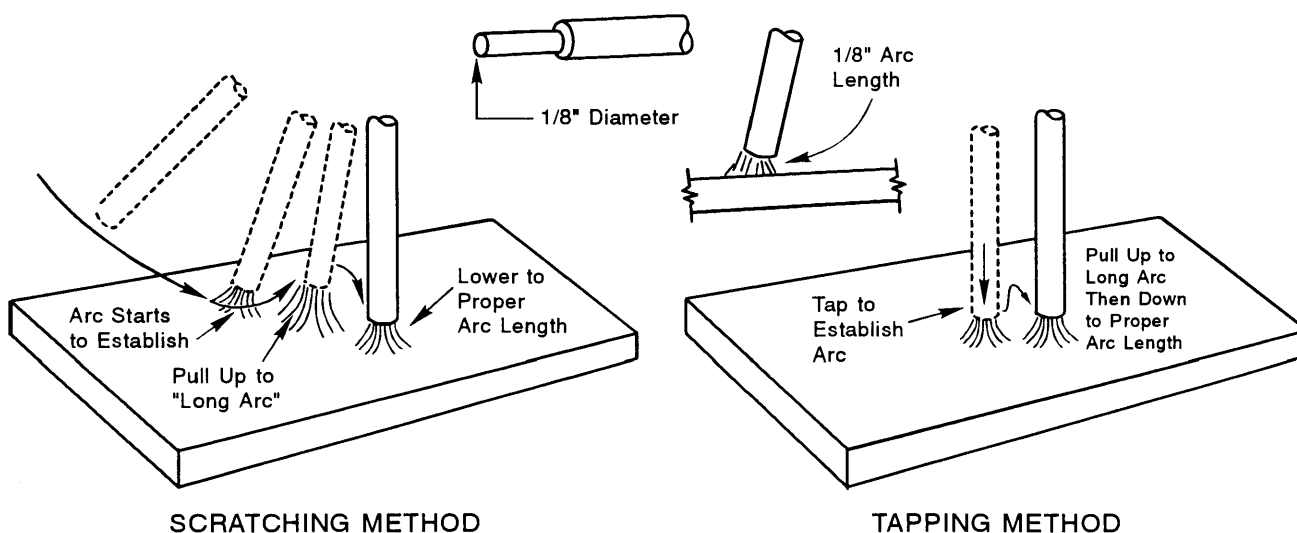
The tip of the electrode is not allowed to remain in the proper position long enough for the groove to be refilled with molten filler metal before the puddle solidifies. In some cases, the original joint may have full penetration and fusion. However, excessive undercutting will result in a weak weld joint because the grooves decrease the effective thickness of the base metal.



Overlap is any excess protrusion of the weld filler metal beyond the weld toe that does not fuse with the base metal. Overlap is caused by too low of an amperage and/or too slow travel speeds. Overlap is often called a “cold weld.” A **tack weld** is a small, short weld used to temporarily hold components together during assembly.

Striking An Arc

There are two basic methods of striking an arc: 1) the **scratching method**, and 2) the **tapping method**. With the scratching method, the tip of the electrode is brought down to the surface of the base metal at a slight angle. The tip of the electrode is quickly drawn across the metal surface in a dragging or sweeping motion as if striking a match.



The challenge is how quickly and far back to withdraw the electrode as it is moved into the desired welding angles and position. If the air gap becomes too wide for the current to jump, current flow will stop. If the air gap is too narrow, the electrode will stick to the base metal.

As stated, normal arc length is about the same length as the diameter of the core rod of the electrode. It is difficult to go from touching the base metal, to a normal arc length in one quick motion. This is especially true when using small 3/32", 1/8", or 5/32" electrodes at amperage settings below 80 A or so.

It is often easier to drag the electrode across the base metal and pull upward to first establish a slight "**long arc.**" Use the light from the long arc to see where the tip of the electrode is actually located, and quickly move it into the desired welding position. Maintain the long arc at the beginning of the weld joint for a second or two to preheat the base metal. Then, shorten the arc length to the normal recommended length. Allow an arc crater to form before starting forward travel. The scratching method with an initial long arc seems to be the easiest for beginners, and for use with AC output welding machines.

With the tapping method, the electrode is brought to the surface of the base metal in a near-vertical position. The tip end of the electrode is quickly tapped against the surface of the base metal. As the tip of the electrode is withdrawn, an arc is established. Again, for the beginner, it may be easier to first establish and maintain a slight long arc as the tip of the electrode is moved to the desired welding position and angles.

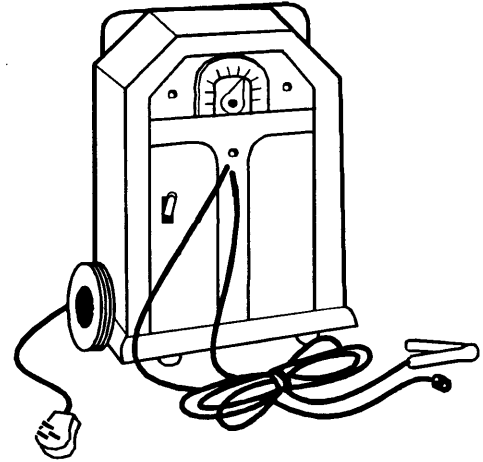
When an electrode does stick, it should be broken off as quickly as possible by bending it back and forth. When the electrode sticks, excessive high-amperage current will continue flowing through the circuit. The entire length of the electrode can become red hot. If the electrode is allowed to remain in the stuck position for more than a few seconds, component parts and wiring insulation inside the welder can become damaged.

If the stuck electrode does not break off by bending it back and forth, immediately release the electrode from the electrode holder. Be careful not to raise the welding helmet before the electrode is disconnected. To do so can result in a severe arc burn to the eyes.

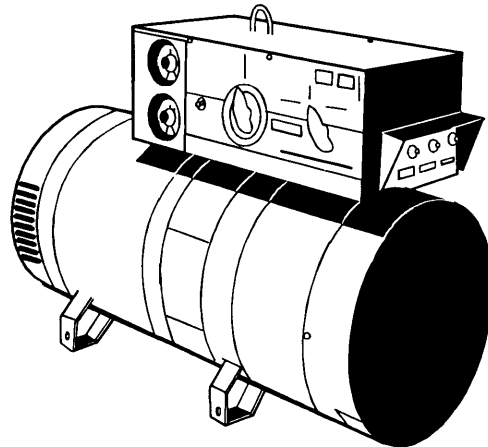
TYPES OF SHIELDED METAL ARC WELDERS

There are several different ways of classifying types of shielded metal arc welders. One method is simply by the type of welding current output. Arc welding machines can be AC, DC, or combination AC/DC output machines. Another way of classifying welding machines is by their power supply source.

An **AC-output/transformer type welder** is connected to a 240 V AC power line source. An internal step-down transformer changes the 240 V/lower-amperage AC into approximately 25 V/higher-amperage AC output for welding. The only adjustment on the transformer type AC welder is the amperage setting. Depending upon the make and model, the amperage adjustment is made by turning a crank, moving a multi-position switch, or moving one of the welding leads to another socket or plug. Small AC-output/transformer type welders with welding amperage ratings up to 225 A are often called “cracker box welders.” They are the least-expensive general-purpose welders for fabrication and repair work.

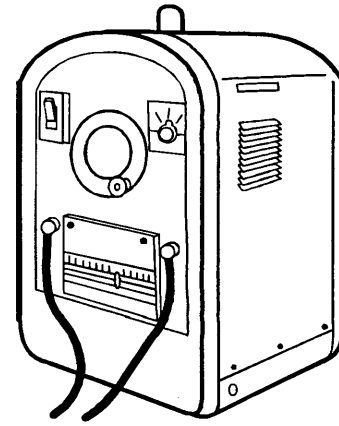


A **DC-output electric motor/generator welder** is connected to a 240 or 440 V AC power line source. The power source is used to power a large electric motor. The electric motor in-turn drives a large DC generator. The large generator produces higher amperage DC output for production-type welding on thicker metal. Some models can produce up to 600 A.

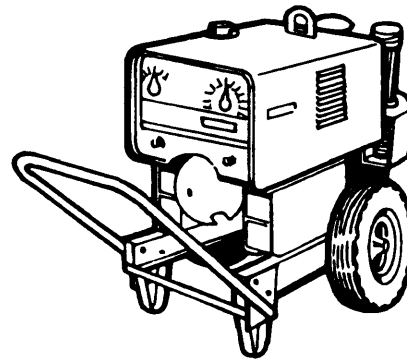
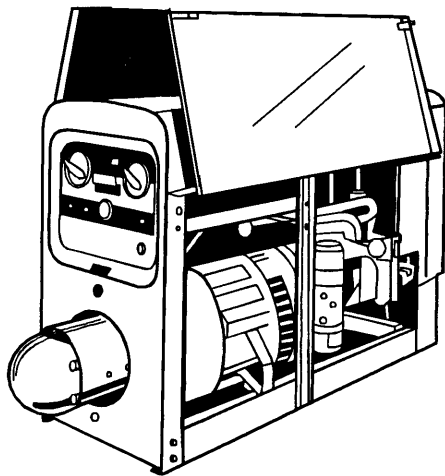


An **AC/DC-output transformer/rectifier welder** is connected to a 240 V AC power line source. An internal step-down transformer changes 240 V/lower-amperage AC into lower-voltage higher-amperage AC.

This is similar to a regular transformer type welder. The alternating current is then converted to direct current output for welding by an internal rectifier diode set. By turning a switch on the rectifier, most AC/DC-output transformer-rectifier welders can provide either DC reverse polarity or DC straight polarity output. By switching the rectifier off, the welder will produce AC output like a standard AC transformer type welder.



AC/DC Output
Transformer/Rectifier Welder



Engine-Driven DC Output and AC Output Portable Welders

An **engine-driven DC output welder** is powered by a gasoline or diesel engine. The engine turns a large generator that produces high-amperage/low-voltage DC output for welding. An **engine-driven AC output welder** is also powered by a gasoline or diesel engine. The engine turns an alternator that produces high-amperage/low-voltage AC output for welding. Some engine-driven AC output welder units are also equipped with a rectifier diode set. The welder then becomes an **engine-driven AC/DC output welder**.

A major advantage of using engine driven welders is portability. The welding machine can be moved to remote locations where an AC power source is not available. Some models are also equipped to produce 120 V/15A - AC or DC output to operate portable hand grinders, drills, metal chop saws, etc.

The capacity of a welding machine is rated by the manufacturer according to 1) its maximum **welding amperage**, and 2) its **duty cycle**. Recall that as amperage in the welding circuit increases, the heat generated at the arc increases because of increased current flow. As the welding output current flow increases, the amount of heat generated within internal components and wiring also increases.

Duty cycle is the amount of time the welding machine can be safely operated at its maximum rated amperage during a ten-minute period of time. It is a standard used by the welding industry for rating welding machines.

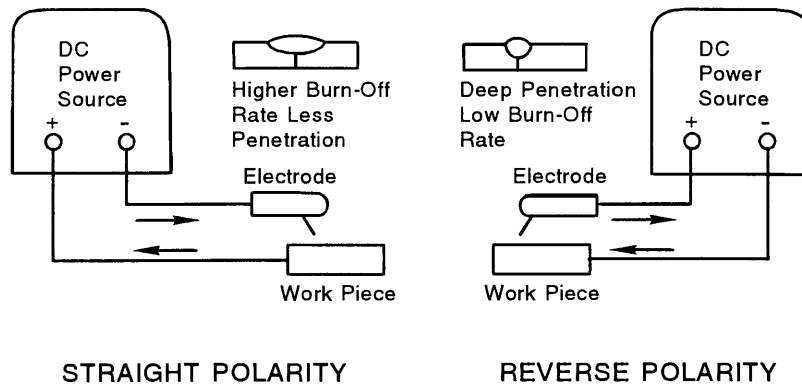
For example, suppose a 225 A -- AC-output/transformer type welder has a 20 percent duty cycle rating. This means that the welder can be safely operated (actual arc welding time) for only two minutes out of each ten minutes at this maximum 225 amperage setting. The welder must then be allowed to cool for eight minutes to prevent it from overheating and causing damage to internal parts and wiring insulation.

As a general rule, the duty cycle for any particular welding application increases as the amperage setting being used decreases. If the same machine is operated at only 125 A, the duty cycle may increase to 60%. At this setting, the welder could be operated (actual welding time) for 6 minutes out of each 10.

The amperage and duty cycle ratings vary with the make and model of welders. To some degree, the duty cycle indicates the quality of the machine. The higher the duty cycle rating for the same maximum amperage rating, the better the quality of insulation and the higher the cooling capacity of welder.

Using AC Vs DC Output Welding Current

The welding circuit of a DC welder has current flowing in only one direction. When the cable with the electrode holder is attached to the negative (-) terminal on the power source and the ground cable is connected to the positive (+) terminal, the circuit has “straight polarity” called **DCSP**. Some references may also refer to this as **DCEN** or **DC -** for direct current/electrode negative.



By theory, the electrons (negatively charged electrical particles) are flowing from the negative terminal, through the electrode, across the air gap, and into the base metal and ground cable, and then back to the power source. Approximately two-thirds of the heat produced by the arc is released into the electrode while one-third is released into the base metal. With the greater amount of heat in the electrode, it melts very rapidly. When the proper electrode is used, welding with DC straight polarity (DCEN or DCSP) normally produces a wider-flatter bead with shallower penetration.

When the electrode cable is attached to the positive (+) terminal and the ground cable is attached to the negative (-) terminal, the DC circuit has “reversed polarity” called **DCRP**. Some references also refer to this as **DCEP** or **DC+** for direct current/electrode positive. By theory, approximately one-third of the arc heat is given off through the electrode and two-thirds is dissipated into the base metal. When the proper electrode is used, welding with DC reverse polarity (DCEP or DCRP) normally provides a slightly narrower bead with deeper penetration.

When welding with alternating current, approximately 50% of the heat is given off into the electrode and 50% into the base metal. With all other factors being equal, welding with AC results in average penetration.

TYPES, CLASSIFICATIONS, SIZES AND USES OF SMAW ELECTRODES

When the arc welding process was first being developed in the late 1910s and early 1920s, bare metal rods were used as electrodes. It was discovered that oxygen and nitrogen from the air would react chemically with the hot molten melt. In addition, the arc would wander from side to side of the bare electrode tip.

The tip of the electrode would melt off in uneven globules making it difficult to control the molten puddle. All these factors resulted in weak welds with very rough appearances.

Through continued research and development, electrodes are now coated with **flux**. The functions of the flux are: 1) to stabilize the arc, 2) provide a gaseous shield, 3) help clean the metal surface, 4) form a protective slag, and 5) in some cases, provide extra filler metal.

The flux is made of silicone and other chemicals. The flux melts at approximately the same temperature as the tip of metal rod. The flux coating helps stabilize the arc and allows the electrode tip to melt off in smaller droplets.

Part of the flux burns and gives off a gaseous smoke that surrounds the arc area to provide an **inert gas shield**. An inert gas is a gas that does not react chemically or combine with hot or molten metal. The inert gas shield protects the tip of the electrode and the molten puddle from oxygen, nitrogen, and hydrogen in the air which weakens the weld. Thus, “shielded” in the SMAW name refers to the inert gas shield around the arc area that is provided by the burning flux.

The flux also helps clean the metal surface of rust, paint, and other impurities. It floats them to the top of the molten puddle to promote fusion. In addition, the flux contains ingredients that form a **protective slag** over the top of the weld bead as it cools. The slag coating provides additional protection from oxidation and allows the bead to cool more slowly. This helps prevent weld cracking due to rapid expansion and contraction of metal in the bead area.

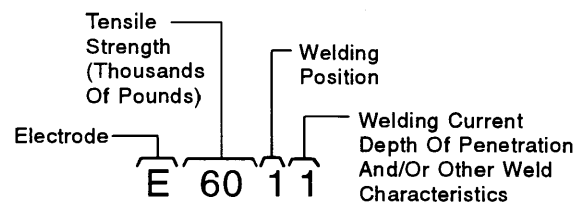
The flux on some types of electrodes may also contain iron powder. This provides extra filler metal into the molten puddle. This allows a higher deposit or **fill rate** without having to use a larger diameter electrode at a higher welding amperage.

AWS Electrode Classifications

All major manufacturers of arc welding electrodes follow the **American Welding Society (AWS)** codes for classifications and specifications. Regardless of the manufacturer, all electrodes with the same AWS number must meet minimum standards.

Electrodes are classified according to: 1) diameter and length, 2) type of flux coating, 3) composition of the weld metal {core filler rod}, 4) the recommended welding positions, and 5) the type of current the electrode can be used with. The AWS # is stamped near the electrode holder end.

Each AWS classification of electrodes has been assigned specific symbols and numbers. The prefix **E** indicates the electrode is for electric arc welding. The first two digits in a four-digit number designate the minimum tensile strength of one square-inch of deposited metal when a weld joint is properly made. This is given in thousands of pounds per square inch (psi).



For example, one-square inch section of weld properly made with **E-60XX** series electrodes should provide a minimum pull strength of 60,000 psi. **E-70XX** series electrodes provide a tensile strength of 70,000 psi. The first three digits of a five-digit number such as **E-110XX** indicate 110,000 psi strength. Most mild steel has a tensile strength of 45,000 to 50,000 psi. Thus, E-60xx or E-70XX series electrodes are satisfactory for general-purpose welding applications you will perform.

The third digit in the four-digit number indicates the welding position(s) the electrodes can be used in. The **E-XX1X** indicates electrodes designed for use in all welding positions. **E-XX2X** indicates electrodes designed for use in only horizontal and flat welding positions. **E-XX3X** indicates electrodes designed for welding in the flat position only. **E-XX4X** indicates electrodes designed for welding in the flat, horizontal, overhead, and vertical down positions.

The fourth digit indicates special characteristics about the electrodes such as weld quality, fill or deposit rate, type of current, composition of the flux coating, characteristics of the arc, and the amount of penetration. Numbers 0 through 8 are used.

AWS #	CURRENT	ARC	PENETRATION	COVERING & SLAG	IRON POWDER
EXX10	DCRP	DIGGING	DEEP	CELLULOSE - SODIUM	0%-10%
EXXX1	AC & DCRP	DIGGING	DEEP	CELLULOSE - POTASSIUM	0%
EXXX2	AC & DCSP	MEDIUM	MEDIUM	TITANIA - SODIUM	0%-10%
EXXX3	AC & DCS & R	SOFT	LIGHT	TITANIA - POTASSIUM	0%-10%
EXXX4	AC & DCS & R	SOFT	LIGHT	TITANIA - IRON POWDER	25%-40%
EXXX5	DCRP	MEDIUM	MEDIUM	LOW HYD. - SODIUM	0%
EXXX6	AC OR DCRP	MEDIUM	MEDIUM	LOW HYD. - POTASSIUM	0%
EXXX8	AC OR DCRP	MEDIUM	MEDIUM	LOW HYD. - IRON POWDER	25%-40%
EXX20	AC OR DCSP	MEDIUM	MEDIUM	IRON OXIDE - SODIUM	0%
EXX22	AC OR DCS & R	MEDIUM	MEDIUM	IRON OXIDE - SODIUM	0%
EXX24	AC OR DCS & R	SOFT	LIGHT	TITANIA - IRON POWDER	50%
EXX27	AC OR DCS & R	MEDIUM	MEDIUM	IRON OXIDE - IRON POWDER	50%
EXX28	AC OR DCRP	MEDIUM	MEDIUM	LOW HYD. - IRON POWDER	50%
EXX48	AC OR DCRP	MEDIUM	MEDIUM	LOW HYD. - IRON POWDER	25%-40%

Other Electrode Classifications

In addition to the official AWS electrode classifications, some manufacturers classify electrodes as **fast-freeze**, **fill-freeze**, **fast-fill**, and **low hydrogen**. Electrodes for special applications such as hard-surfacing and welding aluminum, cast iron, stainless steel, or high tensile strength alloys are available but will not be discussed at this time.

Fast-freeze electrodes produce a snappy, deep penetrating arc with fast-freezing deposits. This means the molten puddle will solidify very quickly as the arc heat is moved away. They are commonly called DC reverse-polarity electrodes (DC+), but can be used with AC welders. They have a fairly low fill or deposit rate and produce flat beads with little slag. They are preferred for vertical and overhead welding but can be used in all welding positions in both general fabrication and repair work. The arc is fairly easy to control. They can be used on plated, painted, or unclean metal. Electrodes in this classification include E-6010, E-6011, E-7010, and E-7011.

Fill-freeze electrodes have a moderately forceful arc and a moderate deposit rate somewhere between the fast-freeze and fast-fill electrodes. They are commonly called straight-polarity electrodes (DC-) but can be used with AC welders. These electrodes produce beads with distinct even ripples with complete slag coverage.

They are an all-position general-purpose electrode for production and repair welding. They are a good choice for welding short-irregular shaped weld joints with poor fit-up that change direction and/or position. Electrodes in this classification include E-6012, E-6013, and E-7014.

Fast-fill electrodes produce a softer arc for shallower penetration, but provide a much faster deposit rate. They have a thicker flux coating that contains up to 50% iron powder. They produce exceptionally smooth weld deposits with a heavy slag that can be removed easily. They are used primarily on clean metal in production-type welding in the flat and horizontal positions. They can be used on medium-carbon steel when low-hydrogen electrodes are not available. Electrodes in this classification include E-7024, E-7028, and E-6027.

There are four basic types of carbon steel: 1) low carbon steel, 2) mild steel, 3) medium carbon steel, and 4) high carbon steel. Most standard metal fabrication is made with mild steel. It can be easily welded with the proper fast-freeze, fill-freeze, or fast-fill mild steel electrodes.

When greater strength and/or harder metal is required, agricultural equipment parts are made with medium carbon steel. In addition, much of the “*used oil-field pipe, tubing, and rods*” purchased for re-use in agricultural construction contains a higher carbon content. **Low-hydrogen electrodes** are especially designed for welding higher-carbon metals.

Medium to high carbon steel can be more difficult to weld than mild steel. Localized hard spots may develop in the weld deposit because of the higher carbon content. This can make the weld joint brittle. Internal and external cracks within the joint can then result due to rapid expansion and contraction of the metal. Weld cracking is also directly related to the amount of hydrogen entering the weld area during the welding process. (You will be introduced to procedures to identify mild steel from medium or high carbon steel in other student topics.)

A special flux on low-hydrogen electrodes provides the proper gaseous shield to prevent excess hydrogen from entering the weld area. A thicker flux coating provides additional slag to protect the molten puddle as it solidifies, and the bead as it cools. In addition, the higher iron powder content in the flux provides a faster metal deposit rate.

Low-hydrogen electrodes can be used for welding thick sections of mild steel requiring high mechanical strength. Low-hydrogen electrodes include E-7016, E-7018, E-7028, and E-7048.

Arc welding electrodes are sized by the diameter of the bare rod without the flux. Standard sizes are 1/16", 3/32", 1/8", 5/32", 3/16", 7/32", 1/4", and 5/16". It is impossible for welding equipment manufacturers to say, "use this exact type and size of electrode, at this exact amperage setting, on this thickness of metal, in this welding position, with this type of welding machine, using this current." There are too many variables that *they* as the manufacturers and *you* as the welder do not have control over. Rather, they publish *general recommendations* under *average conditions*. Shown are general recommendations for three common electrodes you will probably use as a beginning welder.

AWS #	Electrode Polarity	Electrode Size Amperage Range			
		3/32"	1/8"	5/32"	3/16"
E-6011	AC	50 - 85	75 - 120	90 - 160	120 - 200
	DC+	45 - 75	70 - 110	80 - 145	110 - 180
E-6013	A/C	75 - 105	110 - 150	160 - 200	205 - 260
	D/C±	70 - 95	100 - 135	145 - 180	190 - 235
E-7018	A/C	80 - 120	110 - 170	135 - 225	200 - 300
	D/C+	70 - 100	90 - 150	120 - 190	170 - 280

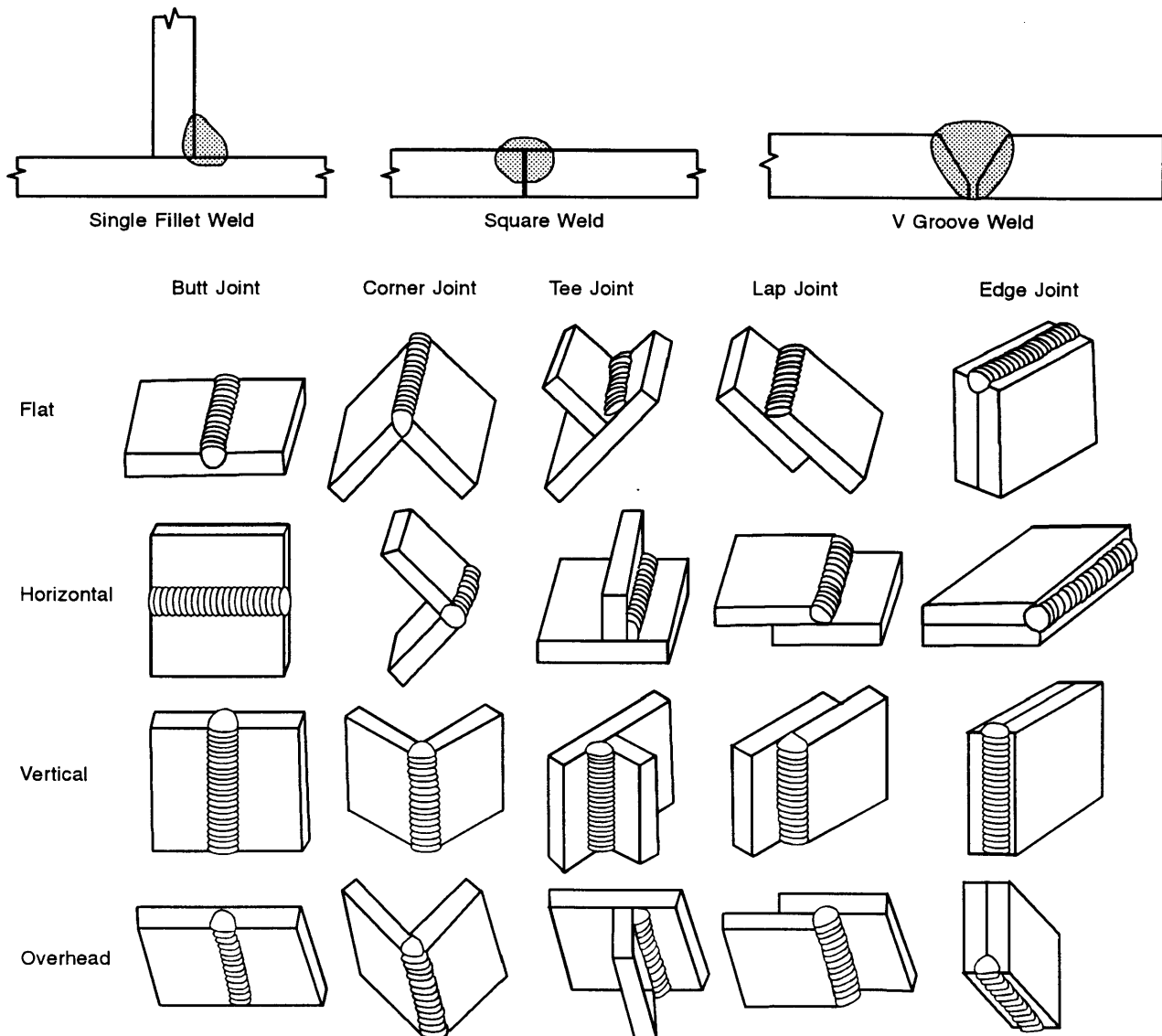
There are 8 basic factors to consider when selecting electrodes. They include:

1. The type of base metal; mild or higher carbon steel.
2. The position of the weld joint; higher welding currents and higher deposition rates are possible in the flat and horizontal positions.
3. The type of welding current available; AC or DC.
4. The type and design of the weld joint; lower penetration electrodes with softer arc for sheet metals and thin plates, deeper penetration for thicker plates.
5. The fit-up of the weld joint; some electrodes are more suitable for bridging across gaps in poor fit-ups.
6. Metal deposition rate; for out-of-position welding, an electrode with a lower deposition rate would be preferred in order to control the crater.
7. Strength requirements of base metal and welded joint.
8. Experience of the welder, production efficiency, and job conditions.

It is important to follow manufacturers' recommendations for storing electrodes after the sealed shipping container has been opened. The flux coating can easily absorb moisture directly from the air. Any moisture at all can affect how well the flux performs its different functions. Excess moisture in the flux can turn to steam as the flux burns causing extra spatter and porosity (small holes) in the weld.

Additional information on electrodes and the recommendations for specific applications are provided in arc welding reference books and in handbooks supplied by electrode manufacturers.

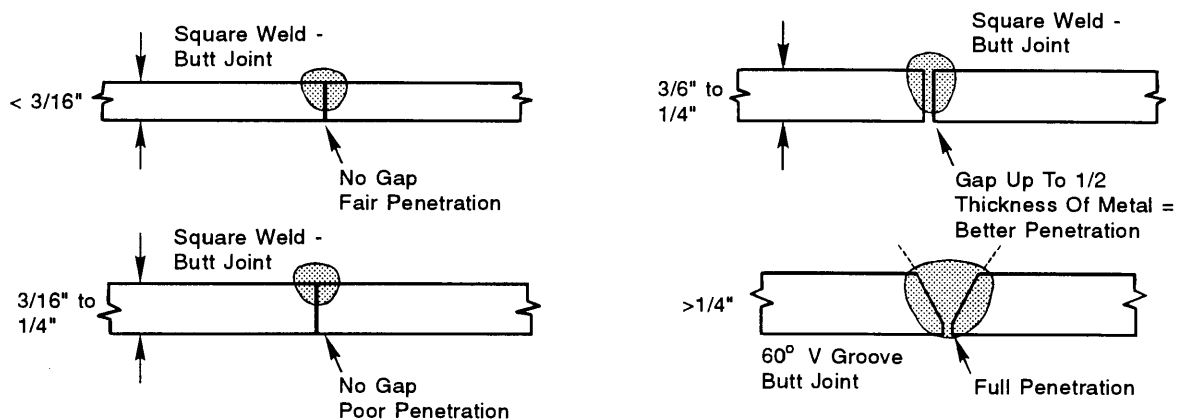
ARC WELDING POSITIONS AND JOINTS



The Five Basic Types of Weld Joints May Be Made In Any Of the Four Different Welding Positions.

The terms joint and weld are not synonymous. There are five basic types of weld joints: **butt joints**, **corner joints**, **tee joints**, **lap joints**, and **edge joints**. These weld joints can be made with **fillet welds**, **square welds**, or **groove welds**.

There are four welding positions. They are **flat**, **horizontal**, **vertical**, and **overhead**. Each of the five types of welding joints can be made in any of the four welding positions. A weld made in the flat position is considered “position welding” and is the easiest to perform. Horizontal, vertical-up, vertical-down, and overhead are considered “out-of-position welding.” Out-of-position welding requires a higher degree of skill.



Square welds and fillet welds are often made without edge preparations. In most applications, $3/16"$ and thinner mild steel can be welded with a square weld on one side with little or no edge preparation. Joints made on $3/16"$ to $1/4"$ metal can be spread apart up to $1/2$ their thickness to allow for deeper penetration. For added strength, groove welds are required on metal over $1/4"$. The edges of the base metal must be beveled or shaped in some way to obtain full joint penetration.

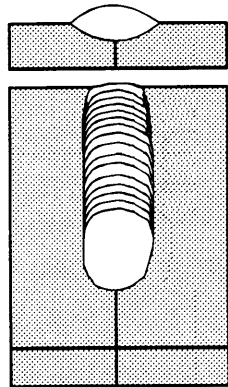
The type of “weld” and the type of “weld joint” to use depends upon: 1) its location within the structure, 2) the strength requirements, 3) the desired appearance, 4) the time allowed to prepare the joint, and 5) the welding position.

Types Of Weld Beads

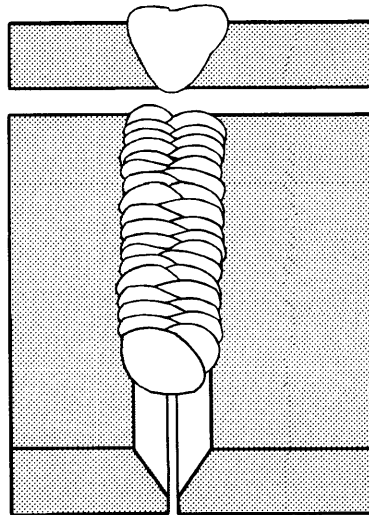
There are two basic types of weld beads: 1) **stringer beads** and 2) **weaving beads**. **Stringer beads** are made with no arc motion except the uniform forward travel and feeding the electrode into the arc crater as it melts off.

SMAW requires a lot of hand and eye coordination. For a beginning welder, it is easier to concentrate only on these two motions.

A key in learning to weld is watching the molten puddle. The size of the molten puddle controls the size of the bead. As a rule of thumb, the width of a stringer bead should be only about 1½ to 2 times the diameter of the electrode. A stringer bead should never be over 3 times the diameter of the electrode.



Stringer Bead



Weave Bead

A **weaving bead** is made by moving the tip of the electrode from side to side in uniform oscillating or circular motions across the width of the weld joint. This is in addition to the forward travel and feeding the electrode into the arc crater. The width of a weaving bead is usually 3 to 4 times the diameter of the electrode, but never over 6.

The purposes of making the additional oscillating or circular arc motions are: 1) to make wider single-pass weld joints, 2) help fuse the edges of multi-pass welds together, 3) help control the molten puddle in out-of-position welding, 4) help prevent undercutting, and/or 5) to stir the molten puddle.

Slag, rust, and other impurities can become trapped in an extra large molten puddle if you try to maintain it with only forward travel. Any impurities trapped in the puddle when it cools will weaken the weld. The oscillating motion allows the arc force to help “stir” the puddle from side to side causing more impurities to float to the top before it solidifies.

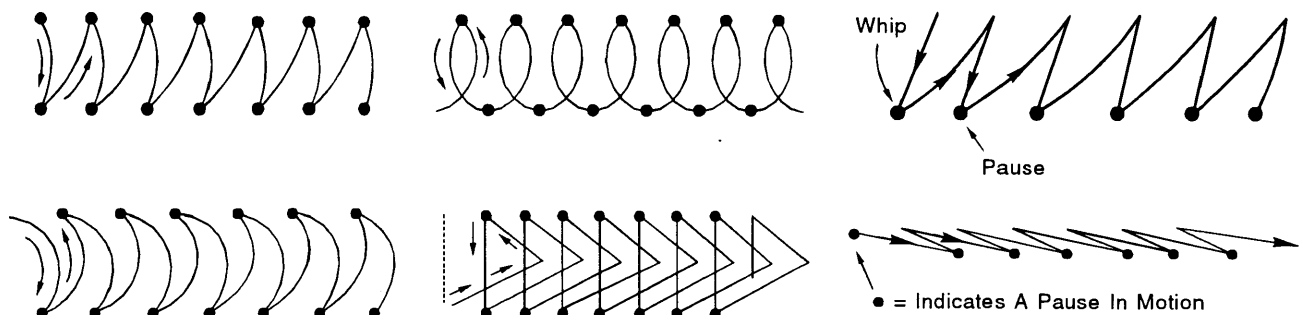
Position and Out-of-Position Welding

Obviously, butt joints made with square or groove welds in the flat position are the easiest to make. Gravity works against us when making lap and tee joints in the flat position, and in all out-of-position welding. Simply, liquid molten metal and slag tends to run downhill and fall out of the arc crater.

When welding different shapes and thickness' of metal together, the smaller and thinner pieces of metal will heat up much faster. This is because there is less mass for the arc heat to travel into. Also, when making a lap or tee joint, the exposed edge will take heat faster than the middle of the flat surface.

As you gain experience, you should learn to “read” the size, shape, and appearance of the molten puddle. Remember that the arc has a definite directional force. You can learn to concentrate the heat where it is needed and use the arc force to “push against and control” the molten puddle in any welding position. You can do this by controlling the: 1) type and size of electrode, 2) current type and amperage, 3) arc length, 4) arc travel speed, 5) arc motion, and 6) electrode angles.

Use the weaving motion to direct the arc heat and prevent a cold overlap or to pause and deposit more filler metal and prevent undercutting. A **whip motion** is an oscillating weave motion that is primarily back and forth in the direction of travel. A slight side to side motion is added as needed. By instantly whipping the arc up out of the center of the crater and pausing to hold a slight long arc for a fraction of a second, the molten puddle can quickly cool and solidify.



Various Weave Motion Patterns

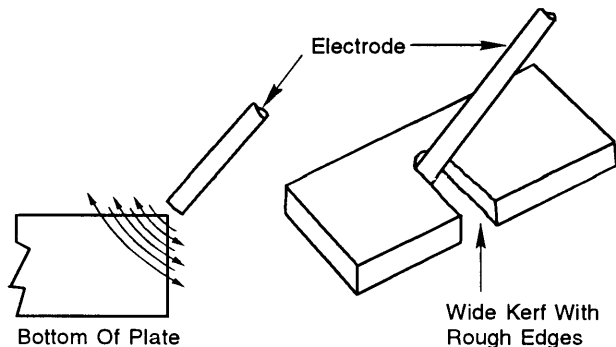
There are other more-complex arc motion patterns shown in arc welding reference books. When a complex motion is added to a stringer bead, out-of-position welding can become very difficult and tiring. To avoid fatigue, learn to watch the molten puddle. Remember the purposes for the weaving motion and for changing the electrode angles. Make the simplest and easiest changes possible to accomplish the desired results. As a rule of thumb, shorten the arc length slightly for out-of-position welding.

When travel speed is too fast, the molten puddle solidifies before the slag and impurities can float to the top. The bead is very narrow and the ripples are very pointed. When the travel speed is too slow, the filler metal piles up. The bead is high and wide and the ripples are straight to slightly arced.

CUTTING METAL WITH AN ARC WELDER

An arc welder can be used to cut mild steel and cast iron by using a higher amperage setting. The higher arc heat melts the metal. The arc force helps blow the molten metal out of the puddle. Gravity allows it to run or fall out of the kerf area before it solidifies. A cut made with an arc welder is not as smooth as a cut made with an oxy-fuel or plasma arc torch. Thus, arc cutting is used mainly in demolition work and when a smooth edge is not required.

Special arc cutting electrodes are available, but may be more expensive. Regular electrodes such as E-6011s with a deep penetrating arc can be used. With a 1/8" electrode, the amperage can be set as high as 160 to 180 A. As a rule of thumb, the cutting amperage is about 25% to 50% higher than the welding amperage on similar thickness metal. Do not set the amperage so high that the electrode becomes red-hot. Remember the duty cycle rating of the welder.



Cutting Metal With An Arc Welder

Some operators prefer to soak the electrodes in water for 10 to 30 minutes before using them for arc cutting. This causes the flux coating to burn off and melt more slowly than the core rod. This helps direct the arc force in more of a straight line and prevents "side arcing" at the higher amperage.

Always support the work piece so that gravity will help the molten metal fall out of the cut area. Start the cut with the electrode at the edge of the metal. Maintain a slight long arc until the metal begins to melt. Shorten the arc and move the electrode in short back and forth whipping motions down the cut line.

Proceed only as fast as the kerf area can be kept clean and open. Arc cutting produces a large amount of smoke, fumes, and sparks. Make sure there is proper ventilation and that hot sparks do not fall on flammable materials.

HARD-SURFACING METAL WITH AN ARC WELDER

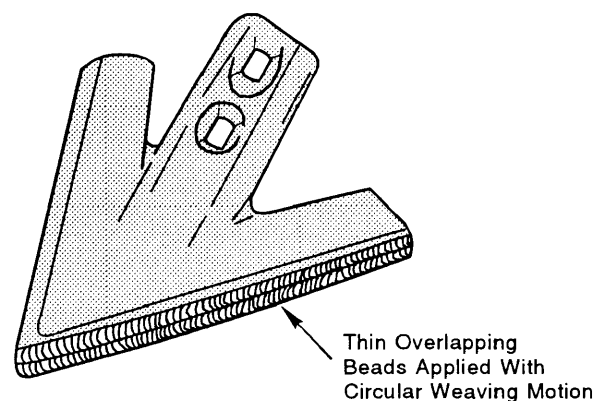
Certain surfaces and edges on tools and equipment wear away rapidly due to: 1) continuous impact, 2) abrasion, and/or 3) corrosion. **Hard-surfacing** is a process of applying a thin layer of harder and more durable metal alloy over a softer base metal surface. The process is also called hard-facing.

It is not always cost-effective to replace an entire part when only a small surface area is worn. Hard-surfacing can be applied when parts are new to make them last longer, or to rebuild worn parts. In some applications, hard-surfacing can be performed with the SMAW process.

Different types of hard-surfacing electrodes are available. The core rod and flux for each type contains different combinations of elements, metals, and metal alloys such as tungsten carbide, chromium, titanium, and carbon. Each type provides different degrees of resistance to abrasive wear, impact, and/or corrosion.

Use a grinder to thoroughly clean the base metal surface of all rust, scale, paint, etc., before applying hard-surfacing material. Follow the manufacturers' recommendations for current polarity, amperage, electrode size, and motion patterns. As a rule of thumb, use the lowest amperage setting possible to provide shallow penetration, yet still maintain the arc.

When possible, perform hard-surface welding in the flat position. To prevent deep penetration, use a medium-long arc to spread the arc heat over a larger area. Use a slow circling or side to side weaving motion to produce thin beads up to $\frac{3}{4}$ " to $1\frac{1}{2}$ " wide. If a larger surface area is to be covered, lay several beads side by side with each bead overlapping slightly.



Hard-Surfacing Being Applied to
Cutting Edge of Plow Point

When a worn surface is to be built-up with several layers of hard-surfacing, allow each layer to cool before adding another. Thoroughly clean all slag before the next pass is made.

When hard-surfacing a part with a thin edge, hold a medium-long arc over the thicker section; then quickly whip out to the thin edge, and immediately back to the thicker section. This will spread a thin shallow deposit onto the thinner edge before the heat builds up and burns through.

CONTROLLING DISTORTION

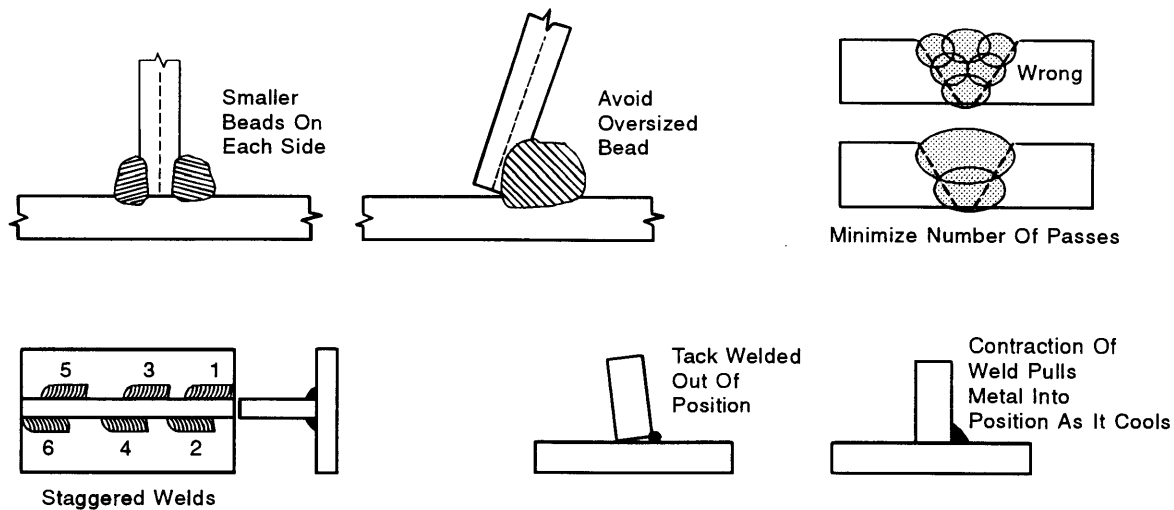
Recall from your physical science courses the principles and natural laws of thermal expansion and heat transfer. Heat travels through a material from the hottest area to a cooler area. Heat causes metal to expand and cooling causes it to contract. For each degree of temperature change, there is a corresponding change in the size of the metal.

When a weld joint is being made, the entire pieces of base metal do not expand and contract uniformly because of the concentrated arc heat near the crater. **Distortion** is caused by the rapid expansion and contraction due to fluctuations in the temperature of the metal. The amount of distortion varies with the type, shape, and thickness of the base metal pieces, the type of welding joint, and the welding amperage used.

Distortion may be temporary or permanent. Distortion can affect how metal pieces fit together. Severe distortion can weaken a weld joint by causing internal and external cracks in the bead area as the metal expands and contracts at different rates.

Various methods are used to prevent and/or control distortion. Several short tack weld beads can be placed at each end and along the length of the welding joint to help hold the metal in the correct position. Tack welds can be placed where shrinkage can change the position of the base metal pieces. If a long weld joint is to be made, it should be tacked at least every 10" to 12" apart. As a general rule, each tack weld should be twice as long as the base metal is thick.

Clamps or jigs are used to hold the pieces of base metal in position. In addition, they help absorb part of the heat allowing the base metal to cool more evenly.



Various Methods to Control Distortion

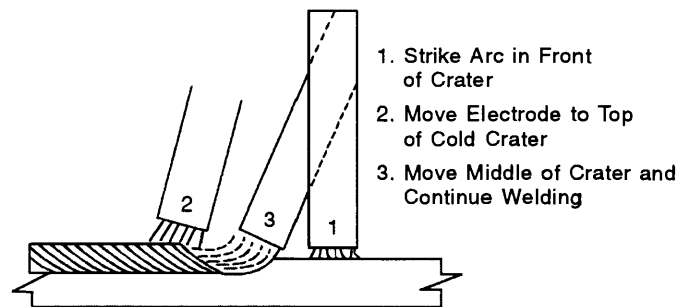
When possible, use short staggered welds. Weld one section and allow it to cool while welding in another area. This helps to balance the expansion and contraction forces. Use larger electrodes with fewer passes. Avoid extra large beads and/or extra passes that simply “pile up filler metal,” but do not add significant strength to the joint. If possible, weld on both sides of a joint with two smaller beads instead of one large bead on one side.

In some applications, you can learn to plan ahead for shrinkage. The base metal pieces are tack welded in the “incorrect position.” When the weld is completed, contraction will pull the pieces into alignment as the metal cools.

STOPPING AND RESTARTING A CONTINUOUS BEAD

When you are ready to stop a bead, you should pause forward travel and push the tip of the electrode into the middle of the crater almost to the point of sticking. Hold it there momentarily, and then slowly break the arc back over the completed weld to allow the puddle to solidify. This will help fill the arc crater and reduce possible stress cracking at the end of the bead.

To restart a bead in the same place for a continuous bead, you should first clean the crater of any slag. Use a chipping hammer and wire brush. Strike the new arc about 1/4" to 1/2" in front of the cold arc crater. Any spatter marks from re-striking the arc can be covered by the continuous bead if you restrike the arc in front of the crater instead of beside or behind it. Move the re-established long arc back to the top of the cold crater. Shorten the arc length and pause momentarily to allow the molten puddle to reform. This will allow any remaining impurities or slag to float to the top. Then, continue welding down the joint as the crater fills.



Restarting A Continuous Bead

BASIC SMAW OPERATING AND SAFETY PROCEDURES

General agricultural mechanics safety information and instruction were covered in student topics #8600 and #8147-A. We all know that serious personal injury and/or equipment damage can result when hand and power equipment are used improperly. Arc cutting and welding equipment is no different. The arc cutting and welding processes can be safe and useful when proper safety precautions and operating procedures are followed.

Operating procedures do vary with different brands and models of welders. It is beyond the scope of this student topic to cover them all in detail. Before you strike your first arc, you should receive proper instruction from your instructor.

Observe demonstrations of any procedures you may be unsure of. Always consult your instructor or supervisor to make sure you are using the proper protective clothing and equipment. Before attempting to operate any welding machine you are not familiar with, review the operators' manual. It contains specific safety information, step-by-step setup instructions, and recommended operating procedures.

Protective Welding Helmets, Clothing, Gloves, and Other Safety Equipment

During the electric arc cutting and welding processes, you must protect yourself from two different types of burns: 1) radiation burns and 2) high-temperature burns.

The arc produces a very bright visible light. However, it is not the visible light that we must be concerned with. The arc also gives off ultraviolet and infrared rays that are invisible to the human eye. These rays are the same as those from the sun. They are very concentrated and intense near the cutting or welding arc. Exposure to these invisible rays can cause radiation burns to the eyes. Severe pain may last from 8 to 18 hours. Those who have received an eye burn say it feels like your eyes are full of hot sand. Over exposure to these rays can lead to permanent eye injury.

Do not look directly at the arc with the naked eyes. Always warn children and others of the danger. The arc is considered harmful up to a distance of approximately 50 feet away. It is necessary for you and anyone nearby to wear proper eye protection.

To avoid eye burns, you must wear a welding helmet equipped with the proper shade of colored filter lens. You must lower your welding helmet **before** striking an arc. You must wait until **after** you break the arc to raise your helmet. The proper filter lens can remove approximately 99.5% of the infrared rays and 99.75% of the ultraviolet rays. The higher the lens number, the darker the colored shading. The common shades used for SMAW are:

- #10 for 1/16" to 5/32" electrodes, or when welding between 75 to 200 A;
- #12 for 3/16" to 1/4" electrodes, or when welding between 200 to 400 A;
- #14 for 5/16" to 3/8" electrodes, or when welding over 400 A.

Through continued research, colored filter lenses have been developed with a gold-colored plating or tint. In addition to filtering the harmful rays, the golden color helps reflect back part of the bright visible light and the high temperature.

Some people may think their eyes are safe if they are not looking directly at the electric arc. However, it is still possible for the intense rays to reflect off of a shiny or light-colored wall, ceiling, or other nearby object and burn the eyes.

A good safety practice is to yell “**COVER**” and then wait several seconds before striking an arc. This is a warning to allow time for you, and anyone in the immediate area to lower a welding helmet, or otherwise protect themselves.



Basic Arc Welding Equipment

In addition to a welding helmet with the proper colored filter lens, you should always wear Occupational Safety and Health Administration (OSHA) approved safety goggles or safety glasses with side shields. They provide additional protection against hot flying sparks or slag that may enter from the back of the helmet.

Some welders prefer to wear safety glasses or goggles with #1 or #2 colored filter lenses. They are called flash goggles. The light-colored flash goggles are worn in addition to the regular welding helmet. When the helmet is up, the flash goggles allow the operator to see to set up work, but still provide some protection from momentary accidental arc flashes. They also help eliminate glare or flashes that may enter from the backside of the welding helmet while welding.

When chipping slag or cleaning metal, it is recommended to remove the welding helmet and wear a clear full-face protective shield. This protects not only the eyes, but the face and neck from flying objects. Some welding helmets are equipped with a hinged flip-up shaded lens on the outside of a stationary clear protective lens. With the shaded lens flipped up, the welder can use the clear protective lens for nonwelding operations such as chipping and grinding.

The ultraviolet and infrared rays from the arc can also cause radiation burns to the skin similar to severe sunburns. When welding at higher amperages, the arc rays can easily penetrate one thickness of normal clothing.

Temperature over 120°F can burn or blister the skin. The electric arc itself can reach temperatures of 11,000°F. Therefore, the base metal being cut or welded can remain hot enough to cause a high-temperature skin burn for a long period of time. The flying sparks and spatter range in temperature from 2,000° to 3,000°F. Thus, they also present a high-temperature skin burn hazard. In addition, sparks and spatter can easily start a fire if they fall on a flammable material.

To provide protection from hot sparks, slag, and spatter, wear a cotton cap or “welding beanie” under the welding helmet. You should wear a heavy, long-sleeved, dark-colored cotton shirt and long cotton pants.

Cotton may smolder, but it will not usually flame up and burn. Synthetic clothing should not be worn. Synthetic fibers such as nylons and polyesters are highly flammable. If they burn, hot melted patches can cling to the skin. Avoid cuffs, open shirt pockets, and rolled up sleeves that can catch sparks. Wear high-top shoes or boots with pants legs down over the tops.

A heavy cotton apron treated with a fire-resistant chemical or a leather jacket, cape, or sleeves provides added protection when welding at a higher amperage or in out-of-position welding.

You should always wear heavy leather gauntlet-type gloves. Gloves should be dry. This helps reduce chances of electrical shock when handling metal that is grounded, or when changing electrodes. However, ***do not*** pick up any hot metal with your hands even though you are wearing heavy leather gloves. Extreme heat can cause leather gloves to instantly shrink and harden around your fingers or hand. Use pliers or metal tongs to handle hot metal.

Additional SMAW Safety Precautions and Operating Procedures

- * The ground clamp must have the capacity to make a good electrical connection and to carry the welding current without overheating and increasing resistance. There should not be any arcing between the work piece and the ground clamp. A ground clamp may become warm from normal welding. However, it should not become hot enough to produce steam if a drop of water touches it. Remember the duty cycle.
- * It is very difficult to weld dirty and corroded metal. Doing so can result in a poor quality of weld. Use a chipping hammer and wire brush to clean the metal. Electric or pneumatic grinders and brushes can also be used. When welding a multi-pass joint, the slag which covers the first weld bead must be removed before the next bead is laid.
- * Weld only in a well-ventilated area. Do not attempt to weld on galvanized metal except under supervision of an expert. The fumes given off when galvanized metal is heated is very toxic.
- * To help reduce the chance of electrical shock, the electrode holder should be completely insulated except on the inside of the jaws which grip the electrode. Do not weld in damp areas.
- * Be sure the welding equipment is properly grounded and has been installed by a qualified electrician. If you are unsure, have you instructor or supervisor inspect the equipment.
- * As a rule of thumb, do not adjust the current selector or current amperage while a machine is under a welding load.
- * Keep welding cables from coming in contact with hot metal or sharp edges. Do not drive over cables.

- * When welding, sit or stand in a relaxed position to avoid fatigue. Hold the electrode holder in a comfortable position that permits free movement.
- * Do not cut or weld on containers which have held combustible materials until proper precautions have been taken. Consult an experienced welder for details.
- * Know the locations of fire extinguishers. In case of an emergency, know the location of power supply disconnect switches for the welder and other power equipment you may be using.
- * Do not weld near combustible materials.
- * Keep work area clean. Place electrode stubs in a proper waste container. Do not throw them on the floor.
- * Keep the uninsulated portion of the electrode holder from touching you or the grounded metal. To prevent an accidental arc flash, always remove the electrode stub before you lay down the electrode holder.
- * Do not wrap live welding cables around your arm or lay them across your shoulder. There is a chance you could get shocked through damaged insulation.
- * Never strike an arc against a compressed gas cylinder of any kind. The cylinder can explode.
- * Use care when handling or moving around metal. Sharp metal edges and slivers can injure your skin.

Always refer to appropriate technical, service, and operators' manuals for specific applications, instructions, repair procedures, and safety precautions. Remember, your personal safety and the safety of others in your work area depends upon you.

It takes a lot of continuous practice to become a proficient welder. As you learn the basic "how to" skills of welding, it is equally important that you also understand the basic scientific principles and theories of operation. As you learn the "how come and whys" of these basic SMAW procedures, your knowledge and skills are easily transferable to more advanced welding processes and applications as you progress.

The curriculum guide for this course of study and the supporting instructional materials were developed for educational use. The applications and components described or pictured are illustrative only. Depiction or description of any product, component, brand name or application does not constitute, indicate, or imply a recommendation or endorsement of any sort.

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Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

TRUE OR FALSE: Circle "T" if the statement is true; circle "F" if the statement is false.

- T F 1. Learning to strike an arc is probably the easiest part of learning to weld.
- T F 2. A fusion weld joint has the potential of being as strong as the base metal parts.
- T F 3. As a rule of thumb, the arc length should be three times the diameter of the bare end of the electrode.
- T F 4. The higher the amperage setting of the welder, the more heat produced by the arc.
- T F 5. When the proper electrode is used, welding with DC straight polarity (DCEN or DCSP) normally produces a wider-flatter bead with shallower penetration.
- T F 6. Some electrodes have extra silicone added to the flux to increase the fill rate.
- T F 7. As a general rule, a tack weld should be twice as long as the base metal is thick.
- T F 8. It is normally not necessary to clean metal of rust or paint before welding because the impurities will always float to the top of the molten puddle in the slag.
- T F 9. Low-hydrogen electrodes are especially designed for welding metals with very low carbon.
- T F 10. A cut made with an arc welder is usually just as smooth as a cut made with an oxy-fuel or plasma torch.
- T F 11. When the proper electrode is used, welding with DC reverse polarity (DCEP or DCRP) normally provides a slightly narrower bead with deeper penetration.
- T F 12. It is normally OK to adjust the current selector or current amperage adjustment while a machine is under a welding load.
- T F 13. If proper protection is not worn, the ultraviolet and infrared rays from the arc can also cause radiation burns to both the skin and to the eyes.
- T F 14. When welding, it is recommended to wear protective clothing made of synthetic fibers such as nylons and polyesters because they do not burn easily.

SHORT ANSWER/LISTING: Respond to the following items in sentences, phrases or short paragraphs in the spaces provided. (Use additional paper when needed.)

15. List four possible causes of undercutting.

- a. _____
- b. _____
- c. _____
- d. _____

16. List any five of the eight basic factors to consider when selecting the electrode to use when welding.

- a. _____
- b. _____
- c. _____
- d. _____
- e. _____

17. List any four of the five functions of the flux coating on an electrode.

a. _____	b. _____
c. _____	d. _____

18. List the two basic methods of striking an arc.

a. _____	b. _____

19. List the two types of burns you must protect yourself from when welding.

a. _____	b. _____

20. List the three common types of welders as classified by the type of welding current output.

- a. _____ b. _____
c. _____

21. List the five main purposes of using an oscillating or circular motion to make a weaving bead.

- a. _____
b. _____
c. _____
d. _____
e. _____

22. List the four positions weld joints can be made in.

- a. _____ b. _____
c. _____ d. _____

23. List the five types of weld joints

- a. _____ b. _____
c. _____ d. _____
e. _____

24. List the three basic types of welds weld joints can be made with.

- a. _____ b. _____
c. _____

25. Briefly explain what the “60” in an E-6013 series electrode indicates.

26. Briefly explain why electrodes must be properly stored after the sealed shipping container has been opened.

27. Briefly explain what is meant by the duty cycle of a welder.

FILL-IN-THE-BLANK: Complete the following statements by inserting the correct word(s) in the blanks.

- _____ 28. _____ occurs when the edges of two pieces of metal are heated so that they melt into liquid molten metal and flow together. When the liquid metal cools properly, a metallurgical bond results.
- _____ 29. An arc is considered harmful and capable of causing radiation burns to the eyes up to a distance of approximately _____ away.
- _____ 30. Electrical current always flows from its source through a _____, and back to its source.
- _____ 31. _____ is the width of the air gap which is the distance between the tip of the electrode and the workpiece.
- _____ 32. The back edge of the molten puddle cools and solidifies to form the _____ as the arc is moved along the weld joint.
- _____ 33. The major advantage of using engine driven welders is _____.
- _____ 34. When trying to control the molten puddle in out-of-position welding, _____ works against us.

MATCHING: Match the letter of the option with the statement it best matches.

a. penetration	b. weld toe
c. overlap	d. hard-surfacing
e. distortion	f. undercut
g. E-xx1x	h. E-xx2x
i. E-xx3x	j. E-xx4x
k. tack weld	

- _____ 35. is the depth the arc crater melts into the base metal and fusion occurs
- _____ 36. is the junction where the face of the weld bead and the base metal fuse together
- _____ 37. indicates electrodes designed for use in only horizontal and flat welding positions
- _____ 38. is an unfilled groove adjacent to the weld bead that was melted into the base metal by the arc
- _____ 39. indicates electrodes designed for welding in the flat, horizontal, overhead, and vertical down positions
- _____ 40. is a process of applying a thin layer of harder and more durable metal alloy over a softer base metal surface
- _____ 41. is any excess protrusion of the weld filler metal beyond the weld toe that does not fuse with the base metal
- _____ 42. indicates electrodes designed for use in all welding positions
- _____ 43. is a small short weld used to temporarily hold components together during assembly
- _____ 44. is caused by the rapid expansion and contraction due to fluctuations in the temperature of the metal
- _____ 45. indicates electrodes designed for welding in the flat position only

ADDITIONAL SKILLS & ENHANCEMENT ACTIVITIES: Perform the following activities or skills as assigned by your instructor.

1. Visit a metal fabrication or repair business. Observe the use of different types of SMAW equipment and processes. **Note!** This activity will require the prior approval by the business owner and shop supervisor.
2. Inspect your school's welding laboratory. Identify any unsafe welding conditions.
3. Break the flux off of an electrode. Attempt to weld on a piece of scrap metal. Observe how hard it is to control the arc and molten puddle. Compare the quality of the bead to one made with a good electrode.
4. Demonstrate the safe use of SMAW equipment. Practice making different types of weld and weld joints, in the four welding positions with different types of electrodes
5. Demonstrate the use of arc welding equipment to cut metal.
6. Demonstrate the ability to apply hard-surfacing with the SMAW process.
7. Visit different metal fabrication and repair businesses in your community. Obtain information about future career opportunities and the technical knowledge and skills required.

- NOTES -

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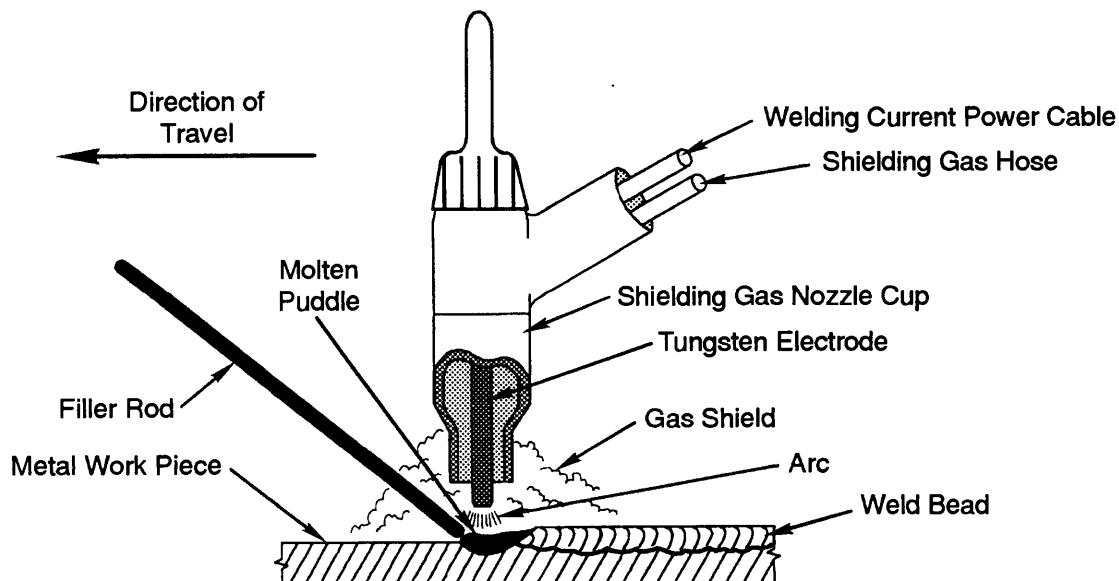
College Station, Texas 77843-2588

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GAS ARC WELDING PRINCIPLES AND PROCEDURES

In student topic #8154-B, you were introduced to fusion welding and to the shielded metal arc welding processes (SMAW). Recall that with the SMAW process, a gaseous shield is produced around the arc area by the burning flux. It protects the molten puddle and electrode tip against adverse chemical reactions with oxygen, nitrogen, and/or other contaminants from the atmospheric air.

Gas Arc Welding is the broad name for another group of electric arc fusion welding processes. One major difference between the gas arc welding processes and the SMAW processes is that the gaseous shield is provided from an externally supplied shielding gas source instead of the burning flux. The gas arc welding torch body is designed so that the shielding gas flows through it and out around the hot molten puddle and electrode tip during the welding process.



Gas Tungsten Arc Welding, or GTAW,
Formerly Tungsten Inert Gas, or TIG, Welding

An **inert gas** is a gas which does not normally combine or react chemically with hot or molten metal. A **reactive gas** will react with certain other chemical elements and with hot metals. If not controlled, adverse chemical reactions can cause defects in the weld bead. Thus for many years, the original gas arc welding processes only used inert shielding gases. Consequently, the two common gas arc welding processes were nicknamed **MIG** for the **metal-inert-gas** welding and **TIG** for **tungsten-inert-gas** welding.

The American Welding Society (AWS) has officially adopted the name “**gas metal arc welding**,” or **GMAW**, instead of metal-inert-gas, or MIG, welding. The tungsten-inert-gas, or TIG, welding process is now officially called “**gas tungsten arc welding**,” or **GTAW**, regardless of the shielding gas used. Today, the shielding gases used with gas arc welding processes may be: 1) an inert gas, 2) a reactive gas, or 3) an inert/reactive gas mixture. Some reactive gases do not cause defects in welds when used properly in the correct proportions. In some cases, small amounts of reactive gases can actually help improve weld quality.

GAS METAL ARC WELDING, OR GMAW, EQUIPMENT

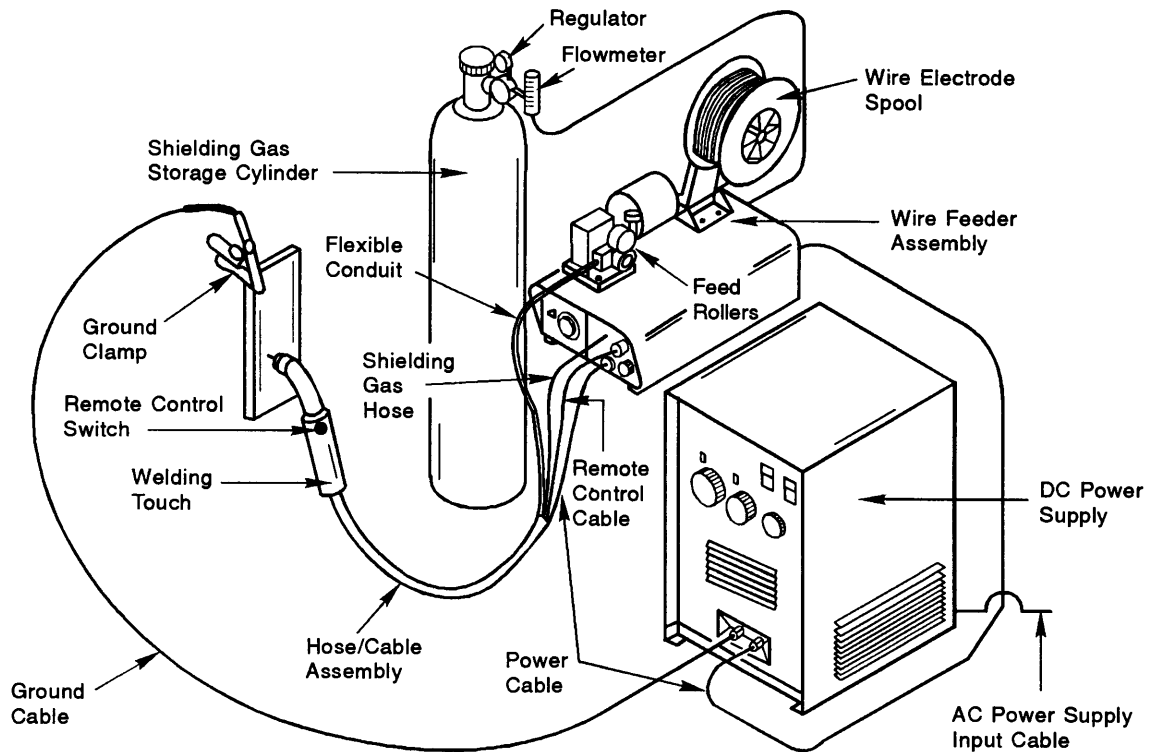
GMAW is a process in which fusion welding is accomplished from the heat of an electric arc established between the tip of a “consumable” metal wire electrode and the metal workpiece being welded. **Current density** is the key to controlling the heat of the arc required for good penetration and proper electrode deposit. Current density is calculated by dividing the welding amperage by the cross sectional area of the wire electrode (in^2). **GMAW** processes are known for their high current density number because of the small diameter electrodes consumed at high amperage settings.

Basic GMAW System Components

The following is a description of the components of the **GMAW** system. **GMAW** requires a special **DC power source** that is capable of providing a constant voltage output during the welding process. The positive terminal of the power source is connected to a power cable within the **hose/cable assembly**. The power cable is then connected to a **copper contact tube** that is located in the middle of the **shielding gas nozzle cup** at the end of the **welding torch**. Some references may refer to the welding torch as the welding gun.

A **flexible conduit** is also located in the hose/cable assembly. This flexible conduit is similar in appearance to the outer spring-steel sleeve often used with throttle cables on small engines. **Feed rolls** within the **wire feeder assembly** pull the small diameter wire electrode from a spool and push it through the flexible conduit to the copper contact tube.

The base metal is connected with a separate ground cable to the negative terminal of the power source to complete the circuit. Electric current is transferred to the consumable wire electrode as it passes through the copper contact tube. During the welding process, electric current jumps a narrow air gap between the tip of the wire electrode and the base metal.

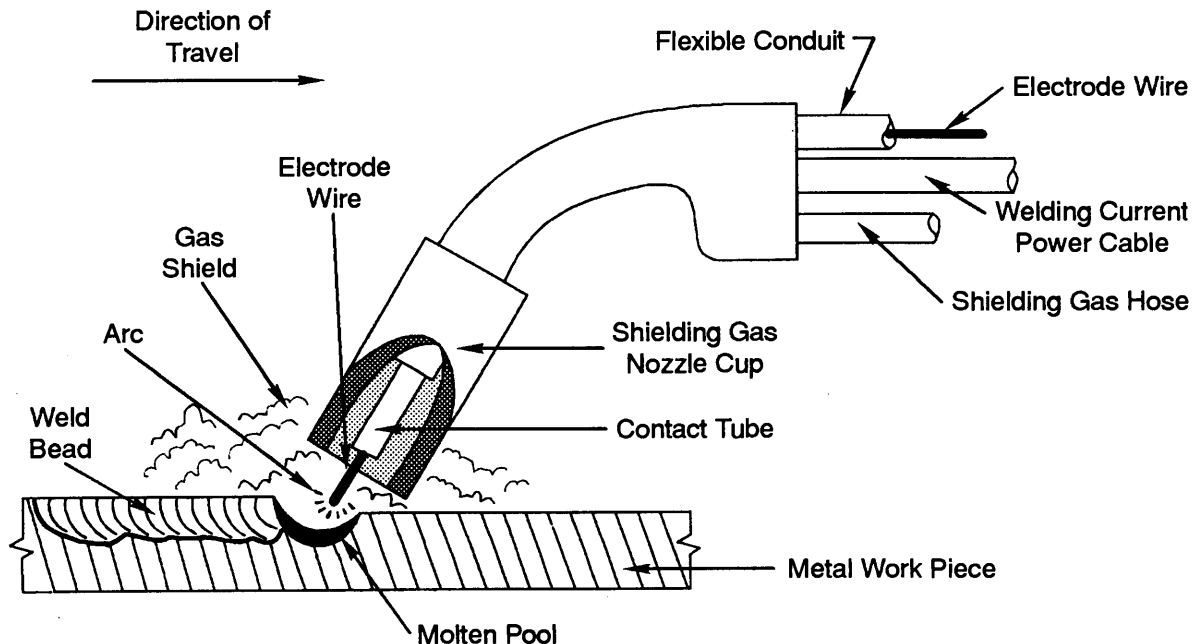


Basic GMAW Equipment

Remote Control and Its Function

The welding torch is equipped with some type of **remote control switch**. Activating the switch: 1) starts the wire feeder mechanism, 2) closes the main contactor switch to start the high voltage welding current, and 3) opens the electromagnetic solenoid valve to start the flow of shielding gas.

For safety reasons, the welding wire electrode is energized only when the remote control switch for the welding torch is depressed. Releasing the remote control switch stops the wire feeder, opens the main welding current contactor switch, and stops the shielding gas flow.



Gas Metal Arc Welding, or GMAW,
Formerly Metal Inert Gas, or MIG, Welding

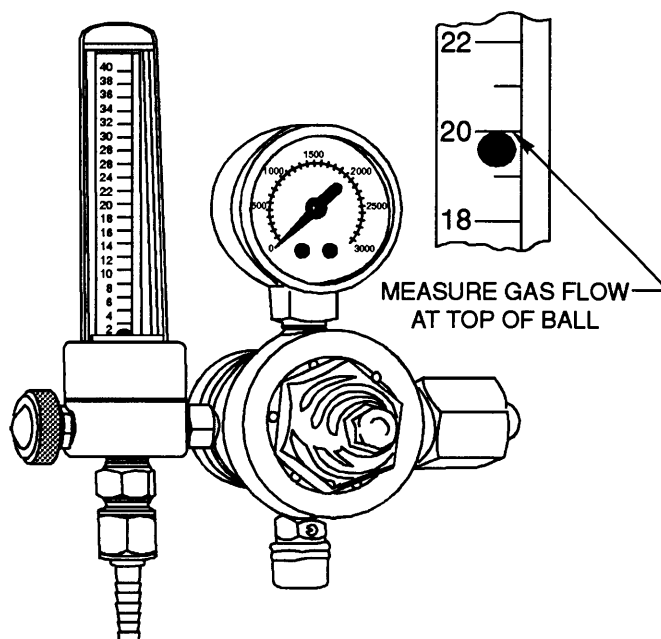
Regulating Gas Flow

The shielding gas used in the gas arc welding process is supplied in high pressure storage cylinders similar to those used to store oxygen for the oxy-fuel cutting and welding processes. Standard shielding gas cylinders contain 330 cubic feet of gas at 3,000 psi. (Review student topic # 8154-A for additional information on storage cylinder and pressure regulator operation and safety.)

The **storage cylinder, regulator/flowmeter assembly, and hose** provide the flow of shielding gas to internal passages within the welding torch body.

The shielding gas hose, welding current cable, control switch wires, and the flexible conduit tube are usually built into one hose/cable assembly. They are enclosed with a protective sheath. The rate or volume of gas flow is measured in cubic feet per hour (cfh).

The flow rate required varies with 1) the type and thickness of base metal being welded, 2) the position of the weld, and 3) the amount of air movement in the arc area due to wind or ventilation.



Shielding Gas Pressure Regulator and Flowmeter

The pressure regulator/flowmeter reduces the pressure of the shielding gas as it comes from the cylinder to a safe working pressure. It also regulates the flow of shielding going to the welding torch. Most regulator/flowmeters are factory-set to provide a constant outlet working pressure of approximately 50 psi. The flow rate is adjusted by the operator according to charts provided with the equipment for the specific application. Depending upon the application, the flow rate setting may range from 15 to 40 cfh.

The shielding gas flows out through orifice holes that surround the contact tube. The shielding gas **nozzle cup** directs the flow of shielding gas around the arc area to protect the tip of the hot wire electrode, the molten puddle, and the weld bead. Shielding gas nozzle cups are available in various sizes and shapes for different applications. The nozzle cups are designed to prevent turbulence of shielding gas that might pull atmospheric air into the arc and molten puddle area.

GMAW Wire Electrodes

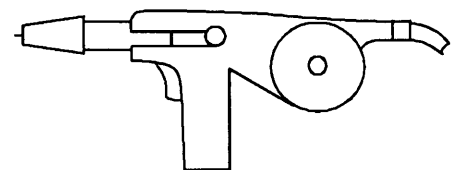
The solid wire electrodes used in GMAW have different metal and chemical compositions to correctly match the type of metal or metal alloy to be welded. Most wire electrodes contain special **chemical deoxidizers** so that they can be used with CO₂ or CO₂ mixture shielding gases. The deoxidizers help reduce the chances of the oxygen from the CO₂ shielding gas and the atmospheric air from reacting with the molten metal and causing porosity in the weld.

Wire electrodes range in size for .020" to 1/8" in diameter. The composition of the wire electrode must be matched to the type of base metal being welded. Wire electrode is purchased in a 1 to 65 pound spool that contains several hundred to several thousand feet of wire. Oxidation or rust on the wire electrode will prevent it from feeding through the flexible conduit smoothly.

Most mild steel wire electrode is copper clad. This means it has a very thin layer of copper around the outside. The purpose of the copper layer is to help prevent corrosion and oxidation from forming on the steel wire while it is in storage and after the roll has been installed on the welding machine. Wire electrode is shipped from the manufacturer in a moisture resistant container. To help prevent the possibility of corrosion, do not open a spool until ready to use.

Wire Feed Assemblies

The **wire feeder assembly** may be: 1) a separate portable unit, 2) a unit built directly into the power source cabinet, or 3) a small unit built into the welding torch. The feed rolls are driven by a variable speed motor. There are different sizes of feed rollers to accommodate the different diameters of welding wire electrode. The welding current is transferred to the welding wire as the wire passes through a copper contact tube located in the middle of the shielding gas nozzle.



Self-Contained
Wire Feeder Assembly
in Welding Torch

There are different sizes of contact tubes for the different sizes of welding wire electrodes. The hole in the contact tip through which the wire passes is only a few thousandths of an inch larger than the wire diameter. A worn or improper sized contact tip will result in an erratic arc due to poor current transfer.

It is sometimes difficult for the wire feeder mechanism to “push” a smaller diameter welding wire electrode through a long wire feeder cable tube without it binding. This is particularly true for softer aluminum welding wire. Thus, some GMAW welding torches contain a small wire feeder mechanism driven by an electric or pneumatic (compressed air) drive motor. A small 1 or 2 pound spool of wire electrode is mounted inside the gun. Self-contained guns of this type are commonly used for soft aluminum wire electrodes up to .045” in diameter, but can be used for other types and sizes of welding wire as well.

Pre and Post-Flow Feature

Most newer GMAW and GTAW units are equipped with an electronic controlled **per flow** and **post flow** feature. When the welding torch remote control switch is activated, the automatic per flow control allows the shielding gas flow to start several seconds before the welding current starts. In the case of a GMAW unit, the wire electrode feed is also delayed several seconds. This purges the hoses of any atmospheric air and allows the gaseous shield to form around the electrode tip before the arc is struck.

Some GMAW and GTAW machines are designed with an automatic, **post flow feature** to protect welds and equipment. This means the shielding gas will continue to flow for several seconds after welding has stopped. In order for the post-flow feature to work, one must maintain the actual welding position of the gun for several seconds after termination of the arc. The flow of the shield gas will continue to protect the hot metal in the weld area or the tungsten electrode from oxygen and nitrogen until proper cooling has occurred.

Preventing GMAW Torch Overheating

Because of the intense heat given off by the electric arc, the GTA and GMA welding torches can overheat. Most lower amperage welding torches are designed to be cooled by the surrounding air and by the flow of the shielding gas through the torch handle and nozzle area.

High amperage, heavy duty welding torches are **liquid cooled**. Water and/or a coolant solution are circulated through separate hoses in the hose/cable assembly to internal passages within the welding torch body. The excess heat is transferred from the torch body to the water or coolant and carried away.

Most TIG units use a water cooled torch. Do not use tap water. Impurities in the water will cause scale and will eventually plug the internal passages and cause the torch to overheat.

TYPES OF SHIELDING GASES FOR THE GMAW PROCESS

Common shielding gases are **carbon dioxide, argon, and helium or mixtures of argon/helium, argon/oxygen, and argon/carbon dioxide**. The operator must choose the correct shielding gas depending on the type of metal being welded. Pure CO₂ or a mixture of 75% argon and 25% CO₂ is commonly used for production type mild and carbon steel. Pure argon or an argon/helium mixture is generally recommended for use on aluminum. Argon/helium mixtures are normally used to weld thicker sections of aluminum, magnesium, and copper. A mixture of helium, argon, and CO₂ is used to weld stainless steel. Argon can be used for all common metals.

Once the operator identifies the type of welding technique and kind of metal to be welded, he/she must consider the recommendations of local suppliers and equipment manufacturers when choosing a proper shielding gas mixture. Because it is so economical to produce, the reactive gas carbon dioxide (CO₂) is now commonly used as a shielding gas for welding mild and carbon steels.

In some applications a controlled mixture of 1% to 5% oxygen is recommended. This will produce wider beads with greater penetration. Units of hydrogen and oxygen are added to the shielding gas to improve **wetting**. Wetting is the uniform fusion along the joining edges of the base metal and the welded bead. Oxygen also improves the weld contour, makes the weld pool more fluid and helps eliminate undercutting. Oxygen stabilizes the arc and helps reduce spatter.

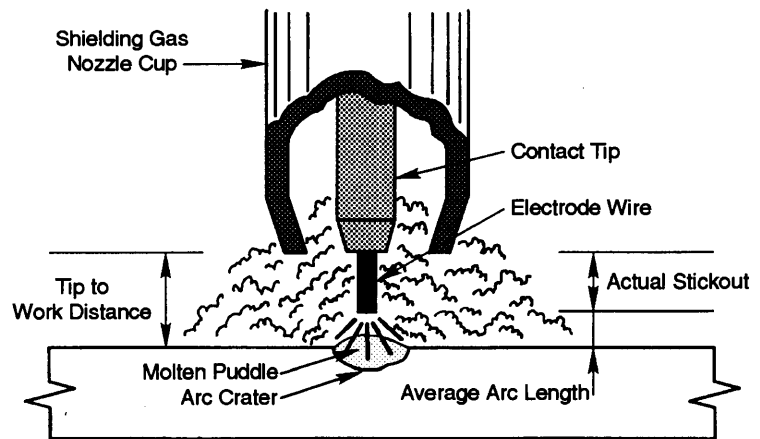
Although the use of oxygen will cause the metal surface to oxide slightly, this oxidation will generally not reduce the strength or appearance of the weld to an unacceptable level. If the shielding gas includes more than 2% oxygen for mild steel welding, the wire electrode must contain additional deoxidizer chemicals. Traces of manganese, silicon, and aluminum are added to the mild steel wire electrode. These deoxidizer chemicals react to the oxygen that is released as oxygen molecules are liberated from the shielding gas.

BASIC GMAW OPERATING INSTRUCTIONS

Striking an Arc

Electrode stickout is the distance from the tip end of the copper contact tube to the end of the wire electrode. Maintaining the proper stickout distance while striking an arc and during the welding process is very important.

Stick out during actual welding varies from approximately $\frac{3}{8}$ " at lower amperage settings to over $\frac{1}{2}$ " at higher settings. If stickout is too great, the wire electrode can preheat, bend, and melt off erratically. Because the nozzle cup is further from the metal surface, the gas shield is more easily influenced by air movement due to the ventilation system or wind. If the electrode stickout is too short, a **burn back** will likely occur and the wire electrode can stick to the contact tube.



To prepare to strike an arc, start with a stickout distance of approximately $\frac{1}{4}$ " to $\frac{3}{8}$ " (at this point, we are assuming the machine has been properly setup with the help of an instructor and all safety precautions have been taken.) If the stickout is too long, use a pair of diagonal wire pliers and trim to proper length. If it is too short, momentarily activate the remote switch to feed out some wire electrode. Trim to proper length if needed.

Hold the welding torch at a **5° to 15° angle** at the beginning of the weld joint. The tip of the electrode wire should be held just slightly above the metal surface. The operator yells "cover" and lowers his/her welding helmet. The operator then activates the remote control switch which: 1) activates the main welding current contact relays, 2) starts the wire feeder, and 3) opens the solenoid valve to start the shielding gas flow.

The arc will start as soon as the wire electrode feeds out enough to touch the metal surface and complete the circuit. There is no scratching or tapping motion required to strike the arc as there is in SMAW. As the molten puddle reaches the proper width for the weld joint, the operator moves the electrode forward.

Adjusting Wire Feed Speed

Newer GMAW machines are more simple to operate because they are equipped with **electronic control modules**. The operator inputs the type and thickness of metal to be welded and the type of shielding gas to be used. The electronic control module automatically adjusts the amperage, wire feed speed, and the shielding gas flow rate as needed. Once the machine is properly setup, the only variables the operator must control during welding are the stickout distance, uniform travel speed, torch angle, and the gas shielding pattern.

As the tip of the wire electrode melts in the arc area, the wire feeder assembly steadily feeds more wire through the contact tube. The wire electrode feed speed is adjustable and must be in a fixed relationship with the welding current amperage used. A slower feed speed requires a low amperage setting. A faster wire feed speed requires a higher amperage setting. When the feed speed and amperage are adjusted properly for the application, the wire electrode is fed into the molten puddle at exactly the same rate the tip melts off.

If the wire electrode feed speed is too fast, the tip of the wire is “forced” into the middle of the molten puddle before it melts. In this case, you will feel a tendency for the welding torch to be “pushed” away from the base metal. In extreme cases, the wire electrode will glance off to the side of the molten puddle before it melts.

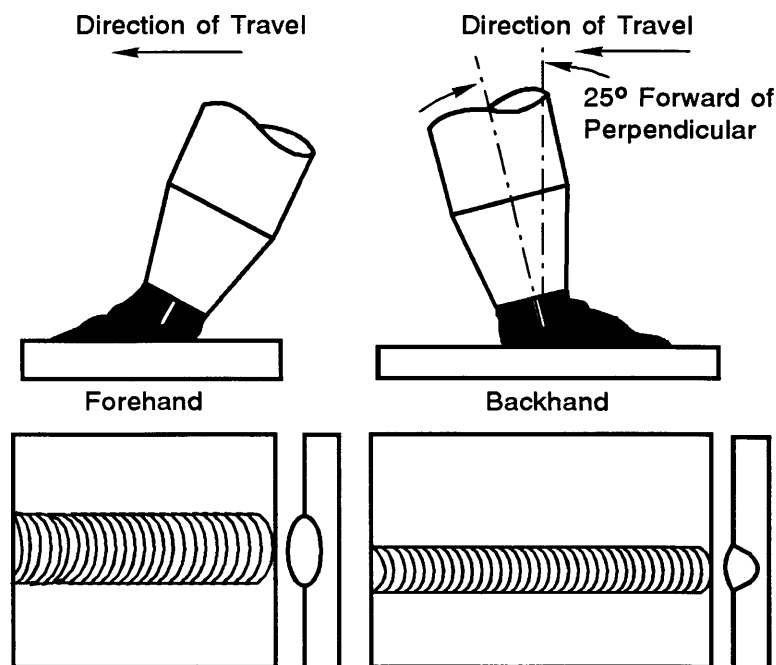
If the feed speed is too slow, the consumable wire electrode will melt off next to the contact tube in an erratic sputter-like manner. It will be very difficult to maintain an arc for proper bead formation. In extreme cases, a “burn back” and “bird nest” can occur. The tip of the wire electrode melts and burns back to the torch and welds itself to the contact tube. This stops the wire feed through the welding torch. If the remote control switch is not released immediately, the wire feed assembly will continue to try to force more wire into the flexible conduit. The wire electrode will become tangled inside the wire feed assembly near the feed rolls.

GMAW Welding Positions and Handling the Torch

Welding positions, types of joints, and weaving patterns are discussed in topic #8154-B. With GMAW, many types of beads can be run with only straight forward travel down the middle of the joint. Others require adding a slight wrist action to move the arc from side to side. By watching the molten puddle, the operator can learn to weave the bead from side to side to deposit more metal as needed.

There are two primary ways of holding the GMAW torch. In the **trailing method** or **backhand method**, the welding torch is held so the wire electrode is fed out behind the torch into of the weld crater. This is also called the backhand method. With a trailing arc, the metal has already been preheated along the joint to some extent. The arc force holds the molten puddle back producing a bead with deeper penetration. Maximum penetration is obtained from a trailing angle of approximately 25 degrees. Although the trailing method will produce a wide bead with deeper penetration, it is difficult for you to see where you are going.

In the **leading method** or **forehand method**, the wire electrode is fed out in front of the welding torch on the leading edge of the weld crater. With the leading method, it is easier to see where you are going. However, the leading method has the arc and wire electrode pressing into cold metal which results in a flatter bead with less penetration.



Adjusting Shielding Gas Flow

The volume of the shielding gas must be adequate enough to produce a straight line flow around the arc. If the volume of gas is too great, the gas may become **turbulent** and mix with the atmospheric air around the nozzle area. If an ample volume of shielding gas is not used and the weld area is not properly protected from the atmosphere, contamination results and a poor quality, porous weld is produced. If the flow is inadequate you will hear a popping sound, the weld will show porosity and the bead will be discolored. A crackling and hissing sound will be heard while welding if the flow is adjusted properly. The recommended flow rate for a given nozzle used in conjunction with a certain shielding gas is provided by the equipment manufacturer.

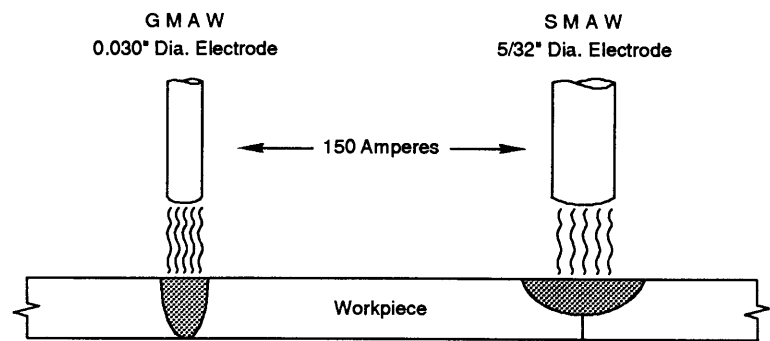
Preventing Spatter

The shielding gas nozzle cups, electrode holders, and contact tube areas on GMA and GTA welding torches accumulate spatter (welding sparks). Spatter accumulations can obstruct shielding gas flow and electrically connect the insulated nozzle cup with the contact tube or electrode. Welding equipment manufacturers recommend the use of a **spatter guard compound**. The chemical compound leaves a slick film that helps prevent spatter from sticking to the welding torch. Spatter guard can be applied by dipping the end of the welding torch into a small can of semi-liquid paste or with an aerosol spray.

ADVANTAGES AND DISADVANTAGES OF USING A GMAW MACHINE

Saving time is one main advantage of using GMAW. The operator is not required to start and stop welding to change electrodes. Because of the continuous feed of the wire electrode, the continuous electric arc, and the continuous flow of shielding gas, weld joints can be made faster and easier in all welding positions.

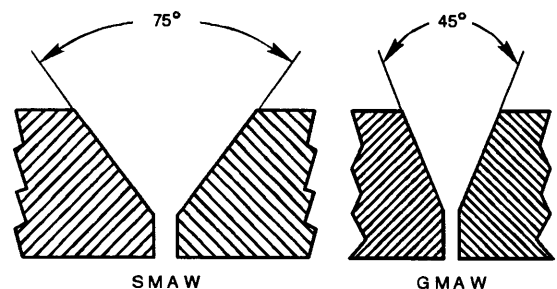
Because the density of the welding current is concentrated within a smaller diameter electrode area, GMAW processes create strong welds with deeper penetration. At the same welding amperage, the arc column with GMAW is sharper and more penetrating as compared to SMAW.



Welding Current Density GMAW vs SMAW

GMAW machines can be used to weld from 20 Ga. to 1 inch or thicker metal in all positions. Because the arc heat is concentrated in a smaller weld deposit area, there is much less distortion of metal with GMAW. This is especially true when welding thinner metals. It is possible to bridge across wider gaps on mis-aligned weld joints without burning through the metal.

The GMAW process is much more versatile than other fusion welding processes. It is difficult or impossible to weld metals such as high carbon steel, stainless-steel, aluminum, copper, and other special alloys with either the shielded metal arc or oxy-fuel welding processes. By selecting the correct wire electrode and shielding gas, GMAW machines can be used effectively to weld these metals as well as mild steel.



Joint Beveling GMAW vs SMAW

Another advantage of using GMAW is minimized joint preparation. Because of the smaller diameter electrode, deeper penetrating arc, and faster deposit rates with GMAW, a narrower bevel angle is required.

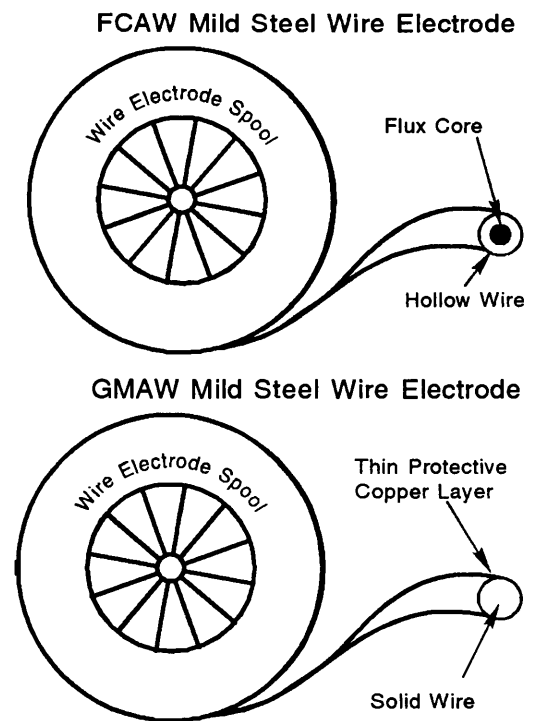
There is very little weld spatter with the GMAW process if the machine is adjusted and used properly. Since there is no flux, clean-up expenses will be minimal. A GMAW weld joint can often be painted with very little or no surface preparation depending upon the requirements of the final finish.

Disadvantages of using a GMAW torch include visibility of the arc area and trying to fit the torch and hose/cable assembly into confined spaces in awkward positions. This often depends upon the type and size of the welding torch and the angle the torch must be held in the joint. Other disadvantages of using the GMA process include the costs of shielding gas and special welding equipment. GMAW equipment can cost up to 10 times more than a SMA welding machine.

However, these extra costs can often be offset by increased productivity. GMAW machines have a higher duty-cycle rating. The metal deposition rate for GMAW with continuous wire electrode feed is approximately four times faster than a hand-feed filler rod with GTAW. For every pound of GMAW wire electrode used, 92% to 98% becomes deposited weld metal. By comparison, only 60% to 70% of a stick electrode used with the SMAW process becomes deposited metal.

FLUX CORE ARC WELDING PROCESS

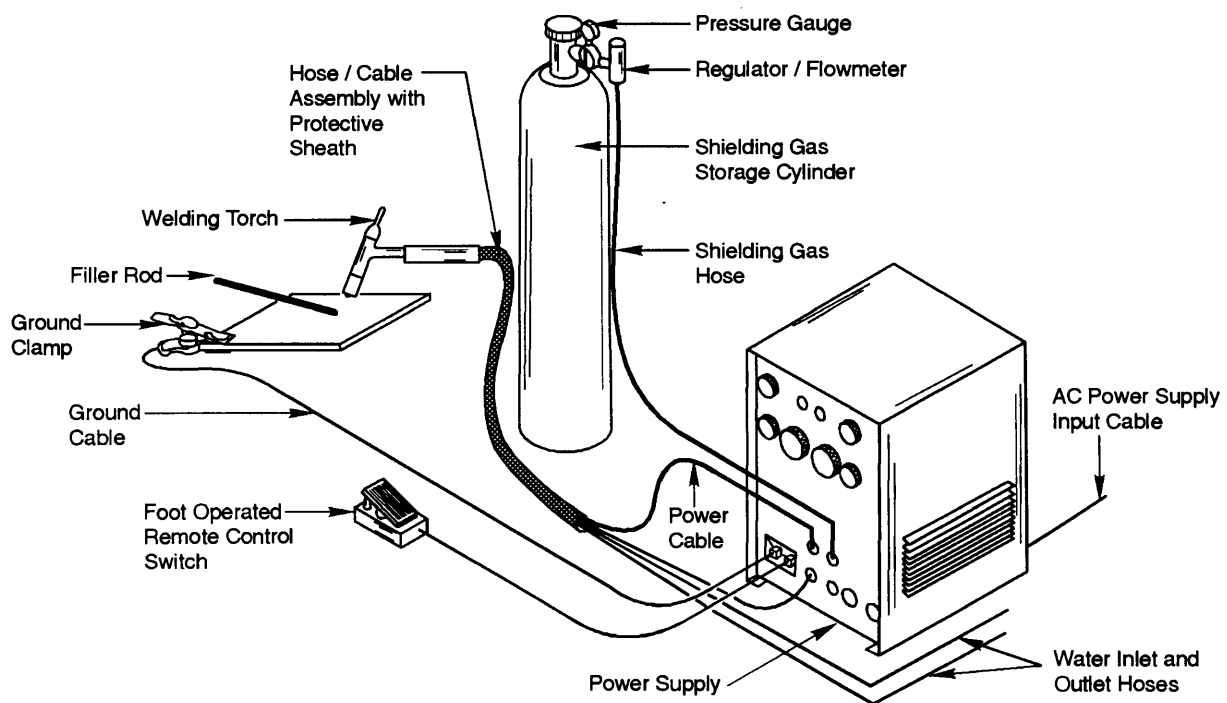
Flux Core Arc Welding (FCAW) is a process comparable to the GMAW process except that the wire electrode used is filled with flux. The flux is similar to the flux attached to the outside of the stick electrodes used in the SMAW process. As the hollow wire electrode melts, the flux core burns, producing a gaseous shield similar to the stick welding process. Additional shielding from an inert gas is optional. The flux helps clean the molten puddle and forms a slag blanket. The wire electrode on some GMAW machines can be replaced by flux core wire electrode and used for the FCAW process without modifying the wire feed system. However, the polarity of the DC welding machine must be checked and/or changed. The FCAW process will not be discussed in detail because it is similar to the GMAW process.



GAS TUNGSTEN ARC WELDING, OR GTAW, PROCESS

The **gas tungsten arc welding**, or **GTAW**, (formerly TIG) process uses the heat of an electric arc in the fusion process. The arc jumps the air gap between a non-consumable tungsten electrode and the base metal. A separate welding filler rod is manually fed into the molten puddle of the base metal as needed by the operator. A shielding gas flows around the arc and molten puddle to keep away oxygen and other harmful atmospheric gases. Gas tungsten arc welding is particularly useful when welding stainless steel, aluminum, titanium and many other nonferrous metals and alloys. Similar to the GMAW process, the shielding gas is supplied from high pressure cylinders through a pressure regulator/flowmeter and hose to the GTAW torch. Originally, helium was used as the primary shielding gas with tungsten electrodes. Because of this universal use, manufacturers initiated and promoted the trade name “Heliarc” for the TIG welding process. GTAW may be performed in any position. It produces intense heat and light, but little metal spatter.

GTAW MAIN SYSTEM COMPONENTS



Basic GTAW Equipment

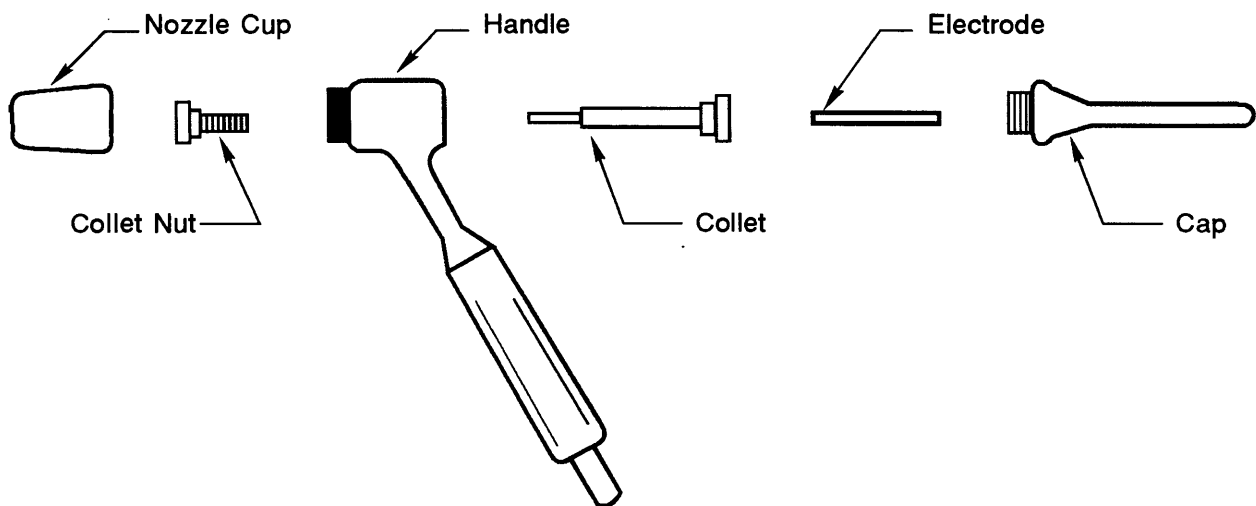
Power Supply and Control

A GTAW unit consists of an electric power unit; remote/panel switch; torch; welding cable; water and gas hoses; and shielding gas supply unit. Filler rod is optional.

Power supply units may be either DC or AC units. The **ON/OFF** switch on the power unit does not stop current flow to all internal parts of the system. Always unplug the power unit from the power supply before you leave the welding area. Never switch from AC to DC or visa versa unless the power unit is turned off.

The **remote/panel** switch controls the amperage output. In the panel position, the amperage output is constant during the welding process. When the remote switch is activated, the operator can vary the amperage during the welding process as needed.

GTAW Torch and Torch System Components



The welding **torch** is designed to deliver the shielding gas to the weld area, hold the tungsten electrode, and give the operator a pistol grip control of the welding process. The torch body is attached to the end of the hose/cable assembly. The hose/cable assembly contains a gas hose, welding current cable, water-in hose, and a water-out hose. The torch does not contain a ground cable, therefore a separate ground cable is required.

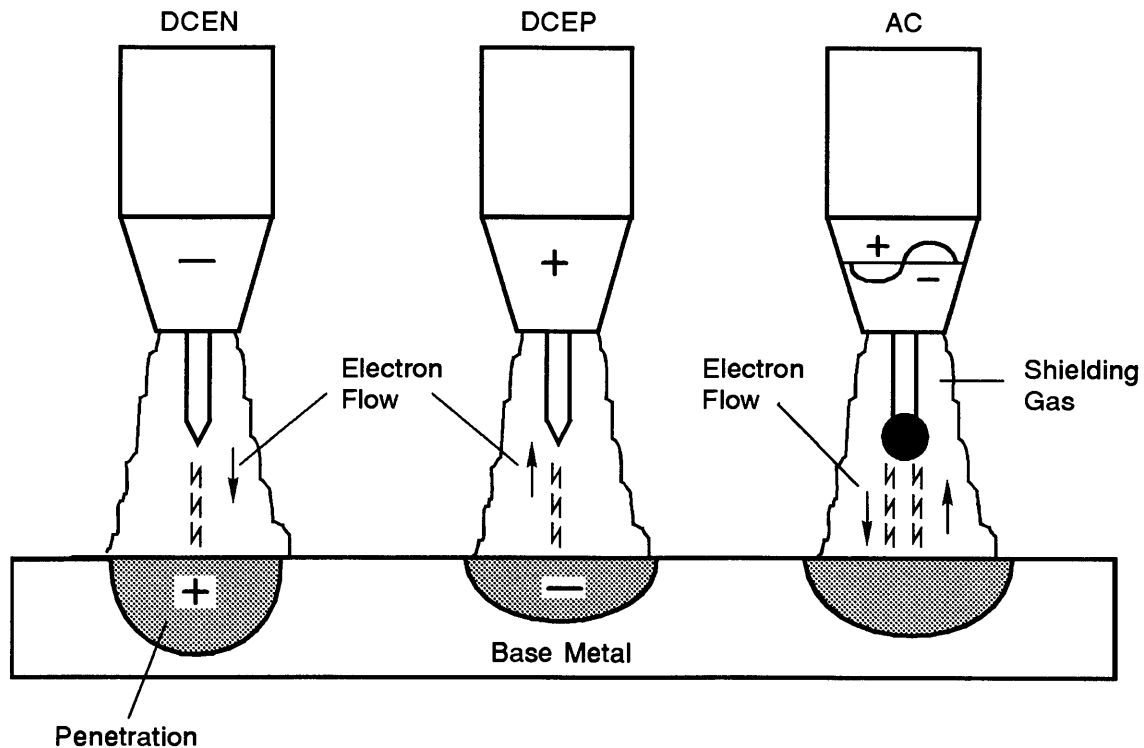
The **nozzle cup**, located in the welding torch, shapes the delivery of the shielding gas and affects its velocity around the weld zone. Nozzle cups are usually made of ceramic. They are identified by a single digit number which represents the exit diameter in 1/16" increments. The nozzle cup should be chosen based on two criteria: the weld zone environment and the velocity of the shielding gas needed.

The GTAW torch is designed so that different diameter tungsten electrodes can be installed for different amperage needs. A **collet** holds the electrode in place and is sized to match the electrode diameter.

A **tungsten electrode** is a “**non-consumable**” electrode which conducts electric current to the arc area. The tungsten electrode has a very high melting point of 6,900°F and ranges in size from .010" to .250". Although the electrode is considered non-consumable, the electrode will become contaminated by molten base metal, atmospheric air, or filler rod and must be cleaned and/or replaced periodically. Tungsten electrodes are very hard and brittle, therefore care should be taken if you try to reshape the electrode.

The polarity and current chosen for welding dictates the necessary electrode shape. Preparing the end of the tungsten electrode requires knowledge and experience of the shaping process. Do not attempt to shape the electrode without the help of an instructor. The electrodes are brittle and can break easily. The tungsten electrode can become contaminated if shaped with a grinder that has been used to grind steel or other materials besides tungsten.

Study the diagram. Notice the positive and negative symbols located on the nozzle tip and on the workpiece. The polarity, indicated in the diagram, directs the flow of the electrons. The electron theory of current flow suggests that electrons move from negatively charged objects to positively charged objects. Direct current, or DC, promotes the flow of electrons from the electrode to the workpiece or visa versa depending upon the polarity chosen by the operator. AC, or alternating current, is different. AC switches direction many times a second, therefore the electrons theoretically flow in both directions.



GTAW Shielding Gases

The **shielding gas** prohibits atmospheric air from contaminating the weld puddle and protects the tungsten electrode. Choosing the correct shielding gas is related to the performance and quality of the weld you produce. The GTAW process requires the use of argon, hydrogen, helium, or a mixture of two gases. Helium provides a higher available heat which allows the operator to achieve deeper penetration in the workpiece and fuse thicker metals. Argon is the most popular gas used and has the following advantages over helium:

1) smoother arc	2) better cleaning action
3) lower arc voltage	4) heavier
5) shields better	6) less gas required

Argon and helium both work well when using DC. However, helium does not work if AC is used during GTAW. Aluminum and aluminum alloys can be successfully welded with AC and pure argon gas, but joining other types of metals are not recommended. Argon and helium mixtures work well as a shielding gas. Mixing other gases together can produce favorable results in certain conditions. Combinations of argon and up to 15% hydrogen allow the operator to speed-up the welding process when fusing stainless steel, nickel-copper, and nickel-based alloys. Hydrogen cannot be used on other metals since it can cause cracks in the weld.

GTAW PROCEDURE

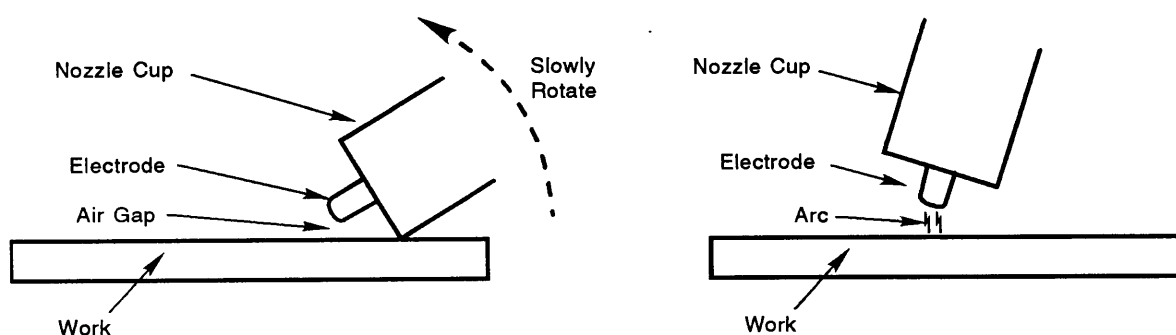
Setting the GTAW Machine Parameters

Selecting the proper machine settings on a GTAW machine is important and directly affects the performance of the current. This topic does not cover the procedure for setting the GTAW machine parameters. However, it is important for you to know that typical GTAW machines have many different settings and optional controls.

Starting the Arc

There are several methods of starting an arc with the GTAW machine. The two methods discussed in this topic are **superimposed high frequency** and the **high voltage** methods. The method chosen depends upon the type of welding machine and metal to be welded. Always check with the instructor and refer to the operator's manual for specific recommendations.

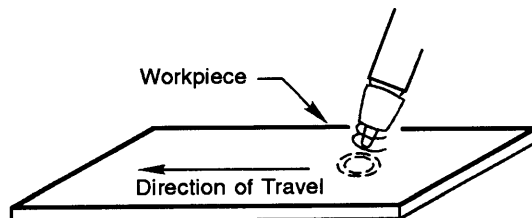
The superimposed high frequency and the high voltage starting techniques are dependent upon machine settings. The GTAW machine is set by the operator before welding begins. The movement of the torch to start the arc is the same for both machine settings.



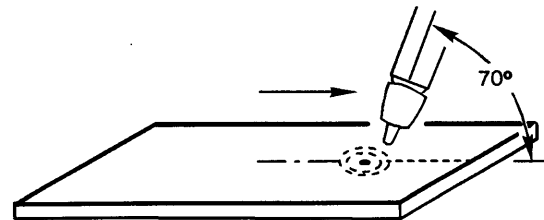
The operator begins by placing the **nozzle cup** (*not the electrode*) against the workpiece surface at approximately a 45° angle. Next, fully depress the remote switch and allow the shielding gas to purge the torch and weld zone. After a momentary pause, begin to rotate the torch towards a vertical position above the workpiece. As the tip of the electrode gets closer to the base metal, the electrons will complete the circuit by jumping the air gap and initiating the arc. Adjust the air gap to about 1/32" to 3/32" and allow the arc to stabilize.

After the arc has stabilized, place the torch at an angle of 60° to 75° and begin to make a puddle. It is necessary to become proficient at starting the arc properly. In most applications, touching the tungsten electrode tip to the base metal will cause it to become contaminated.

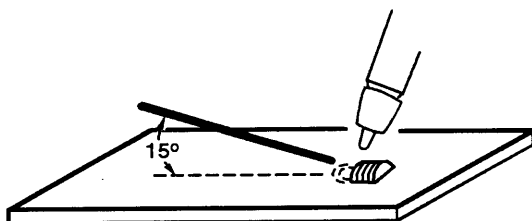
Penetration and Movement



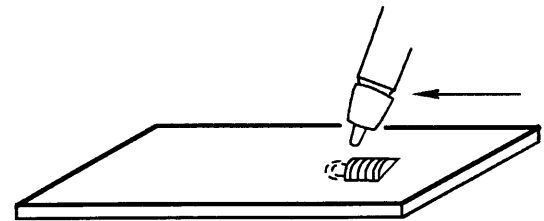
Develop the Puddle



Move Torch Back



Add Filler Metal



Move Torch to Leading Edge of the Puddle

If the amperage, electrode stickout, and clearance are correct a puddle should form on the metal surface. Penetration is controlled by the variable remote control. Once you have created a puddle, you can begin to add filler material and move the torch to begin making a bead as shown in the preceding diagram. As in oxyfuel welding, the operator should move the arc using the **oscillating** or the **circular method** (Discussed in student topic #8154-A). Control of the puddle and the required direction of travel both depend on the movement of the torch.

Hand Positions for GTAW

Hold the torch and filler rod as shown previously. Place the filler rod into the weld zone (shielded area) and move the torch to the front of the puddle. To add filler rod, simply move the torch to the back of the puddle and push the filler rod to the front of the puddle. Next, pull the filler rod away from the puddle and move the torch forward to create a new puddle. Do not take the filler rod out of the weld zone.

The melted end of the filler rod is drawn into the middle of the molten puddle by capillary action. To avoid contaminating the tungsten electrode, do not allow the electrode tip to contact the base metal or the filler rod.

Continue this technique in the direction of the weld. Adjust the amperage and clearance distance to change penetration depth. The temperature of the arc may be controlled by changing the fine current with the remote control switch and by varying the arc length. The diameter of the tungsten electrode and the thickness and kind of base metal will determine the amperage setting to be chosen by the operator. When the weld is finished, allow the shielding gas to flow for a few seconds in order to protect and cool the weld zone and the tungsten electrode tip.

BASIC GMAW AND GTAW SAFETY PRECAUTIONS

Basic safety procedures and recommendations for protective clothing and other equipment associated with metal arc welding were discussed in student topic #8154-B. These same basic safety procedures and recommendations apply to GMA and GTA welding.

Recall the discussion on the dangers of the **ultraviolet and infrared rays** produced by an electric arc. The rays created by the GMAW process are potentially two times more harmful than the rays from SMAW. This is because there is no smoke screen from the burning flux to help filter the rays. These rays are intensified even more when welding on aluminum, stainless steel, or other alloys with a shiny reflective surface because they are reflected back and forth.

Thus, it is important for the operator and others who may be working nearby to wear proper dark colored clothing and adequate eye protection. Leather or heavy-weight cotton clothing is recommended. Light-weight polyester clothing is not recommended. Ultraviolet rays can penetrate through the clothing and can cause severe skin burns. In addition, if synthetic material is ignited, it will burn rapidly and melt into the skin. The operator should wear flash goggles and a welding helmet with a No. 12 filter lens.

WELDING TERMINOLOGY

Porosity is the presence of tiny holes in the weld. The holes may be on the very top of the bead where they are visible or inside the weld joint itself. Porosity results when excess atmospheric air reacts with the hot molten puddle.

Porosity is caused by: 1) inadequate volume of shielding gas, 2) the incorrect shielding gas for the type of metal being welded, 3) excessive cross draft because of wind or a ventilation fan that is blowing the shielding gas away, and/or 4) too short of a pre-flow or post-flow time interval.

Undercutting is the melting away of base metal on either side of the weld bead which is not replaced by the fusion of other base metal or by the electrode filler. This is a result of incorrect travel speed, improper arc voltage or amperage, and/or improper wire speeds.

Weld cracking is divided into two categories: hot cracks and cold cracks. Cracking is caused by stress which is greater than the strength of the base metal or the weld. Hot cracks are formed when the weld cools too rapidly. Cold cracks may run the entire length of the weld. Cold cracks are caused by exceeding the tensile strength of the weld.

“Whiskers” is a weld defect that is found in GMAW and FCAW. The wire electrode is pushed out beside the weld joint or through an opening in the root area of the weld joint and does not make contact with the base metal. When the wire electrode makes contact with a grounded surface, an arc is established and a short section of wire melts off and fuses to the metal. It is caused by improper wire speed or improperly aiming the welding gun.

CONCLUDING REMARKS ABOUT THE GMAW & GTAW PROCESSES

There are numerous makes and models of both GMA and GTA welding machines. It is beyond the scope of this topic to go into detail on specific setup, adjustment, and operating procedures. This topic does not cover adequately the instructions for selecting specific shielding gas, wire electrodes, or filler rods. Always refer to appropriate technical, service, and operators' manuals for specific procedures and additional safety precautions.

Before operating any equipment, consult the instructor or supervisor. Remember, personal safety, the safety of others, and the quality of the work performed depends upon you.

Many GMA and GTA welding processes are performed in fabrication and repair shops with manually operated hand torches. However, in repetitive, fabrication systems, where the production of a part is repeated several times or parts are welded together in a uniform fashion, GMA and GTA welding torches are attached to computer-controlled robotic arms. A computer operator can manage several machines at one time from a computer monitor in an office. Robots can also weld objects in environments that are unsafe for humans.

The curriculum guide for this course of study and the supporting instructional materials were developed for educational use. The applications and components described or pictured are illustrative only. Depiction or description of any product, component, brand name, or application does not constitute, indicate, or imply a recommendation or endorsement of any sort. Always refer to appropriate technical and service manuals for specific applications, instructions, repair procedures, and safety precautions.

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Acknowledgments

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service and Mr. Douglas M. Kingman, Graduate Assistant, Department of Agricultural Education, Texas A&M University developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

TRUE OR FALSE: Circle "T" if the statement is true; circle "F" if the statement is false.

- T F 1. Inert gases do not normally react chemically with molten metal.
- T F 2. Current density refers to the hardness of a solid wire electrode.
- T F 3. Hot cracks are formed when metal gets too hot.
- T F 4. The melting point of a tungsten electrode is 6,900°F.
- T F 5. Most mild steel wire electrodes used in the GMAW process are copper clad which prevents corrosion and oxidation.
- T F 6. Because carbon dioxide (CO₂) is very expensive, it is rarely used for a shielding gas during the GMAW process.
- T F 7. During the GTAW process, atmospheric air can contaminate a tungsten electrode.
- T F 8. During the welding process, aluminum reflects ultraviolet and infrared rays and increases the danger of these harmful rays.
- T F 9. GMAW machines cannot be used to weld aluminum and stainless steel.
- T F 10. The leading method typically has a deeper penetration than the trailing method.

MATCHING: Match the letter of the term with the description it best matches.

A. bird nest	G. superimposed high frequency
B. contact tube	H. chemical deoxidizers
C. remote control, GMAW	I. whiskers
D. turbulence	J. wire electrode
E. tungsten electrode	K. 92% to 98%
F. 60% to 70%	L. wetting

- _____ 11. method of starting an arc with a GTAW machine
- _____ 12. uniform fusion along joining edges of base metal and the welded bead
- _____ 13. a tangled mess inside the wire feed assembly near the feed rolls
- _____ 14. percent of metal deposited during the SMAW process
- _____ 15. percent of metal deposited during the GMAW process
- _____ 16. closes main welding current contact relays
- _____ 17. non-consumable electrode that is hard and brittle
- _____ 18. consumable electrode used in the GMAW process
- _____ 19. component of most wire electrodes that helps prevent oxygen from causing porosity in the weld bead
- _____ 20. may result from improper adjustment of the flow of shielding gas
- _____ 21. weld defect found in GMAW and FCAW
- _____ 22. component of the GMAW torch where welding current is transferred to the wire electrode as the wire passes through the torch

FILL-IN-THE-BLANK: Complete the following statements by inserting the correct word(s) in the blanks.

- _____ 23. _____ is a welding term used to describe tiny holes present in a weld bead.
- _____ 24. A _____ is sized to match the diameter of the tungsten electrode and hold it in place.
- _____ 25. _____ is a compound used to prevent the adhesion of sparks to the welding torch.
- _____ 26. The _____ feature allows shielding gas to continue to flow through the torch after the operator has stopped the welding process.
- _____ 27. Changing the fine current with the remote control or varying the arc length affects the _____ of the arc during GTAW process.
- _____ 28. The regulator/flowmeter controls the pressure and the _____ of the shielding gas.
- _____ 29. The current of the GTAW machine dictates the _____ of the end of the tungsten electrode.
- _____ 30. If the electrode stickout is too short, a _____ will likely occur and the wire electrode can stick to the contact tube.
- _____ 31. The **ON/OFF** switch on the GTAW machine does not stop current flow to all _____ parts of the system.
- _____ 32. The methods of torch movement during the GTAW process are known as the _____ and the _____ method.

SHORT ANSWER/LISTING: Respond to the following items in sentences, phrases, or short paragraphs in the spaces provided. (Use additional paper when needed.)

33. List the four advantages of using Argon, instead of Helium, as a shielding gas.

a. _____

b. _____

c. _____

d. _____

34. Describe how wire electrode used in the GMAW process is protected from corrosion and oxidation.

35. Name two types of current used in the welding process.

a. _____ b. _____

36. Describe the direction of the flow of electrons when using the polarity setting of DCEN during the welding process. Do the electrons flow from the electrode to the work, from the work to the electrode, or continuously alternate directions from the work to the electrode and visa-versa?

37. Explain why tungsten electrodes are easily broken.

38. List five major components of a GMAW system.

ADDITIONAL SKILLS & ENHANCEMENT ACTIVITIES: Perform the following activities or skills as assigned by your instructor.

1. Visit the AWS web site ([HTTP://www.amweld.org/](http://www.amweld.org/)). Discuss one item you didn't expect to find on the AWS home page or something you learned about the welding industry from the home page. Present your observations and findings to the class.
2. Ask your physics or science teacher if you can give an oral report depicting the flow of electrons during the welding process. In your presentation, discuss how your knowledge of the principles of electron theory and electron flow improved your ability to understand and use your practical knowledge about welding procedures.
3. Produce a poster or some type of visual aide highlighting the advantages and disadvantages of the GMAW process verses the SMAW process. Include in your comparison arguments concerning: practicality, initial investment costs, operating costs, percent electrode deposit, labor needs, ease of use, and/or skill level required
4. Make a list of 5-10 employers in your area or county and two from a large town within 100 miles of your school that hire people to weld. Explain what you would need to do in order to obtain and maintain a job with one of these companies. Contact the person who hires welders and ask them to explain the criteria for being hired at their company.

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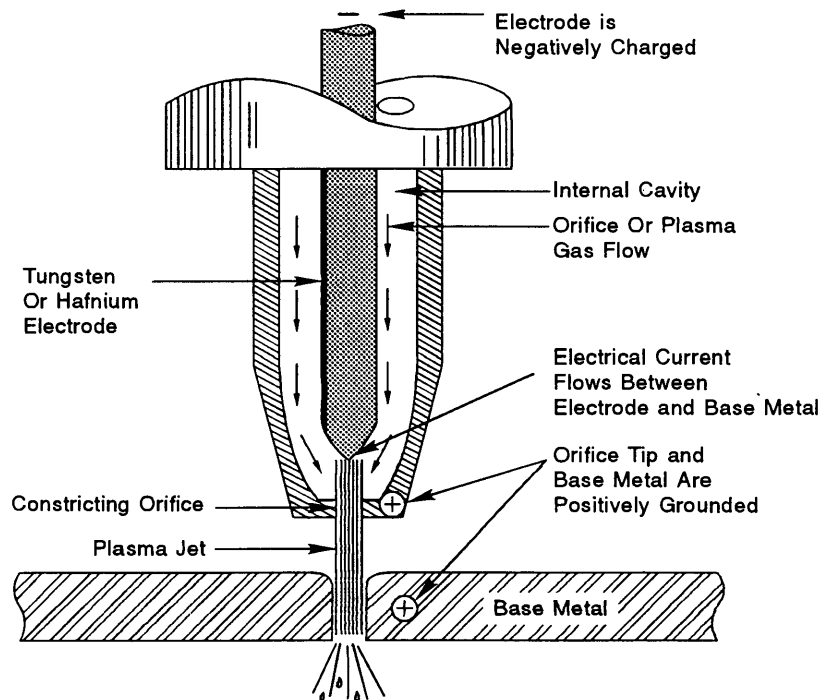
Texas A&M University

College Station, Texas 77843-2588

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PLASMA ARC CUTTING AND WELDING PROCEDURES

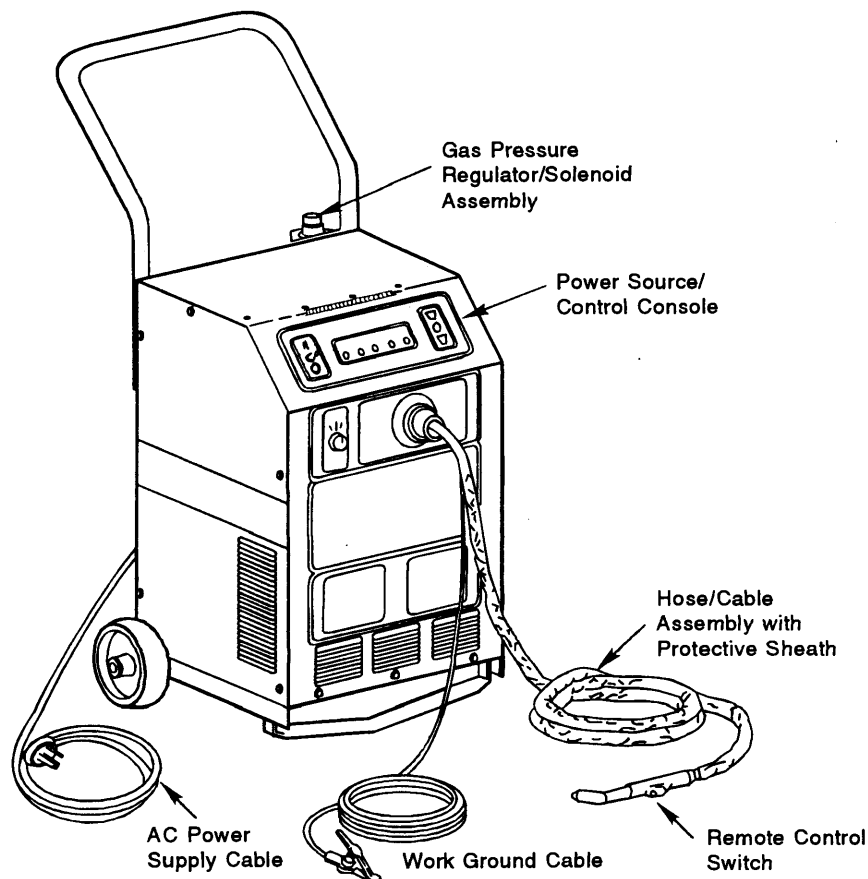
Plasma arc is one of the newer processes used for metal cutting and welding. It uses the principle of passing an electric arc through a quantity of gas which is flowing through a small orifice. The gas is superheated to a very high temperature by the electric arc. As the gas is heated, it turns to **plasma**. Plasma is the temporary physical condition of a gas as it is being heated by an electric arc. It is the term physicists use to describe a fourth state of matter. It is not a solid, a liquid, or a gas, but plasma.



Schematic Drawing Of The Plasma Arc Cutting Process

The gas becomes partially **ionized** as it is converted to plasma by the electric arc. This means that as the gas is heated and is rapidly expanding, its atoms are gaining and losing electrons. Through this process, the plasma gets extremely hot and is capable of conducting an electrical current.

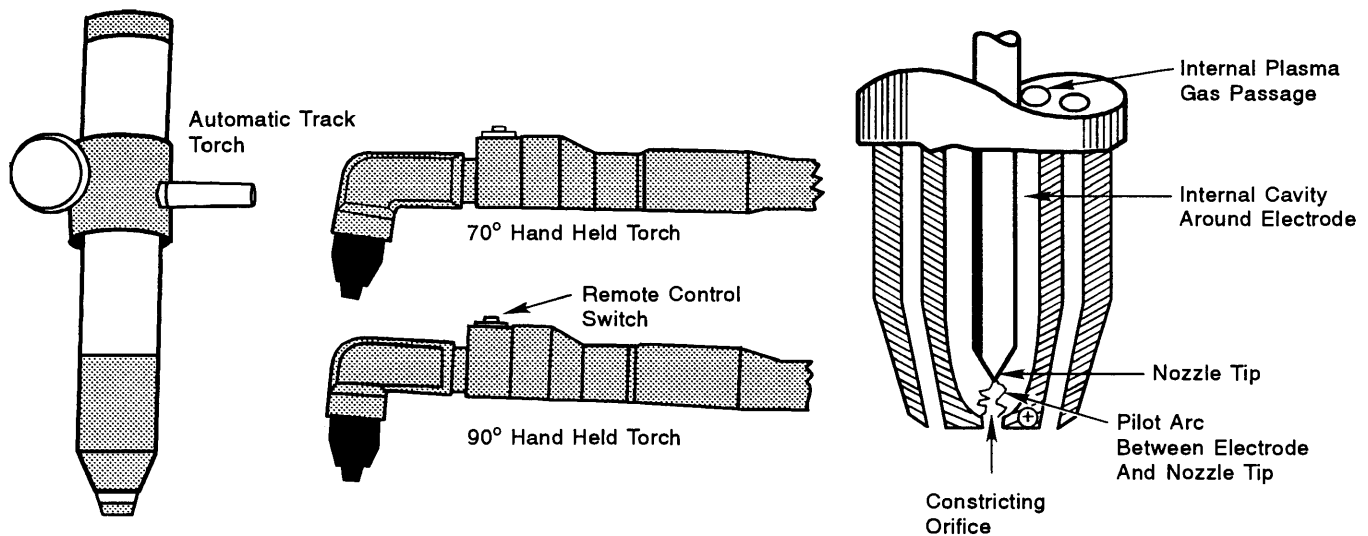
The temperature of the plasma jet created by the electric arc and gas can range between 25,000° F to 30,000° F. As the plasma jet leaves the torch nozzle tip, it starts to cool and turn back into a gas. As it cools, the extra heat created is released onto the workpiece. Thus, the heat released from a plasma jet is used for the cutting or welding process to be performed.



Basic Transferred-arc Plasma Arc Cutting Unit

The basic parts of the plasma arc unit are the **power source/control console**, the **gas pressure regulator/solenoid assembly**, the **hose/cable assembly**, and the **torch**. Plasma arc power source/control console units vary in size from 120 V/10 A to 440 V/1,000 A. An internal rectifier bridge within the control console converts incoming alternating current (AC) from the power supply to direct current (DC). The negative output lead from the power unit/control console is routed through the hose/cable assembly. It is connected to an electrode holder within a special torch body.

In addition to the main electrical power cable, the hose/cable assembly also contains the remote control power leads, a positive-ground return cable, and the gas hoses. The hoses and cables are all neatly routed side-by-side and wrapped with a protective sheath. Although the sheath provides some protection, the plasma jet stream and hot molten metal *should not* be directed toward the hose/cable assembly. As will be explained later, the unit may or may not have a separate ground cable to connect the workpiece back to the power supply.



The plasma arc torch consists of a handle grip, an internal electrode holder, internal gas passages, a nozzle tip with constricting orifice, and a shielding cup. A manual plasma arc torch will have a remote control switch. The constricting orifice is the small hole in the end of the torch nozzle tip through which the plasma arc and plasma jet flow. The electrode holder centers the electrode tip with respect to the orifice hole in the nozzle tip.

Closing the remote control switch on the torch activates the electromagnetic valve in the regulator/solenoid assembly. This allows gas to flow through the pressure regulator/flowmeter; through the hose assembly; to an internal cavity within the torch body; and out through the nozzle orifice tip. The internal cavity is directly around the electrode. This gas is called the **plasma gas** or **orifice gas**. As the plasma gas flows, it first purges the system of any other gases and/or possible moisture condensation. After a short automatic time-delay to complete the purge, a high frequency **pilot arc** is established inside the torch between the tip of the electrode and the nozzle orifice tip holder.

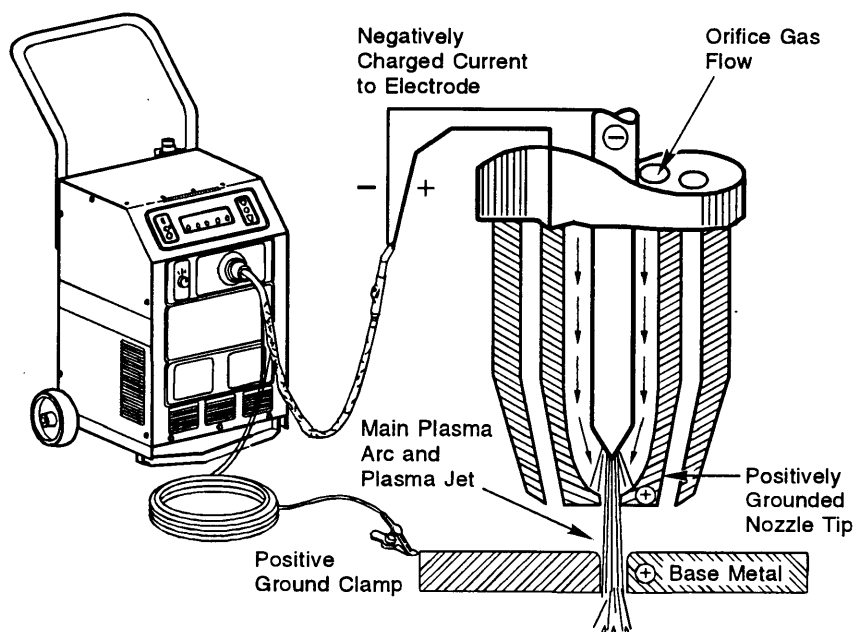
Most units are equipped with safety interlock switches. If the compressed air or other plasma gas supply pressure drops below a preset level of 40 psi, the pressure safety switch will open. This will turn off the main control unit power switch. Most units are also equipped with thermal switches. If an internal transformer, rectifier, or other control console component should overheat, a thermal safety switch will open and shut down the system. When the overheated component cools, the switch closes allowing the unit to be operated again.

Plasma arc torches are available in both manual-handheld and automatic models. The manual hand torches are available with heads set at 70° and 90° angles in relation to the handle grip. On most automatic track torches, the nozzle tip is in a straight line (180°) with the attaching body.

Types of Plasma Arc Processes

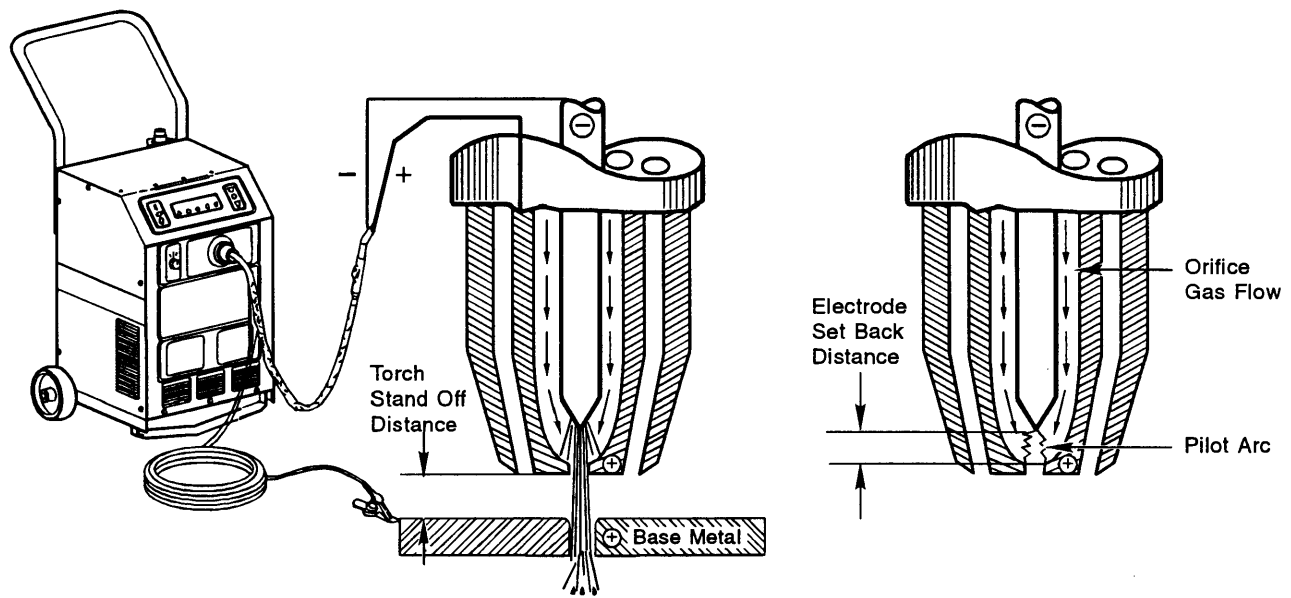
In other types of electric arc cutting and welding procedures, the arc is very diffused or scattered. However, with the plasma arc system, the electric arc and plasma jet remain constricted as they flow through the small orifice in the nozzle tip. Consequently, the extreme heat is concentrated into a smaller area.

There are two different modes of operation for the plasma arc process. They are the **transferred plasma arc process** and the **nontransferred plasma arc process**.



With the **transferred plasma arc process**, negatively-charged direct current (DC) is supplied from the power supply unit through a cable to the torch electrode. The torch nozzle tip holder is grounded back to the power supply through a positive ground cable in the hose/cable assembly. The metal workpiece is also grounded with a separate positive ground cable back to the power supply.

Electrode setback is the distance that the electrode tip is set back away from the constricting orifice of the torch nozzle tip. When the remote control switch on the torch is closed, a high frequency pilot arc jumps between the electrode and the nozzle orifice tip holder. As the pilot arc starts, the orifice gas is heated and begins to turn into plasma. The rapid expansion of the heated orifice gas causes a plasma jet to flow out through the constricting nozzle tip.



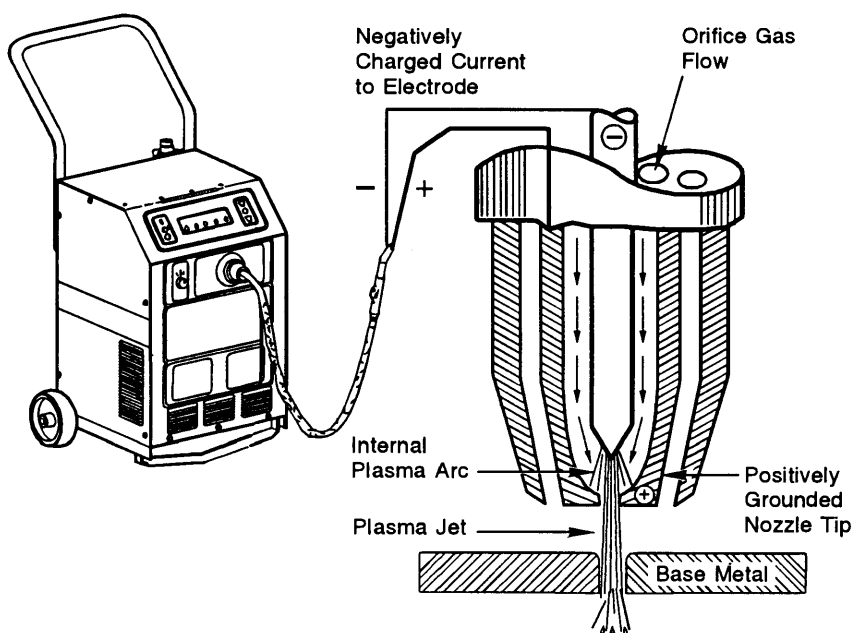
Remember, the plasma created can now conduct electrical current. As the nozzle tip comes close to or touches the grounded metal workpiece, the plasma jet “transfers” the electrical current directly to the workpiece. Thus, the metal workpiece now becomes a part of the electrical circuit. This establishes an intense **main plasma arc** from the electrode, through the orifice hole of the nozzle tip, to the grounded workpiece. On most transfer plasma arc systems, the internal high frequency pilot arc will automatically stop once the main plasma arc is established.

The **torch standoff distance** is the distance from the outer face of the constricting orifice nozzle tip to the workpiece surface. With the transferred arc process, the main plasma arc will go out if the arc runs off the edge of the grounded metal. It will also stop if the torch standoff distance becomes too great for the electrical current to jump to the grounded workpiece. There is no longer a complete circuit through the base metal workpiece back to the power supply. If the main plasma arc goes out, the orifice and shielding gases will continue to flow for several seconds to cool the torch body. When the torch is cool, gas flow will stop because of automatic controls.

On some more expensive models of transfer arc process systems, the pilot arc will automatically restart if the electrical circuit with the grounded workpiece is interrupted. This will occur as long as the torch control switch is held closed.

This can be very helpful in applications where the metal is covered with thick paint or excessive rust, oil, or scale. It is also useful for continuous cutting of many smaller pieces or sections such as expanded metal. When the main plasma arc stops because of a wide air gap or the insulating effect of paint or rust, the pilot arc will automatically restart. This prevents the operator from having to manually release the torch control switch and press it again to restart the pilot arc.

The transferred arc process has the advantage of greater heat transfer to the workpiece. However, it requires that the workpiece be electrically conductive. The transferred arc process is the most common type used.



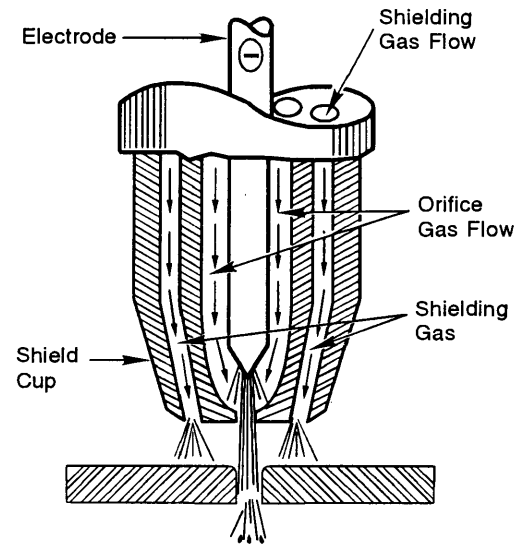
In the **nontransferred plasma arc process**, the electrical circuitry is different. The metal workpiece is not grounded with a separate ground cable. The high frequency pilot arc is established internally between the tip end of the electrode and the torch nozzle tip holder. This is similar to the transfer process.

As the orifice gas is heated and turns to plasma, it conducts the electrical current. This causes a more intense main plasma arc to be established internally. As the main plasma arc is established, a plasma jet is forced out through the constricting orifice nozzle tip by the rapid expansion of the heated orifice gas.

Remember, with the nontransferred mode, the workpiece is not actually a part of the plasma arc electrical circuit. The nontransferred arc process creates less heat than the transfer arc process. Even though the main plasma arc is not transferred to the workpiece through an electrical circuit, the plasma jet has sufficient heat to melt the workpiece. This process is used for applications where lower heat concentration is desirable for cutting or welding thinner materials.

In the nontransferred process, the torch control switch must be opened (turned off) by the operator whenever the cutting or welding process is complete. If the control switch is not opened, the main plasma arc will continue inside the torch and can cause damage to the system.

Most plasma arc units also use a **secondary shielding gas** in addition to the orifice gas. The shielding gas is channeled through additional internal passages into the torch body. The shielding gas flows out around the outside of the nozzle orifice tip through a number of holes.



The purpose of the shielding gas is to:

- 1) assist the high speed plasma jet in blowing the molten metal from the kerf,
- 2) help reduce spatter on the end of the torch,
- 3) help cool the torch body and add life to the consumable electrode and nozzle tip, and
- 4) provide a gaseous shield around the plasma arc area to prevent chemical contamination and/or oxidation of the heated metal.

Factors that help control the plasma jet include the:

- 1) amperage and voltage of the electric arc,
- 2) type of plasma or orifice gas used,
- 3) type of shielding gas used,
- 4) gas velocity,
- 5) gas flow (cfh),
- 6) size of the constricting orifice in the nozzle tip,
- 7) type of electrode used,
- 8) torch standoff distance, and
- 9) electrode set back distance.

PLASMA ARC CUTTING OR PAC

Plasma arc cutting (PAC) is a thermal or melting process. This is different from the oxidation process used in the oxyfuel cutting process. In the PAC process, the material to be “cut” is melted by the extreme heat of the plasma jet. The high velocity of the plasma jet and the shielding gas literally blows the molten metal away, thereby creating a kerf. The **kerf** is the width and shape of the space left after a cutting process has been performed.

Originally, PAC systems were developed for cutting nonferrous metals. Nonferrous metals are those that do not contain iron. The original torches all used tungsten electrodes and an inert plasma and shielding gas. An **inert gas** is a gas which does not normally combine or react chemically with a hot or molten metal.

In recent years, new technology allows the plasma arc process to be used for cutting ferrous as well as nonferrous metals. PAC units can be used to cut aluminum, copper, brass, cast iron, carbon steel, nickel, stainless steel, mild steel and other alloy metals. In some special applications, the nontransferred plasma arc process has been successfully used to cut nonmetallic materials such as concrete. A plasma arc can also be used as a heat source in some welding processes as will be discussed in this topic.

Most manufacturers of PAC systems recommend nitrogen, nitrogen-hydrogen mixtures, or argon-hydrogen mixtures as the plasma and shielding gases for cutting nonferrous metals. Other gases used include carbon dioxide and varying mixtures of argon and helium. Carbon steel and mild steel can be cut satisfactorily using compressed air or nitrogen for plasma gas.

In many applications, the same gas can be used for both the orifice and the shielding gas. Even when the same gas is used, the functions of the orifice and shielding gases in the plasma arc process are still different. For special applications, dual gas flow models are equipped with two regulators, two gas hoses, and a special torch. This allows a different plasma and shielding gas to be used at the same time.

The incorrect shielding gas will not protect the kerf area from the atmospheric air or it may react with the heated metal itself. This will change the chemical composition of the base metal. For example, a nitride buildup left on the kerf area during plasma arc cutting can greatly effect the quality of a weld that may be performed later. When the metal is welded, the welding machine operator may get blamed for a poor quality weld; however, the poor weld was actually caused by the improper shielding and/or plasma gas when the metal was first cut.

Some newer models of PAC systems are designed primarily for cutting mild steel. These units utilize inexpensive compressed air or “shop air” as both the plasma gas and the secondary shielding gas. Under these conditions, the compressed atmospheric air does not contain enough pure oxygen to cause an oxidation problem for mild steel. Some lower amperage PAC units are designed for cutting only thin mild steel sheet metal and do not even use a secondary shielding gas.

OPERATING AND SAFETY PROCEDURES

Operating procedures vary with each brand and model of plasma arc equipment. It is beyond the scope of this topic to cover them all in detail. Before attempting to operate any plasma arc equipment, always consult the operators’ manual for that system. It contains specific step-by-step setup instructions, recommended plasma and shielding gases, operating procedures, and safety precautions. In addition, it is always helpful to first consult an experienced operator. If possible, observe him/her demonstrate any procedure you may be unsure of.

If the specific information is not contained in the operator’s manual, ***do not*** experiment. Serious personal injury and equipment damage can result. Contact the technical assistance department of the equipment manufacturer for additional information and recommendations. Most manufacturers now provide a “1-800” number. Others can be contacted through E-mail and WWW Home Page sites.

Tungsten torch electrodes are used with most inert plasma gases. Hafnium electrodes are used with most compressed air units. A hafnium electrode will not oxidize as quickly as a tungsten electrode when it is heated and exposed to oxygen from the compressed air. Follow specific manufacturers instructions when installing an electrode and adjusting the electrode setback distance.

Nozzle tips are available with various size orifice holes. The diameter and the actual design of the nozzle needed is determined by the type of PAC unit and plasma gas used, the amperage, and the type of metal to be cut. Larger diameter orifices are required for higher amperage cutting currents. The thicker the metal and the higher the cutting amperage, the greater the standoff distance.

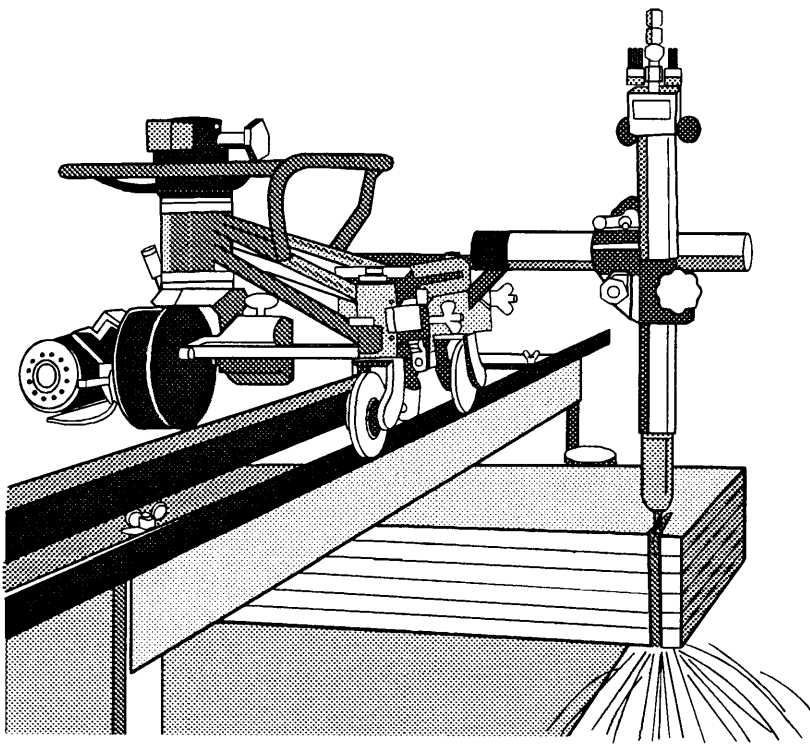
The selection of the orifice and shielding gases is dependent on the type and thickness of base metal to be cut or welded, and the particular brand and type of equipment used. The required quality of the kerf surface or weld is also a factor to be considered. Be sure the proper size and type of electrode and nozzle tip are installed. The electrode type must correspond with the cutting mode and the type of orifice gas used.

Orifice gas flow rates will vary with the diameter of the orifice in the nozzle tip. For example, a 1/8" diameter orifice will require approximately 200 cfh flow. If compressed shop air is used, make sure the compressor and hoses have the capacity to supply the desired volume at the desired pressure.

Compressed air used as the plasma and/or shielding gas must be free of oil, condensation moisture, and other contaminants. Excessive oil and moisture can cause poor cutting performance as well as rapid electrode and nozzle tip wear. When compressed shop air is used, it is recommended that an extra in-line air filter be installed just before the power unit regulator.

To test the quality of compressed air, move the power unit control panel switches to the "set or gas purge mode." See specific equipment instructions for details. Place a clean welding lens in front of the torch tip but *do not initiate the arc!* Direct the gas flow onto the lens surface. Any oil or moisture in the air will be visible on the lens.

High pressure compressed gas cylinders can be dangerous. Make sure that cylinders are handled properly and are properly secured. When setting up a system, make sure the pressure regulators used are designed to accommodate the specific orifice and shielding gases. If in doubt, contact the welding equipment or cylinder gas supplier for specific information.



PAC units can be effectively used in **stack cutting** operations. When many pieces of the same shape are needed, several plates of 1/16" to 1/4" thick metal can be "stacked" and tightly clamped together. A single cut is made through the stacked metal with no preheating. This is because of the concentrated heat from the constricted plasma arc. The result is a very narrow kerf with little or no heat distortion of the top plate in the stack.

Plasma arc cutting can be performed manually or with automatic track equipment. Automatic torches are attached to and used in the same type of carriage track or shape cutting equipment as oxyfuel torches. However, the travel speed for the plasma arc torch must be adjusted significantly faster to make clean-cut edges.

Like all electric cutting or welding arcs, the plasma arc emits intense ultraviolet and infrared radiation (light). It is necessary for you and those who may be working around you to wear eye and skin protection. Always use a welding shield with the proper filter lens. A #4 filter or darker is recommended for drag cutting. A #10 filter or darker is recommended for standoff cutting. Always wear dry heavyweight leather gloves and heavy cotton or leather clothing. Make sure no part of your body or your helper's body comes in direct contact with the workpiece while the torch is activated.

A good safety practice is to yell "**COVER**" and then wait several seconds before starting the plasma arc. This is a warning to allow time for anyone in the area to lower their welding shield, or otherwise protect themselves. Some people may think that their eyes are safe from painful burns if they are not looking directly at an electric arc. However, the very intense ultraviolet and infrared rays from the

plasma arc can still reflect off shiny or light-colored walls, ceilings, or other nearby objects and cause serious burns.

Routine inspection, adjustment, cleaning, and repair of the hand torch and cable/hose assembly is required. Always replace any damaged or cracked torch body parts. Electrodes, nozzle tips, and shield cups are considered consumable supplies. They will wear or burn away even with normal use.

Plasma arc equipment typically operates at a higher open-circuit voltage than other types of electric arc cutting and welding equipment. Thus, plasma arc equipment operators and helpers should be aware that this presents a greater hazard for possible electrical shock.

Remember, there is electrical current flow to some internal power source/control console components even when the main ON/OFF switch on the power source unit is in the OFF position. ***Always*** disconnect the power source unit from the AC power supply ***before*** disassembling, inspecting, and repairing the power unit, torch control switch, torch body, or the hose/cable assembly.

Drag Cutting versus Standoff Cutting with a PAC Unit

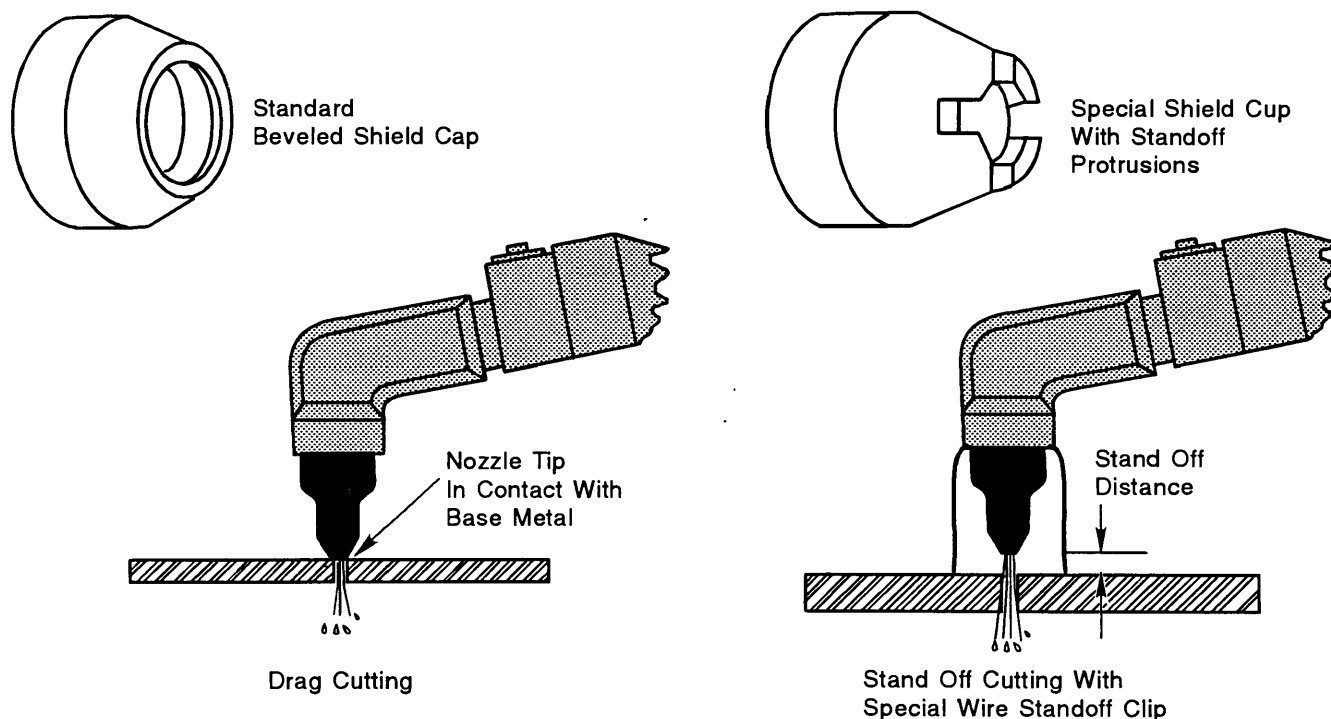
To start plasma arc cutting on the edge of a piece of metal, hold the torch perpendicular to the workpiece. The tip should be right on the edge of the workpiece at the point where the cut is to start. Remember, no preheating is required. Activate the torch control switch to establish the main plasma cutting arc as quickly as possible. For maximum electrode and nozzle tip life, do not operate the torch in the pilot arc mode any longer than necessary. “Piloting” is actually harder on the internal parts than cutting. When starting a cut on the edge of the plate, do not pause or force the main plasma arc to “jump or reach” for the metal.

After all cutting operations are completed, it is recommended to wait several minutes before turning off the main ON/OFF switch. This allows the cooling fan to continue to operate and cool the internal parts.

Drag cutting with a PAC unit refers to the simple process of: starting the pilot plasma arc; placing the orifice nozzle tip directly on the metal workpiece surface as the main plasma jet is formed; and “dragging” the torch along the cutting line

to cut the metal. For drag cutting, a standard shield cup has a beveled edge. This permits the operator to maintain the desired cut angle while maintaining tip contact with the workpiece. For normal drag cutting, hold the torch with the arc directed at a slight angle in the same direction of travel. As a general rule of thumb, drag cutting is recommended *only* when the plasma arc cutting current amperage is set below 45 amps.

To help prevent damage to the nozzle orifice tip and shielding cup caused by excess heat and spatter, **standoff cutting** is recommended when the PAC amperage is set above 45 amps. On some higher amperage models, the shielding cup may actually extend out beyond the end of the nozzle orifice tip. However, remember that torch standoff distance is measured from the workpiece surface to the outface of the orifice nozzle tip, not the outer face of the shield cup.



As the plasma arc cutting amperage increases above 45 A, the recommended torch standoff distance increases proportionately from 1/16" to approximately 1/2". Improper standoff distance can adversely affect nozzle tip and shield cup life. Too long of a standoff distance causes a wider bevel angle in the kerf area.

When performing a standoff cut, it may be difficult to maintain the proper standoff distance and travel speed at the same time. Special shield cups have been developed with protrusions that extend out beyond the end of the nozzle tip. They

are available with different length protrusions for the different recommended standoff distances. In addition, adjustable standoff clips have been designed that can be attached to standard shield cups.

These attachments allow the operator to place the torch against the workpiece surface. The plasma jet can then be moved along the cutting line while maintaining the proper torch standoff distance. Even though the special shield cup or standoff clip is resting on the surface, this is not considered “true” drag cutting. This is because the nozzle orifice tip is not in actual contact with the workpiece surface. For normal stand-off cutting, direct the arc at a 90° angle straight down at the workpiece.

Some equipment manufacturers recommend the use of a **spatter guard compound**. The chemical compound leaves a film on the end of the torch to help prevent spatter (hot slag and sparks) from sticking. Spatter guard is available in semi-liquid paste and aerosol form. Always follow the manufacturers’ instructions for applying. Even with the use of the spatter guard compound, some spatter will build up on the torch. It can restrict the flow of the shielding gas. Use a small wooden stick to remove spatter from the contact tip and shield cup. A wooden craft or ice cream bar stick will work fine. Do not use a metal rod to remove spatter.

Plasma arc cutting can be performed in any position. However, always be aware of the direction that the stream of molten metal will be blown while the plasma arc cut is being made. Hot molten metal and sparks can damage nearby painted surfaces, glass, or plastics. It can easily ignite combustible materials.

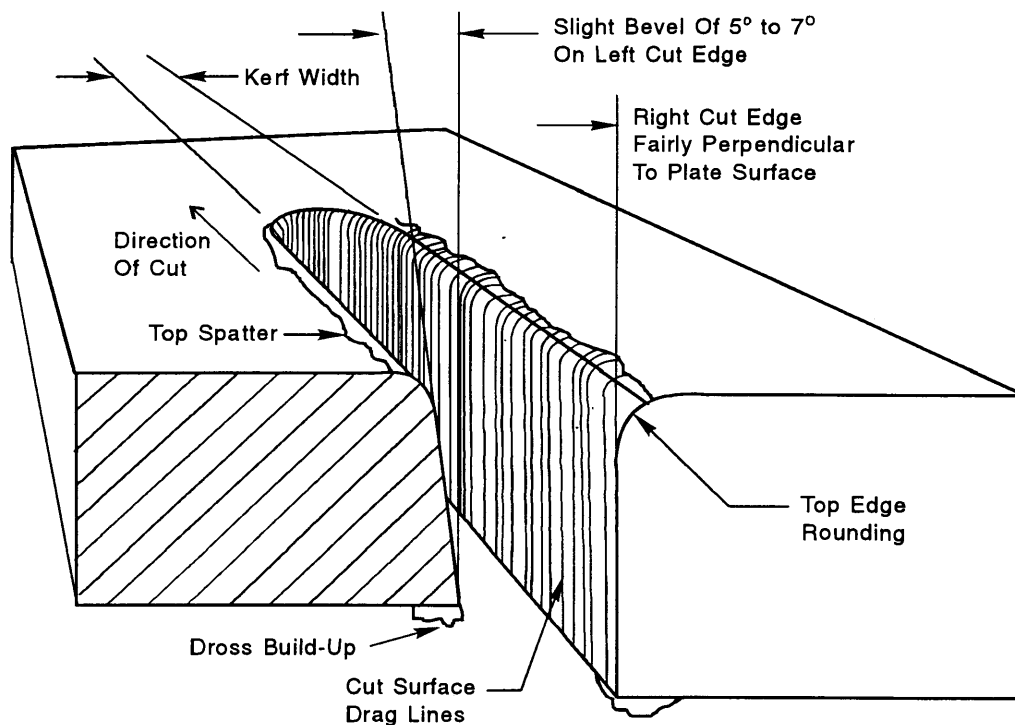
Unavoidable by-products of the plasma arc process are the fumes and gases. In large enough quantities, they can harm your health. The composition and rate they are generated depends upon the arc current, cutting speed, the type of metal being cut or welded, and the type of orifice and shielding gases used. Adequate ventilation *must* be used to remove smoke and fumes from the work area.

The plasma arc process produces a very intense high frequency noise. The noise level increases as the amperage of the main plasma arc increases. Hearing protection is recommended not only for the equipment operator, but any person who may be in the immediate area. Depending upon the noise level, the required hearing protection may range from industrial quality ear plugs to ear muffs.

QUALITY OF A PLASMA ARC CUT

The volume of dross (also called slag) on the bottom edges of the kerf, the kerf edge squareness, kerf width, and the sharpness of the top kerf edges are all indicators of the quality of the plasma arc cut.

The direction of travel used when making a plasma arc cut helps to determine the quality and angle of the kerf edges. The reason is that most plasma arc torches are designed to create a slight swirl in the orifice plasma gas as it flows around the electrode and leaves the nozzle tip. This provides a more efficient transfer of arc heat to one side of the kerf. On most equipment, the plasma rotation is clockwise. The result will be a reasonable vertical edge on the right side of the kerf and a slight bevel of 5° to 7° on the left side of the kerf.



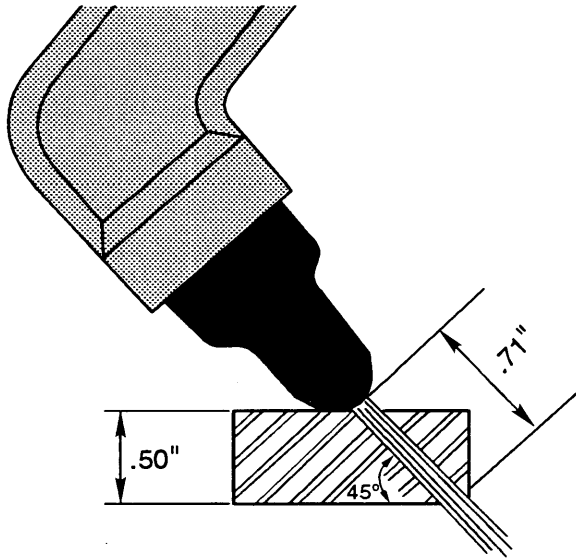
Cut Quality Characteristics

The right and left sides of the kerf are always based on the direction of travel of the cut. If there is to be a “scrap side,” it is helpful to plan the direction of cut.

On carbon steel, dross or slag on the top of the plate is normally caused by too fast torch travel speed and/or too high torch standoff distance. This dross is usually hard to remove. Dross along the cut line on the bottom side of the plate is more easily removed. It is often caused by torch travel speeds that are too slow.

As a rule of thumb, a cut is considered excellent when the kerf edges are smooth, and the kerf width is two times the diameter of the hole in the nozzle orifice tip. This means the equipment is setup, adjusted, and being operated properly.

Making Bevel Cuts with Plasma Arc Cutting Units



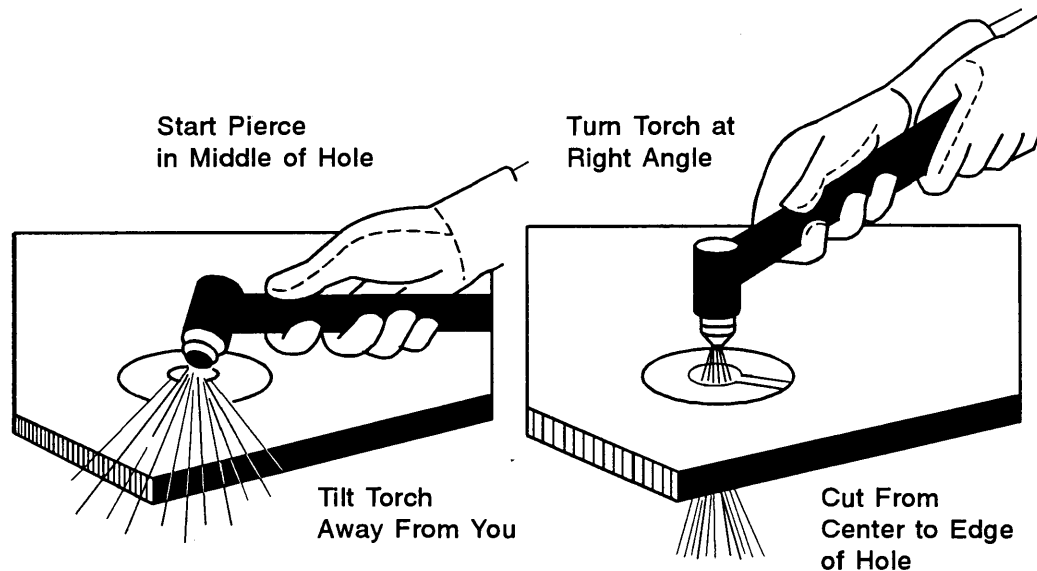
Some people seem to have difficulty making bevel or angle cuts with a PAC torch even though they have even double checked the equipment settings and adjustments based upon the thickness and type of metal being cut. One common mistake however is the failure to recognize the “hypotenuse of a right triangle.” Suppose someone is making a 45° bevel cut on 1/2” thick mild plate steel. In effect, there is approximately 3/4” of metal to be cut at the bevel instead of 1/2”.

Depending upon the type of equipment being used, there may be significant differences in the recommended travel speeds, standoff distances, orifice diameters, amperage settings, and/or flow settings for 1/2” vs 3/4” metals. In addition, suppose a particular PAC unit is only rated for cutting metal up to 1/2” thick. Consequently, the 3/4” bevel cut is in effect exceeding the maximum thickness specifications for the unit.

Cutting Holes in Plate Metal

Before using a PAC unit to cut holes in metal, check the specifications for the recommended settings and maximum metal thickness. Excessive slag and heat blowback during the hole cutting operation can greatly shorten the life of the torch parts. Remember to spray or dip the end of the torch with an antisplatter compound to help minimize the amount of spatter build-up.

When cutting a hole with a hand-operated PAC torch, always start the pierce in the middle of the hole, away from the desired cutting line. Tilt the torch slightly to one side. This will allow the majority of the slag to be blown away from you and the torch. After the initial pierce through the metal, quickly turn the torch perpendicular to the workpiece surface. Cut out toward the desired cutting line to complete the hole. Remember to plan the direction of the cut around the circle to obtain the desired kerf edges. When cutting holes, always clean the spatter from the shield cup and tip as soon as possible after the initial pierce is complete. Do not allow the spatter or slag to buildup on the shield cup or nozzle tip.



ADVANTAGES AND DISADVANTAGES OF USING THE PLASMA ARC CUTTING PROCESS

There are many advantages of using the PAC process. Steel 1" thick or less can be **cut up to five times faster** with the proper PAC torch as compared to an oxyfuel torch. The very intense heat of the constricted plasma jet allows **instant cutting with no preheating**. There is **little or no distortion of the metal**. Because of the faster cutting speeds and no preheating, excess heat does not have time to flow out away from the kerf area. This is a major advantage when cutting thin sheet metal. By using the proper orifice and shielding gases, **both ferrous and nonferrous metals can be cut**.

There are also disadvantages of using the PAC process. **The sides of the kerf may be slightly beveled** unless special torches and techniques are used. Plasma arc cutting can be **more expensive even though it is faster**. This is because of the higher initial cost of the equipment. In some applications, there is the additional cost of specialized orifice and shielding gases. Torch electrodes, nozzle tips, and shielding cups are considered consumable supplies. They must be replaced regularly even with proper adjustment and operation.

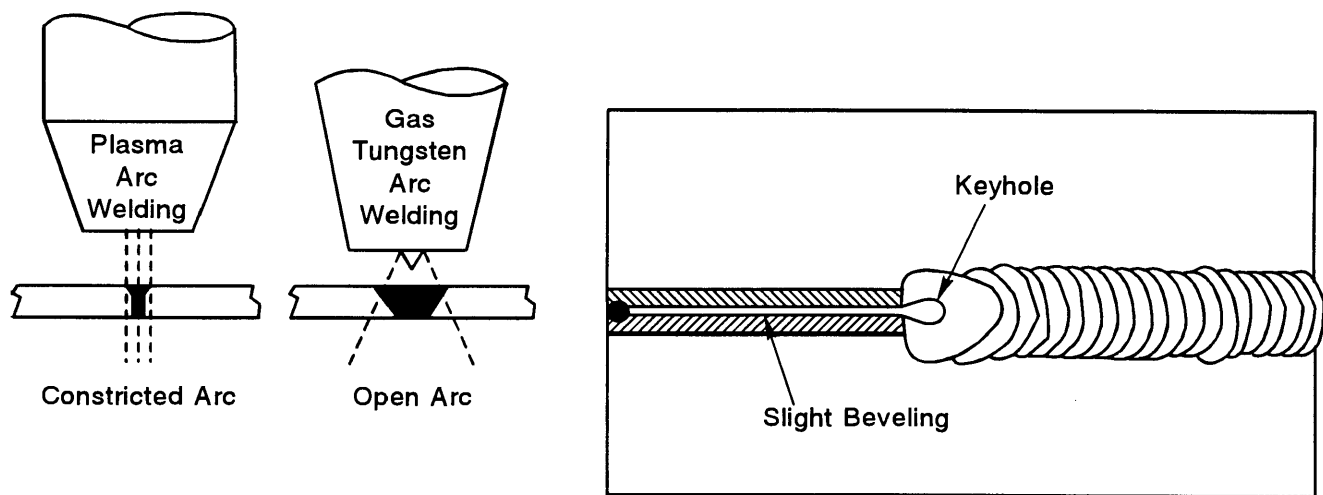
A major disadvantage of PAC units is the **potential health hazards created because of the excessive noise and fumes**. This is particularly true in large scale production-type operations where higher amperage PAC units are used.

In such operations, water tables are often used with the PAC unit. A large container of water is positioned directly under the cutting table. The metal to be cut is placed just above the water surface on racks. The hot molten metal from the cut is directed into the water. The water helps muffle the sound and absorb the fumes. The water from the table is filtered and circulated to keep it cool.

Another method used in industrial applications is underwater plasma arc cutting. The plate to be cut is submerged in a special cutting table beneath 2 1/2" to 3" of water. This underwater plasma cutting uses a special plasma torch and automatic track equipment. In the **water shield plasma cutting process**, water is used as both the shielding and cooling agent. Water is circulated through internal passages to cool the torch body similar to the shielding gas. A water spray is used in place of the shielding gas to shield and constrict the plasma jet. The cutting actually takes place under the water surface. The water in the table absorbs the excess noise, fumes, and heat, and almost completely eliminates ultraviolet radiation from the plasma jet.

PLASMA ARC WELDING OR PAW

The **plasma arc welding (PAW)** process uses many of the same principles and procedures as the plasma arc cutting process. In some respects, the equipment is very similar. However, separate power units are required and most component parts are not interchangeable.



The plasma arc welding process can be performed manually with a handheld torch or with an automatic track torch. When a handheld PAW torch is used, a metal filler rod is added into the molten puddle similar to the oxyfuel or gas tungsten-arc welding processes. With a track torch PAW system, the filler wire is added automatically.

Plasma arc welding uses the "keyhole" method. The leading edge of the molten puddle resembles the shape of a small keyhole. This is because the plasma arc is stabilized and the intense heat is concentrated into a smaller area. The plasma arc keyhole welding process allows full penetration on thicker metals with less beveling. In some applications where the PAW keyhole process is used, two pieces of 1/2" plate metal can be welded in a single pass with very little, if any, beveling.

The size, shape, and depth of the keyhole is controlled by adjusting the current amperage, the gas flow, forward travel speed, and torch standoff distance. If the keyhole of the molten puddle becomes too large, the molten metal will "fall through."

Both transferred arc and nontransferred arc processes can be used in PAW. In industry, PAW is often used as a substitute for gas tungsten-arc welding because of the greater heat concentration and improved arc stability. The constricted plasma arc welding process provides faster welding speeds; better weld quality; and lower width-to-depth ratio of the puddle for better penetration.

The curriculum guide for this course of study and the supporting instructional materials were developed for educational use. The applications and components described or pictured are illustrative only. Depiction or description of any product, component, brand name or application does not constitute, indicate, or imply a recommendation or endorsement of any sort. Always refer to appropriate technical and service manuals for specific applications, instructions, repair procedures, and safety precautions.

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Pierre, E., *Welding Processes and Power Sources*, Burgess Publishing Company, Minneapolis, MN.

Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

TRUE OR FALSE: Circle "T" if the statement is true; circle "F" if the statement is false.

- T F 1. Plasma is the temporary physical condition of a gas as it is being heated by an electric arc.
- T F 2. The two different modes of operation for the plasma arc process are 1) transferred plasma arc process and 2) nontransferred plasma arc process.
- T F 3. With the transferred plasma arc process, an intense main plasma arc is established from the electrode, through the orifice hole of the nozzle tip, to the grounded workpiece.
- T F 4. Plasma arc cutting (PAC) is a thermal or melting process.
- T F 5. Operating procedures are the same for each brand and model of plasma arc equipment.
- T F 6. With the nontransferred plasma arc process, the metal workpiece is a part of the electrical circuitry of the plasma arc.
- T F 7. Carbon and mild steel can be cut satisfactorily with a plasma arc torch using compressed air as the plasma gas.
- T F 8. The thinner the metal and the higher the cutting amperage, the greater the standoff distance.
- T F 9. Even when a person is not looking directly at a plasma arc, it is possible to receive painful burns to the eyes from intense ultraviolet and infrared rays that reflect off shiny or light-colored walls, ceilings, or other nearby objects.

FILL IN THE BLANK: Complete the following statements by inserting the correct word(s) in the blanks.

- _____ 10. An _____ is a gas which does not normally combine or react chemically with a hot or molten metal.

- _____ 11. The _____ is the width and shape of the space left after a cutting process has been performed.
- _____ 12. The _____ is the distance from the outer face of the constricting orifice nozzle tip to the workpiece surface.
- _____ 13. The direction of travel used when making a plasma arc cut helps to determine the quality and angle of the _____ edges.
- _____ 14. To help prevent damage to the nozzle orifice tip and shielding cup from excess heat and splatter, _____ is recommended when the PAC amperage is set above 45 amps.
- _____ 15. The plasma arc keyhole welding process allows _____ on thicker metals with less beveling.
- _____ 16. _____ is the distance the electrode tip is set back away from the constricting orifice of the torch nozzle tip.
- _____ 17. When making a 45° bevel cut, it is necessary to consider the _____ to determine the actual thickness of the metal to be cut.

SHORT ANSWER/LISTING: Respond to the following items in sentences, phrases or short paragraphs in the spaces provided. (Use additional paper when needed.)

18. What type of electrode is used with most compressed air units?

19. What type of electrode is used with most inert plasma gases?

20. List any three of the four purposes of the secondary shielding gas.

- a. _____

- b. _____

- c. _____

21. List four main advantages of using the plasma arc cutting process.

- a. _____
- b. _____
- c. _____
- d. _____

22. List three main disadvantages of using the plasma arc cutting process.

- a. _____
- b. _____
- c. _____

23. List any six of the nine factors that help control plasma jet.

- a. _____
- b. _____
- c. _____
- d. _____
- e. _____
- f. _____

ADDITIONAL SKILLS & ENHANCEMENT ACTIVITIES: Perform the following activities or skills as assigned by your instructor.

1. Visit a metal fabrication or repair business. Observe the use of plasma arc cutting and welding equipment. **Note!** This activity will require the prior approval by the business owner and shop supervisor.
2. Study the operator's manual for several different types and brands of plasma arc cutting and welding equipment. Compare the recommended operating procedures and orifice and shielding gases for each.
3. Demonstrate the safe use of plasma arc cutting and welding equipment.

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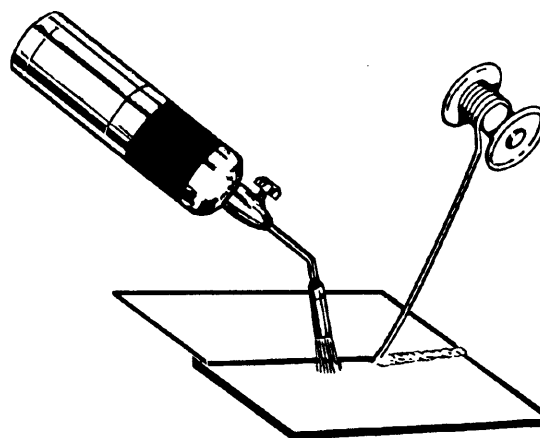
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SOLDERING PRINCIPLES AND PROCEDURES

Soldering is a low-temperature welding process used to join two pieces of base metal together without melting either of them. The pieces may be similar types of metal or they may be different. Soldering is not a fusion welding process, but an **adhesion process**.

An **alloy** is a mixture of two or more types of metal that are melted and mixed together during manufacturing. The different "filler metals," or **solders** used to join or adhere the pieces of base metal together are special nonferrous alloys. A nonferrous metal is one which contains no iron. These nonferrous alloys *must have* a melting point that is lower than the base metals being joined.



Some references divide the soldering process into two categories or classes: 1) soft soldering and 2) hard soldering. **Soft soldering** uses a softer, nonferrous solder made primarily of tin and lead that melts below 840°F.

Hard soldering uses a solder that melts above 840°F, but still below the melting point of the base metals. Other than the melting temperatures, the only major difference in the two processes is that the hard soldering process allows the use of filler metals for solders which can produce a slightly harder and stronger joint. "Brazing and silver soldering" are examples of hard soldering processes which use solders with melting points higher than 840°F. They use solders containing higher amounts of copper, zinc, and silver.

The soldering process is commonly used in many areas of agriculture. Uses include fabrication and repair of: copper plumbing, cooling system radiators, low-resistance connections in electrical and electronic circuits; sheet metal for heating, air conditioning, and ventilation ducts; and stainless steel food and agricultural chemical processing equipment.

The soldering process produces a fairly strong bond without the use of excess heat. In soft soldering, the melting temperature is usually well below 840°F (450°C). The soft soldering process is the preferred method to join many thin base metals because the lower heat requirements reduce the chances of heat damage or warpage. However, hard soldering (brazing or silver soldering) and fusion welding do produce stronger, more heat-resistant connections.

TYPES OF SOLDERS

Most solders used in the past were primarily alloys or mixtures of tin and lead. Pure tin melts at 450°F, while pure lead will melt at 620°F. By mixing the tin and lead in equal quantities, the mixture will melt at a lower temperature of 420°F.

Many solders are sold as a proportion or ratio of the amount of tin to lead or other metals. In the ratio, the tin content is expressed as the first number(s) and the companion metal content is given as the last number(s). In the past, a **general purpose solder** contained 50 percent tin with 50 percent lead, or a 50/50 ratio. Solders in a 40/60 and 60/40 ratio of tin and lead are also available.

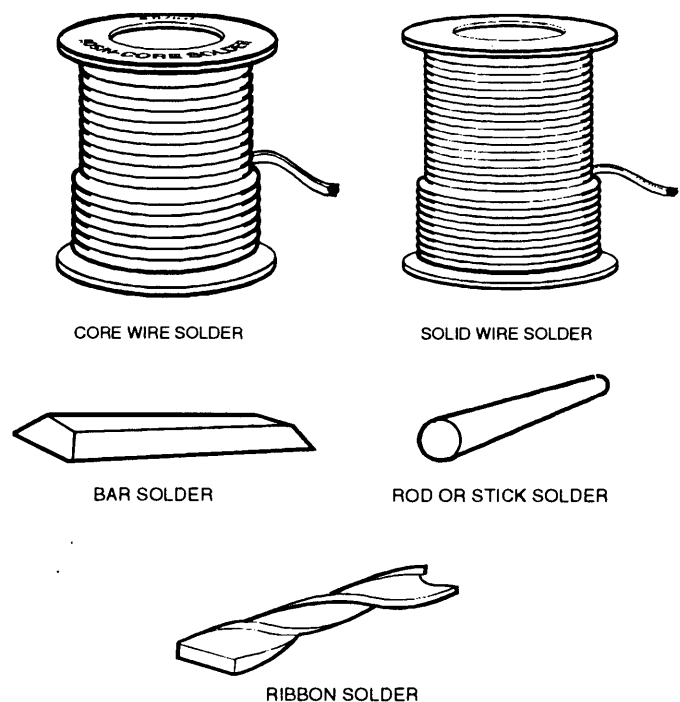
Traces of nickel, antimony, zinc, copper, aluminum, cadmium, indium, and brass are often added to the solder alloys. By varying the amount of tin, lead and other metals used in the solder, different melting temperatures can be achieved. The different solder alloys also have different strengths, characteristics, and degrees of hardness. Nonmetal products are also added to obtain stronger, cleaner connections. The **tensile strength** of the solder selected should not exceed the tensile strength of the base metals. Tensile strength is the amount of force or stress needed to stretch and break a given material.

The **plastic range** of a solder is the temperature range from which solder first starts to melt from a solid form to the temperature at which it becomes a molten liquid. The narrower the temperature range, the greater the fluidity. The more fluid the molten solder, the easier it is drawn into small spaces and gaps. Solders with greater plasticity are often preferred when it is difficult to preheat and to maintain a constant temperature. However, with a broader melting range, solders are able to fill wider gaps in poor-fitting joints.

Due to the toxic nature of lead and environmental concerns, lead solder usage is now diminishing and highly regulated. However, some lead alloy solders are still available. Today, nickel, antimony and phosphorus are used as lead substitutes.

Before using any solder which contains lead, check local codes and ordinances. Lead alloy solder should not be used on any food processing or handling equipment, or to join copper pipe or tubing used for potable (drinking) water. Also, solders which contain cadmium alloys produce toxic fumes when heated. Use this type of solder with extreme care only in properly ventilated areas. Solder with a higher percentage of tin is normally recommended for making electrical connections.

A true "silver solder" contains more than 10 percent silver; melts above 840°F; and is normally considered a "hard solder" for silver brazing. However, several companies now make a special lead-free "soft silver solder" made of an alloy containing 96 percent tin and 4 percent silver. It has a melting point of approximately 440°F. The new "soft silver solder" is used to join copper plumbing and stainless steel foodhandling and processing equipment where lead-alloy solders have been banded. A new tin-antimony solder is also designed to avoid lead contamination.



Common Forms of Solder

Solder is available in: solid wire, core wire, bar, stick, rod, and ribbon forms. Depending on the size of the job and metals being joined, select a compatible and workable form of solder for your specific needs. For most small jobs, solid or core type wire solders are often easier to handle.

SURFACE PREPARATION AND CLEANING FLUXES

The presence of oxides and other contaminants on base metals will prevent the solder from properly adhering to the surfaces. This can weaken the overall strength of the joint. In order for adhesion to occur, it is essential that the joint area be cleaned and all impurities removed.

Both chemical and mechanical cleaning may be required. **Mechanical cleaning** is often necessary to first remove any paint, grease, dirt, rust, etc., from the surface. Fine grit emery cloth, # 00 steel wool, files, wire brushes, or power sander/grinders may be used. Stainless steel brushes or brush attachments are recommended for most metals.

Excessive high-speed brushing, buffing, or sanding with power tools may cause the surface to "burnish." This is similar to buffing wax into the pores of a wood or tile floor and making the surface very slick and shiny. A burnished surface may look clean and shiny, but may actually be too slick to allow the solder to bond.

Flux is a **chemical cleaning compound** used to clean oxides and other residues from the pores of the base metal surfaces after mechanical cleaning. It should be noted that the flux is not designed to remove the paint, varnish, rust, dirt, or grease from the metal. If needed, the surface should be mechanically cleaned *before* the flux is applied.

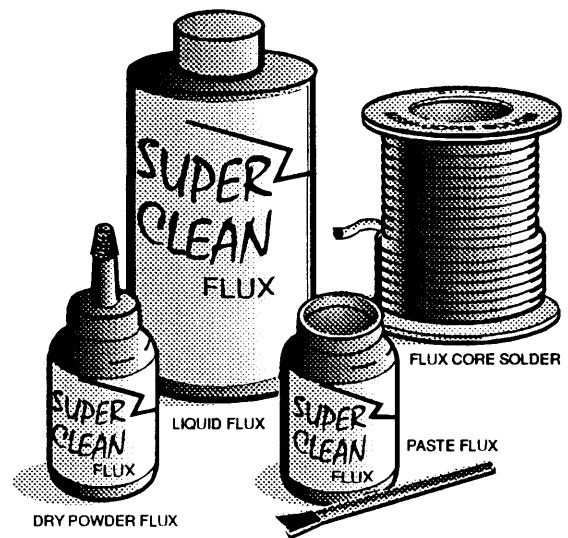
Fluxes are generally classified as **corrosive** and **noncorrosive** fluxes. Most **corrosive-type fluxes** have a zinc chloride or hydrochloric acid (dilute muriatic acid) base. Corrosive-type fluxes are usually more effective for cleaning the oxides from most types of metal before soldering. However, they can leave a residue of corrosive material on the metal surfaces *after* the soldered joint is completed and allowed to cool. Some types of fluxes are more corrosive than others.

If the corrosive flux residue is not removed after soldering, it may absorb moisture and cause the base metal to corrode or deteriorate later. Depending on the type of flux used, wash and clean the area after the soldering process is complete and the base metal has cooled. A mild soap and water or an appropriate cleaning solution should be used.

It is difficult to remove all the corrosive residues from irregular shaped surfaces. If not removed, corrosion is likely to continue. This can create high resistance connections, damage the electrical equipment, or cause the copper pipes to corrode. For these reasons, corrosive-type fluxes are not recommended for copper plumbing or electrical and electronic connections.

Noncorrosive-type rosin fluxes are used for soldering copper, brass, and electrical and electronic connections. Noncorrosive fluxes are made with white rosin dissolved in benzoic acid or ammonium chloride mixed in a petroleum jelly base. Tallow and stearine are also examples of noncorrosive-type fluxes. Rosin fluxes can generally be left on the joint surface unless a paint or other finish is to be applied later.

Flux may be purchased in **paste, liquid,** and **dry-powder** form. Wire solder can also be purchased with a flux-filled core. It is commonly referred to as **flux core solder**. It is available in both **acid core** (corrosive-type flux) and **rosin core** (noncorrosive-type flux) form. When using rosin and acid core wire solders, always crimp the ends shut when the soldering job is completed. This will prevent the rosin paste or liquid acid from leaking during storage.

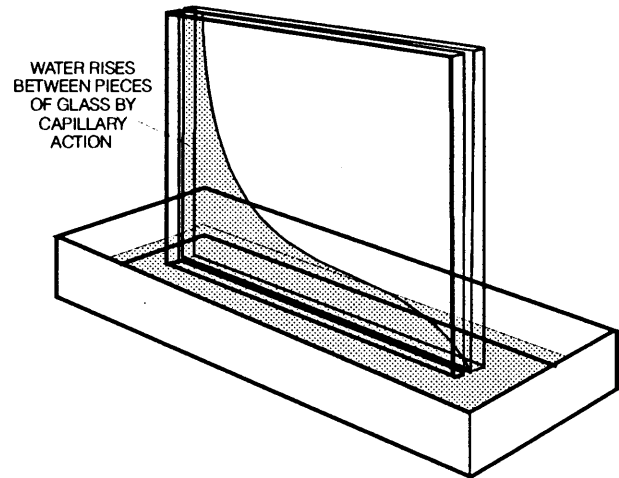


Common Forms of Soldering Flux

Always keep flux containers closed when not in use. This will prevent them from being spilled, from absorbing moisture from the air, and/or from becoming contaminated. Use separate brushes for mechanical cleaning and for applying the flux. Dirt, grease, etc., from the metal surfaces can contaminate the flux container if the same brush or applicator is used.

Some flux should remain on the joint after chemical cleaning. Care should be taken when handling the base metals. Even an oily film from dirty hands or gloves can cause contamination and potentially weaken a joint. Once clean metal is heated, oxygen and moisture in the air can cause oxides to quickly re-form. The joint should be soldered as soon as possible after cleaning to prevent recontamination.

The flux remaining on the surface allows the molten solder to flow by capillary action. **Capillary action** is a process in which a liquid or molten metal is "drawn" into the space between closely fitting surfaces, against the forces of gravity. Capillary action can be demonstrated with two pieces of flat glass held together and inserted into a pan of water. A thin film of water will rise up above the water level between the pieces of glass if they are held closely together.



Care should be taken to try to confine the flux to the actual joint area. The molten solder will try to flow where flux has been applied because of the capillary action. If excessive flux is applied all around the joint, the molten solder will flow from the joint area and be wasted.

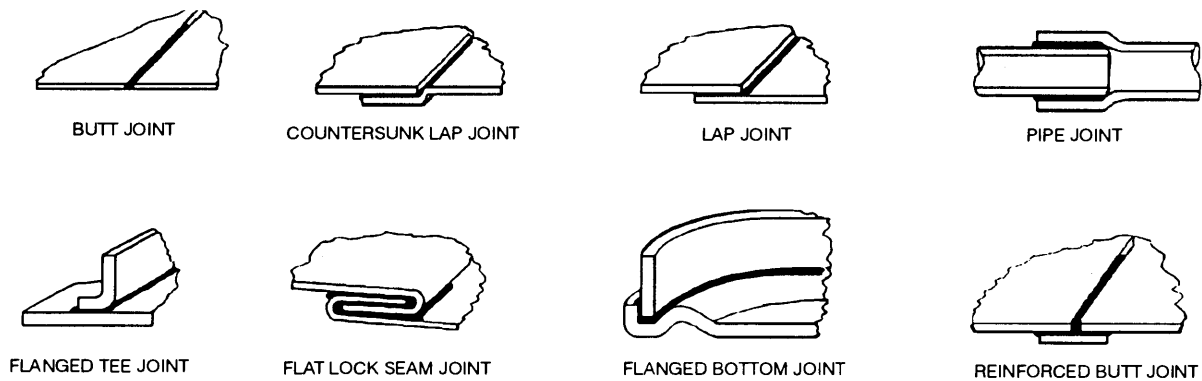
There is not a single flux that is perfect for all solders, nor one solder that is perfect for all situations. The compositions and approved usages of many fluxes and solders are constantly changing. Solders and fluxes that may produce toxic fumes when heated should be used only in adequately ventilated areas.

For safety and proper eye protection, protective gloves, clothing, and eyewear should be worn during the cleaning and soldering processes. Always consult container labels for the latest manufacturer's recommendations and follow the specific directions listed.

COMMON TYPES OF SOLDERING JOINTS

In the soldering process, the two pieces of base metal are closely fitted together after they have been mechanically and chemically cleaned. The space between the two joint surfaces is normally between .002 and .007 of an inch. This is approximately the thickness of a sheet of paper. For most practical purposes, this means that the two pieces of metal are touching or nearly touching. Even the surfaces of flat sheet metal in a lap joint are usually rough or wavy enough to maintain a thin air space or gap between them.

Some joints are shaped to provide some additional mechanical strength and/or to increase the size and width of the actual soldering surface. To strengthen sheet metal joints, a crimped or interlocking joint is often used. The molten solder will move by capillary action to all surfaces. Too large a spacing will prevent the solder from flowing to all the necessary surfaces.

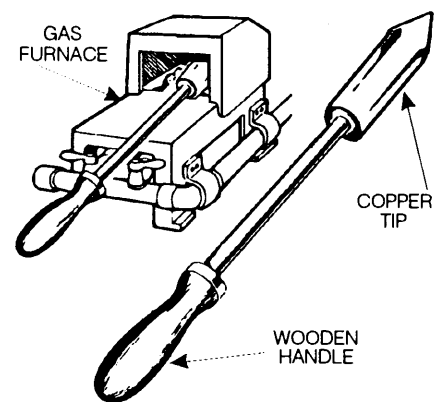


(The actual joint spacings are exaggerated for purposes of illustration.

Normal spacing is .003 to .007 inch.)

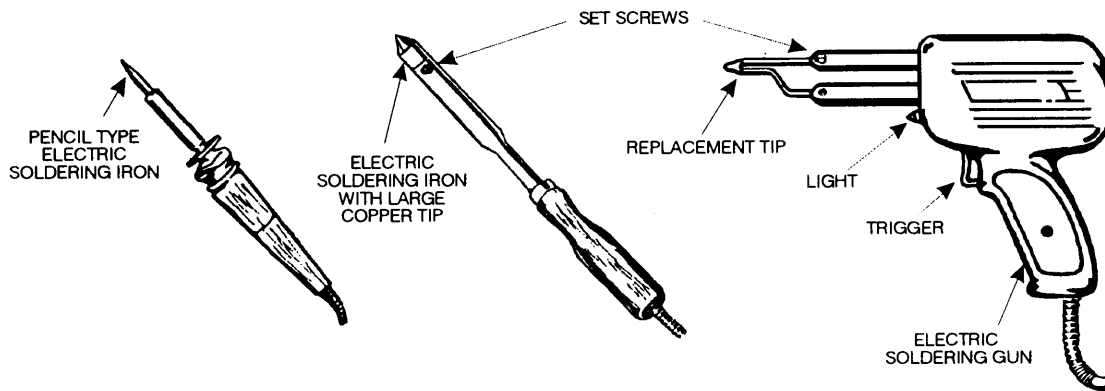
COMMON TYPES OF HEAT SOURCES FOR SOLDERING

For many years, **soldering coppers**, or **soldering irons** as they are also called, were used as the primary source of heat for soft soldering. They are still used today in many shops. The large tip is made of copper because of its ability to readily absorb and transfer heat. A soldering copper is heated with a separate heat source such as a small gas furnace, oxyfuel torch, propane torch, or a separate electrical heating element. The heated soldering copper is then used to preheat the base metals to a temperature that will melt the solder. The large copper tip is ideal for preheating flat sheet metal surfaces.



A major disadvantage of using a soldering copper is that as it gives up its heat to the base metal, it cools rapidly. It is difficult to maintain a constant temperature in the base metals. Two soldering coppers are often used when a large quantity of soldering is performed. While one is being reheated, the other is being used. Soldering coppers are available in different designs, shapes, and weights. The larger the soldering copper, the more heat it will hold.

Electric soldering irons (coppers) are available in a wide range of sizes and heat ranges. A built-in electric heating element heats the copper tip to a constant temperature. The higher the wattage rating, the more heat it will produce. Small 25- to 35-watt **pencil type electric soldering irons** are commonly used for soldering small wiring, circuit boards, etc.



Electric soldering guns are available in sizes ranging from 100 to 260 watts. Cordless rechargeable models are also now available. Most soldering guns are trigger operated. The tip does not heat until the trigger is pulled. When the trigger is pulled, the tip will heat in 5 to 10 seconds.

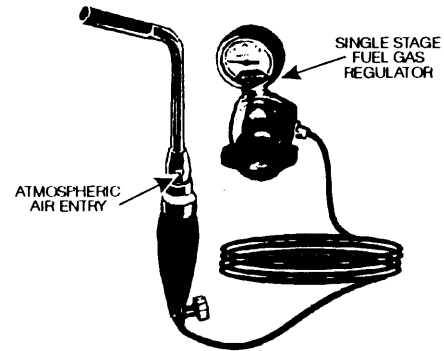
Most electric soldering guns are equipped with replaceable tips of various sizes and shapes for different applications. Some heavy-duty soldering guns are capable of producing a tip temperature of approximately 1000°F. With the smaller tips, the heat is concentrated in a smaller area. However, this may be a disadvantage for some types of sheet metal and plumbing work.

Propane bottle torches provide a convenient source of heat for many larger soft soldering and some hard soldering applications when electricity is not available. Oxygen from the air combines with the compressed propane gas from a small 14 oz. cylinder as it leaves the torch head. Different sized and shaped torch heads are available for different applications. Some heads can produce a low to medium temperature flame up to approximately 2,300°F. Propane bottle torches may be used to preheat soldering irons, or to preheat the base metals themselves.



Air-fuel torches are used when a low to medium temperature flame up to approximately 2,500°F is needed. Air-fuel torches are used extensively for soft soldering large quantities of copper plumbing, and for hard soldering applications.

Most air-fuel torches use acetylene as the fuel gas. They produce a slightly larger and hotter flame than the smaller propane bottle torches. The oxygen to support combustion is also provided by air from the atmosphere. However, the air is drawn through small orifices in the side of the torch body. The air is premixed with the fuel gas *before* it burns.



Oxyfuel welding torches equipped with even a very small tip are capable of producing a flame up to approximately 5,600°F. Oxyfuel torches are sometimes used by experienced personnel for some hard soldering applications or to preheat soldering coppers.

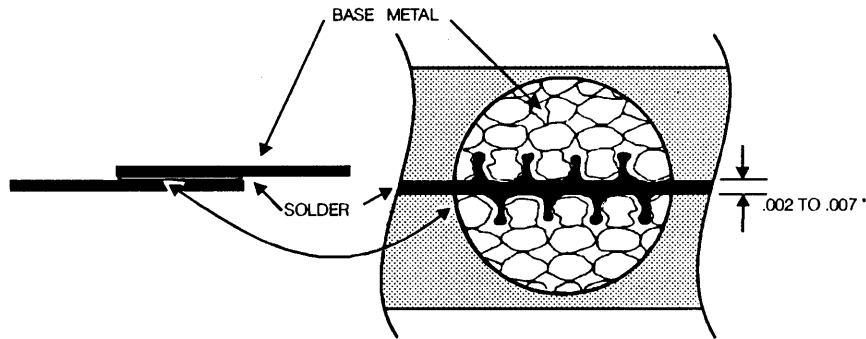
It is possible to accidentally ignite surrounding combustible materials, or to quickly overheat the base metals when using an open flame heat source. Exercise extreme caution *especially* in a confined area. **For example:** when using a torch to assemble copper plumbing within a wall or other area, it may be necessary to use a flame-resistant blanket to protect the surrounding area.

Because there are many different makes and models of propane, air-fuel, and oxyfuel torches, always follow manufacturer's instructions for specific operating procedures.

BASIC SOLDERING PROCESS

Adhesion is the tendency of unlike molecules to stick together. Molten solder is applied to the properly cleaned, positioned, and preheated base metal surfaces. It "adheres" or bonds to the porous surfaces by molecular attraction or adhesion. When the heated base metals and molten solder are allowed to cool, a solid joint is formed.

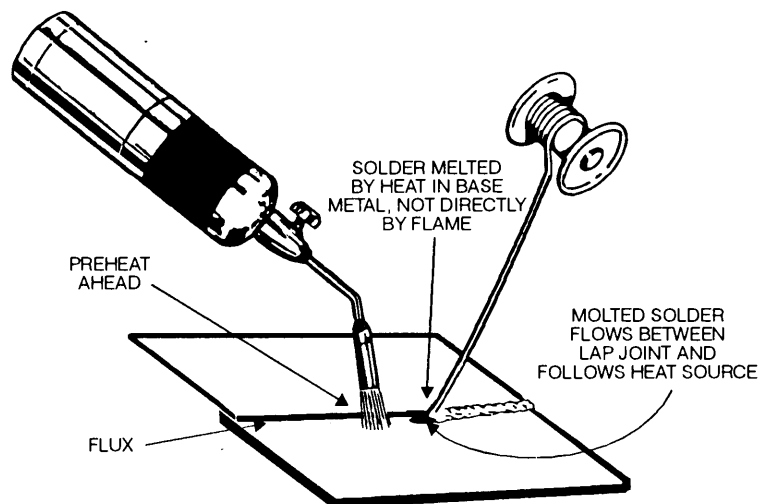
One common misconception about soldering is that the heat source (soldering copper, soldering gun, or torch) is used to melt the solder. This is not true. The base metals are preheated with the heat source. The heat remaining in the base metals is *then* used to melt the solder.



Microscopic View of Solder Adhering to the Pores of the Metal Surfaces

The pieces of base metal are preheated with a heat source *only* to the point the solder will melt. Preheating also causes the grainy structure or pores of the base metal to open slightly so the solder will adhere better. As a general rule, the ideal temperature is reached when the base metal is preheated enough for the flux to melt and/or change color.

To see if the area has been preheated enough, the heat source is removed or moved further down the length of a long joint or seam. The end of the solder is quickly touched to the preheated area of the joint. If the base metal is hot enough, the solder will melt and flow between the closely fitted surfaces by capillary action.



If the solder does not melt, does not flow smoothly, or beads, it should quickly be moved back out of the way. The heat source should then be returned to the preheated area and more heat applied.

Remember, the heat source *should not* be used to melt the solder and try to get it to adhere to the base metal. The molten solder will run off the cold metal surfaces, or will only stick but not properly adhere. The joint can be easily pulled apart. The solder should be melted only by the heat in the base metal.

On a long joint or seam, the heat source is slowly moved ahead. The end of the solder is occasionally touched to the preheated joint area. The molten solder should flow into the joint and follow the heat source as it is moved. Additional solder is fed into the joint only as needed. If the solder does not melt or stops flowing toward the heat source as it is moved along, more preheating is needed.

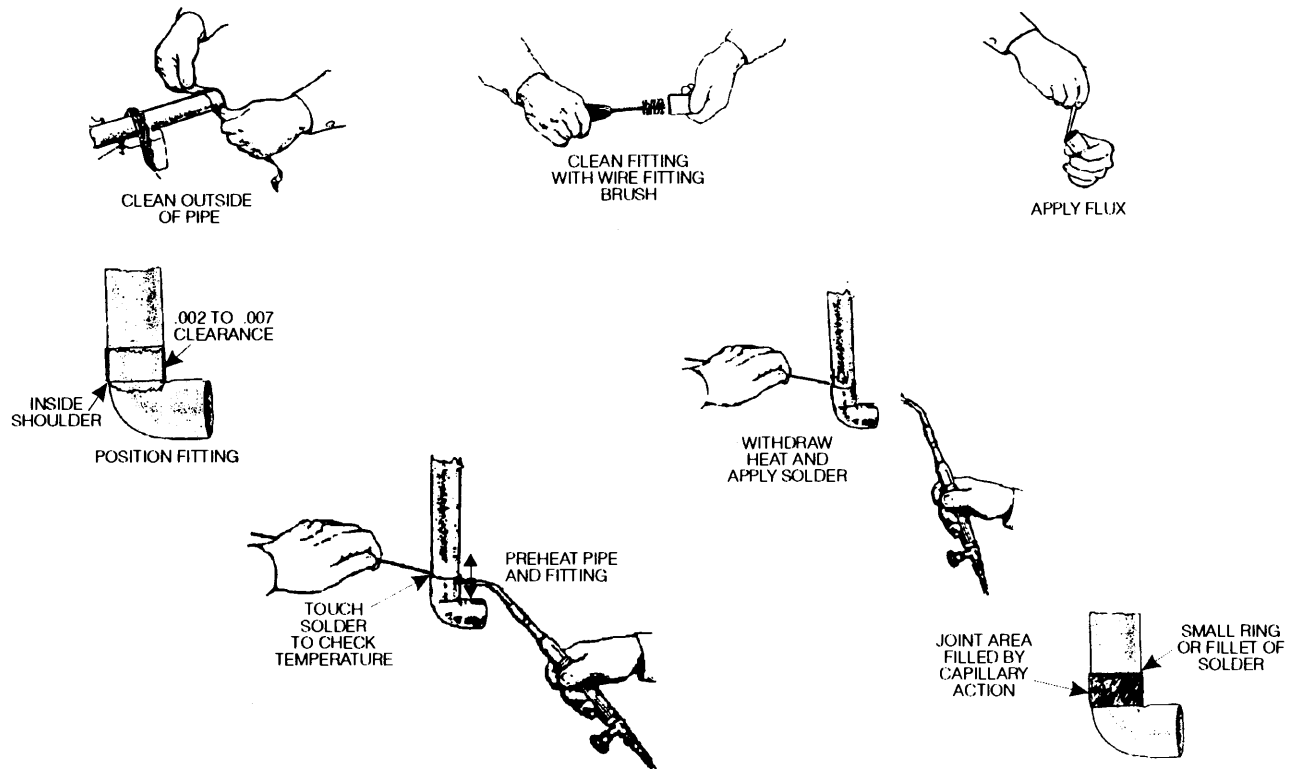
Care should be taken to ensure that base metals do not become overheated. Too much heat has likely been applied when the solder quickly melts and flows directly through or runs off the joint. This is not to be confused with the situation that occurs when solder melted directly by the heat source does not properly adhere or bounces off the base metal that is too cool. Too much heat can also cause the base metals to warp or discolor.

When soldering, *always* support the base metals so they do not move. During the cooling process, solder is brittle and weak. If pieces of base metal, pipe or wires are allowed to move while the joint is cooling, flaws and cracks in the solder may form. On a good connection, the solder is shiny and smooth after it cools. A dull, rough, porous appearance indicates the solder moved while cooling and a poor connection will result.

SWEAT SOLDERING COPPER PIPE OR TUBING

To "sweat solder" a copper plumbing fitting, the copper pipe or tubing is cut to length with a tubing cutter. Any large burrs on the ends should be removed with a copper tubing reamer. Emery cloth, steel wool, or specially designed brushes can be used to mechanically clean the outside surface of the pipe and the inside surface of the fitting. Any loose dirt or grit particles should be removed.

Immediately apply the proper type of flux *only* to the joint area of the pipe and fitting that will be in contact. Assemble the pipe and fitting. Most fittings are designed to allow for the correct spacing. Push and turn the fitting on the pipe until the pipe is bottomed against the inside shoulders of the fitting. This will also help ensure all joint surfaces are evenly coated with flux. Check the alignment and secure the pipe and fitting in the proper position.



Sweat Soldering Copper Pipe Fittings

Direct the heat from the heat source to the pipe or tubing just above the fitting. This preheats the pipe first without overheating the fitting. Keep the heat source moving slightly so the heat is not concentrated in one spot. When the pipe is preheated, the heat source is then directed to the fitting. To check for proper temperature of the fitting, slowly touch the end of the solder wire to the joint area *on the opposite side* of the fitting away from the heat source.

If the solder melts, remove the heat source. Gently feed a small amount of solder into the joint from the opposite side as the heat was applied. The solder will be drawn by capillary action into and around the fitting. When the joint is filled and complete, a small fillet or ring of solder should form around the pipe just above the fitting.

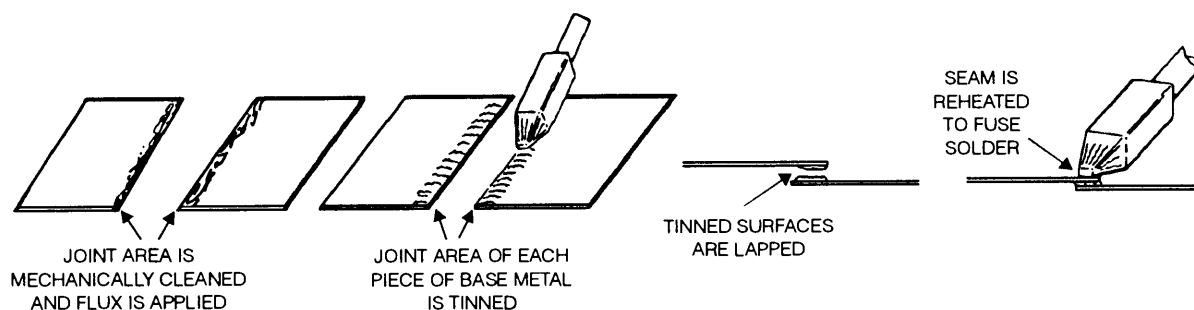
On larger diameter pipe, it may be necessary to preheat the pipe and one side of the fitting first. Solder is then applied to the preheated area as the heat source is moved around the fitting as if soldering a long seam.

Very little solder is actually needed to fill the narrow space in the joint area. **For example:** to solder a common $\frac{1}{2}$ inch diameter copper fitting joint, only $\frac{3}{16}$ to $\frac{1}{4}$ inch of $\frac{1}{8}$ inch diameter solid wire solder is actually needed.

SWEATING A SEAM JOINT

It is sometimes necessary to solder a wide lap seam or joint together, or to solder smaller pieces of flat metal to larger surfaces. The joint surfaces are first mechanically and chemically cleaned.

The mating surfaces are then **tinned**. Applying a thin layer of solder to a metal surface is called "tinning." Tinning is an expression that started when a layer of tin alloy was first applied to the surfaces of sheet steel used to make cans. "Tin cans" are actually steel cans with a thin layer of tin alloy "tinned" to the surfaces.



To sweat solder a seam joint or patch, each piece of the base metal must be tinned. One piece of the base metal is preheated in the joint area. When the proper temperature is reached, a thin layer of solder is applied to the joint surface and allowed to cool. If the metal has been properly cleaned and flux applied, the solder should flow out in a smooth flat layer *only* to the joint area. The joint area of the second piece of base metal is tinned in the same way. The two pieces of base metal are then placed together in the desired position and supported. Heat is then directed to the joint area. As the joint area is *reheated*, the solder that has been tinned to the two surfaces of the joint will *remelt*.

If a soldering iron is used as the heat source, slight pressure can be applied to force or "iron" the sheet metal together. If a flame-type heat source is used, a wooden handle or other similar object with a smooth end can be used to press the seam together. On a longer seam, it is necessary to start reheating on one end and slowly work to the other end. A damp cloth can be used to clean the joint and remove excess solder that may have flowed out from between the joint.

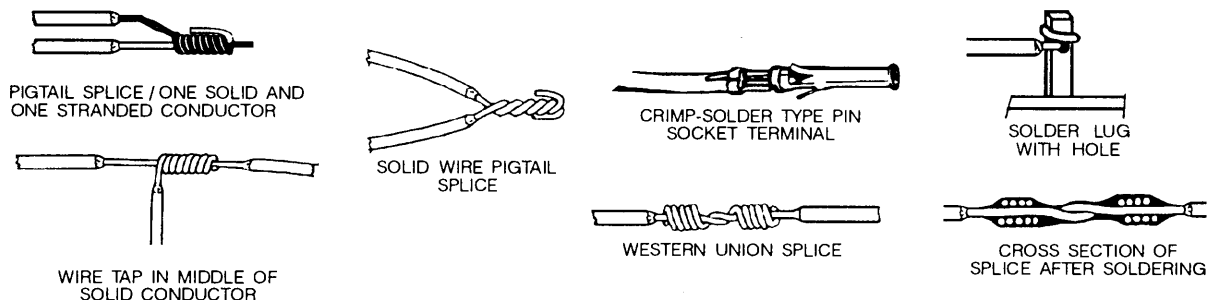
Most metals that can be brazed or fusion welded can also be soldered. With some exceptions, the soldering process is used to join or repair galvanized sheet metal, steel, stainless steel, copper, copper alloys, lead, and alloys with a high nickel content. One disadvantage of using the soldering process is the soldered assembly must be kept at a very low operating temperature. If the operating temperature is allowed to rise near or above the melting point of the solder, it will soften and remelt. If the pieces of base metal are in stress, or are allowed to move, the heated joint will come apart. This is the reason some joints are first mechanically crimped or riveted, and electrical wires twisted together before they are soldered.

If needed, most soldered connections can be taken apart by reheating the joint to the temperature at which the solder remelts. When the solder remelts, the joint can usually be pulled apart without damage to the base materials. A suction bulb can be used to "suck up" the molten solder. Also, a short section of finely braided copper wire coated with flux can be used as a wick to absorb the solder as it is melted. The joint can then be mechanically and chemically cleaned and resoldered.

SOLDERING ELECTRONIC OR ELECTRICAL CONNECTIONS

In cases where solderless wire nuts or crimp-type wire connectors are not appropriate, the soldering process is used to make low-resistance connections. Wiring harness terminals used in many new electronic monitor, sensor, and controller circuits of agricultural buildings and equipment are often crimped, then soldered. A 60/40 rosin core solder is normally recommended for electrical and electronic circuits.

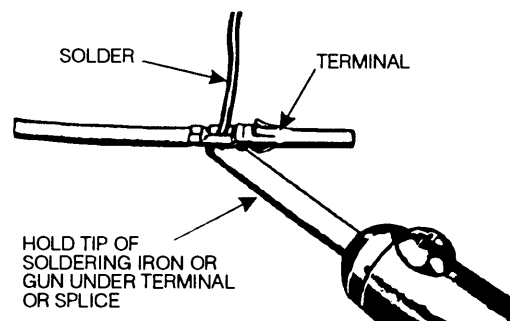
To make a solder connection, a short section of insulation is removed from wire ends. The amount of insulation to remove will vary with the size of the wires and the type of connection. It is normally better to leave as much insulation as possible rather than having to re-cover the area with electrical tape later.



Clean the wire ends by scraping them lightly with a knife, or by rubbing them with steel wool or emery cloth. Mechanically secure the wire ends to each other or to the soldering lug. This is done by firmly twisting the ends together and bending them back over. Some soldering lugs may have a small hole through which to thread the wire end. Be careful not to nick or cut the wires.

If a rosin core type solder is used, extra flux is normally not needed. *Do not* use acid core solder. If a solid wire solder is to be used, first coat the wires' ends and solder terminal or lug with a noncorrosive-type flux. Remember to confine flux only to the actual joint area. Molten solder will flow where flux has been applied.

Select an appropriate sized soldering gun and tip for the size and number of wires being soldered. It is necessary to keep tips cleaned and properly tinned. A small 25- to 35-watt pencil type soldering iron is adequate for many small wire connections, terminals, circuit boards, etc. Larger 100- to 250-watt soldering guns can provide instant heat and can be used on larger wires and terminals. A non-electric soldering iron (copper) may be used for larger electrical jobs if a means to keep it preheated is available. **Note!** Exercise caution when using large soldering guns or soldering irons. The concentrated heat can quickly melt wiring insulation and/or cause heat damage to other electrical components.



Soldering a Crimp-Solder Type Wire Terminal

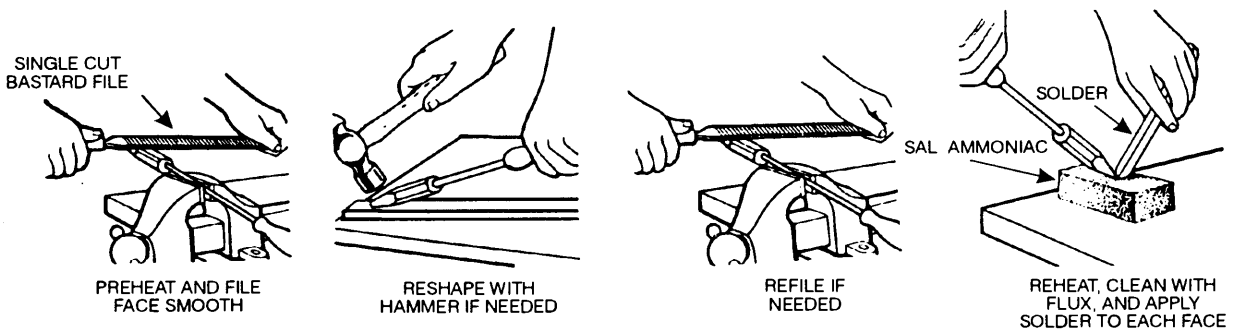
If possible, hold the tip of the soldering iron or gun under the wires or terminal. Periodically touch the end of the solder to the top of the connection. *Do not* melt the solder with the tip of the soldering gun. **Caution!** Excessive molten solder can drip into or onto electrical motors, circuit boards, or other components and cause damage.

When the wires have reached the proper temperature, the solder will quickly melt and flow around and through the connection. Do not jar or wiggle the wires while the solder is cooling, or a poor connection will result.

CLEANING AND TINNING SOLDERING IRON AND SOLDERING GUN TIPS

Through use, the heating tips of soldering irons and solder guns will become pitted, corroded, misshaped, and coated with oxides. These conditions will restrict heat transfer from the tip to the base metals and prevent the solder from flowing smoothly. The process of cleaning and coating the tip of a solder iron or gun with solder is also called "**tinning**."

To tin a non-electric soldering iron, preheat it until it is a dark cherry red color. Use a file to clean and shape each face of the copper tip until it is smooth and bright. If the tip is badly pitted or misshaped, it may be necessary to first heat the tip and carefully reshape it with a ball peen hammer.



Tinning a Soldering Iron (Copper)

When the tip is reshaped and each side of the face is filed smooth, reheat the tip to a normal soldering temperature. Rub each face of the tip on a block of sal ammoniac to chemically clean the surfaces. **Sal ammoniac** is a special cleaning flux in hard block form. If sal ammoniac is not available, a rosin flux may be used. While rubbing the tip on the sal ammoniac block, melt the solder and coat each face. Wipe the tip with a damp cloth to remove excess flux and solder.

The smaller heating tip of an electric soldering iron or gun should be tinned in much the same way. The smaller tips can usually be mechanically cleaned with steel wool, emery cloth, wire brush, or a small file. After cleaning, coat the tip with flux. Heat the tip to a normal soldering temperature. Coat the tip with a thin layer of solder. Wipe the tip with a damp cloth to remove excess flux and solder.

When using a soldering iron or gun for a large job, it may be necessary to periodically "re-tin" the tip. However, it should not be necessary to file and mechanically clean the tip each time. Simply preheat the tip, coat with flux, and apply more solder.

Due to the frequent heating and cooling cycles, the tip set screws or locking nuts on electric soldering irons and guns will loosen. It is therefore necessary to periodically re-tighten tip set screws or locking nuts to maintain normal operation.

REFERENCES

The Oxyfuel-Oxyfuel Handbook; Linde Reference Library, New York, N.Y.

Fundamental of Service Welding; Deere and Company, Moline, IL.

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Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, and Mr. Donald Krobot, Intern, Department of Agricultural Education, Texas A&M University, developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

TRUE OR FALSE: Circle the "T" if the statement is true; circle the "F" if the statement is false.

- T F 1 A nonferrous metal is one which contains iron.
- T F 2. Soldering is a fusion welding process.
- T F 3. The soldering process cannot produce a strong bond without the use of excess heat.
- T F 4. Traces of nickel, antimony, zinc, copper, aluminum, cadmium, indium, and brass are often added to the solder alloys to provide different melting points and different strengths and degrees of hardness.

FILL-IN-THE-BLANK: Complete the following with the correct word or phrase.

5. The ____ range of a solder is the temperature range from which solder first starts to melt from a solid form to the temperature at which it becomes a ____ liquid.

6. ____ is often necessary to first remove any paint, grease, dirt, rust, etc., from the surface.

7. Fluxes are generally classified as ____ and ____.

MATCHING: Match the term in the left-hand column with the phrase in the right-hand column.

____ 8. Electric soldering guns

A. a built-in heating element heats the copper tip to a constant temperature

____ 9. Propane bottle torches

B. capable of producing a tip temperature of approximately 1000°F

____ 10. Electric soldering irons

C. produce a low to medium temperature flame up to approximately 2,300°F

____ 11. Air-fuel torches

D. even when equipped with a very small tip, they are capable of producing a flame up to approximately 5,600°F

____ 12. Oxyfuel welding torches

E. are often used when a low to medium temperature flame up to approximately 2,500°F is needed

SHORT ANSWER: Complete each statement with the correct word, phrase, or statement.

13. What is adhesion?
14. To what temperature should the base metals be preheated when soldering?
15. Why should you always support the base metals when soldering?
16. Define "tinning" and explain how it first began.
17. What conditions will restrict heat from transferring from the tip to the base metals and prevent the solder from flowing smoothly?
18. What is soldering?
19. What is the major difference between hard soldering and soft soldering?
20. List three common uses of the soldering process in agriculture.
 - a.
 - b.
 - c.

ADDITIONAL SKILLS AND ENHANCEMENT ACTIVITIES: Perform the following activities as assigned by your instructor.

1. Contact your county health department and other offices who issue building permits. Determine what regulations apply for the use of soldering containing lead.
2. Visit local hardware supply stores. Check on the availability of new lead-free solders and different types of corrosive and noncorrosive fluxes. Read the manufacturer's labels for specific recommendations.
3. Demonstrate procedures for safely tinning soldering iron (copper) and soldering gun tips.
4. Demonstrate procedures to safely solder copper pipe joints, seam joints, and electrical or electronic wiring circuit connections.

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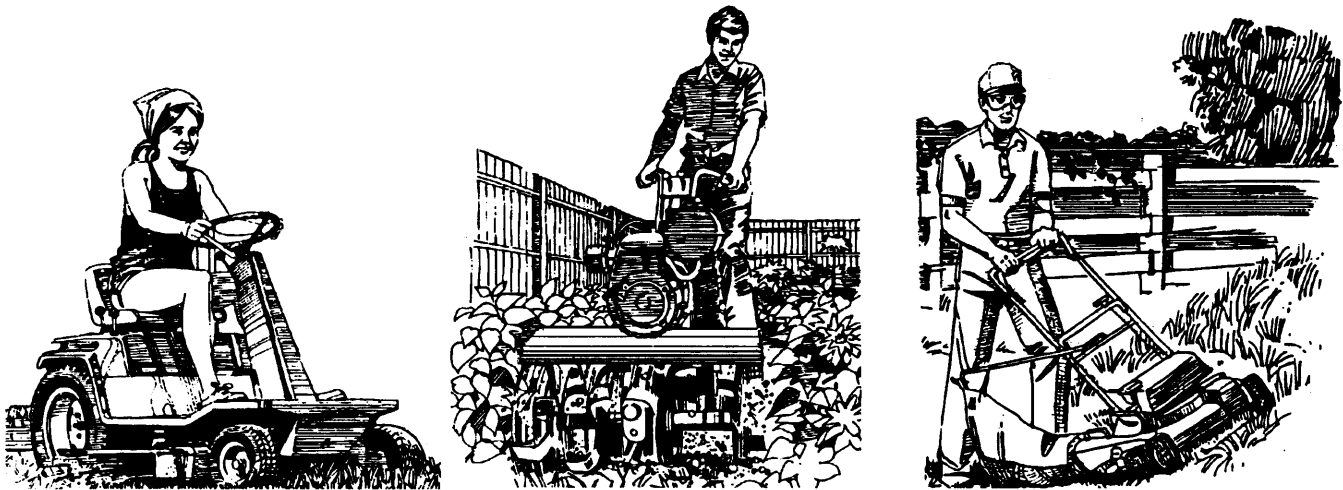
College Station, Texas 77843-2588

N1993

SMALL ENGINE SAFETY EQUIPMENT REGULATIONS

INTRODUCTION

The use of labor-saving devices powered by small engines has increased in recent years. Examples include: power lawn mowers, cement mixers, portable air compressors, chain saws, grass trimmers, and garden tillers.

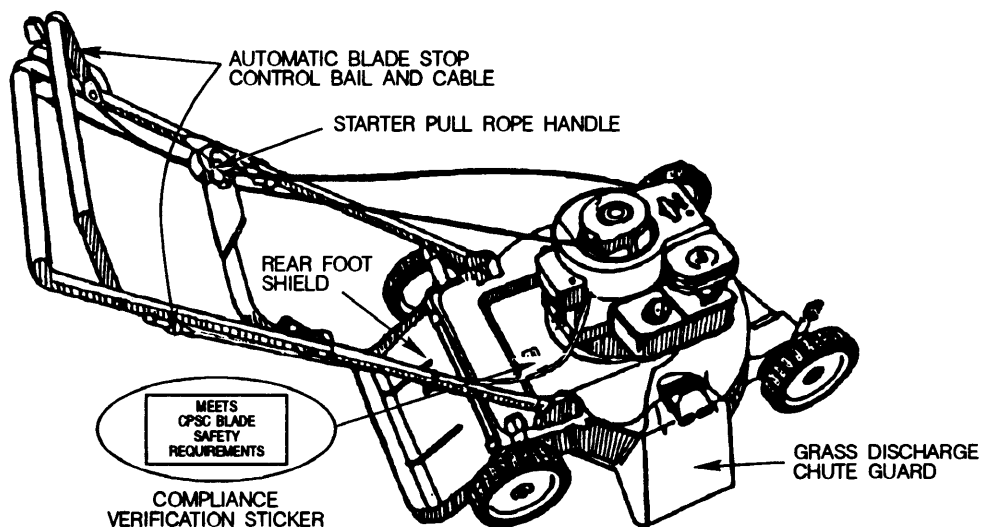


An estimated 29 million walk-behind lawn mowers, 22 million rider mowers, and 6 million rotary tillers are in use in the United States alone. With the increased use of small engine-powered equipment, the number of related accidents has also increased. An estimated 180,000 serious injuries occur each year because of improper and unsafe use of small engine-powered equipment. Many of these accidents have involved walk-behind lawn mowers. Some of the accidents have resulted in permanent disability and even death.

The **Consumer Product Safety Commission (CPSC)** is a regulatory agency of the federal government. Congress empowered the CPSC in 1972 to promote safety of products used by the general public. The CPSC regulates the design, manufacturing, and repair of many specific consumer products. The CPSC does not deal with commercial or industrial models of similar products.

Code #1205 of the CPSC deals specifically with consumer models of walk-behind rotary lawn mowers. Safety regulations were established for these types of lawn mowers because of the extremely high number of accidents and injuries. Changes are being made in equipment design. Safety devices are being added to provide: 1) greater operator safety, and 2) greater safety from flying objects for others who may be nearby.

All walk-behind rotary lawn mowers manufactured since June 1982 must have: 1) an automatic blade stop feature, 2) the starter mechanism located on the push handle, 3) a rear foot shield, and 4) a grass discharge chute guard. The mowers are designed with **operator present controls**.

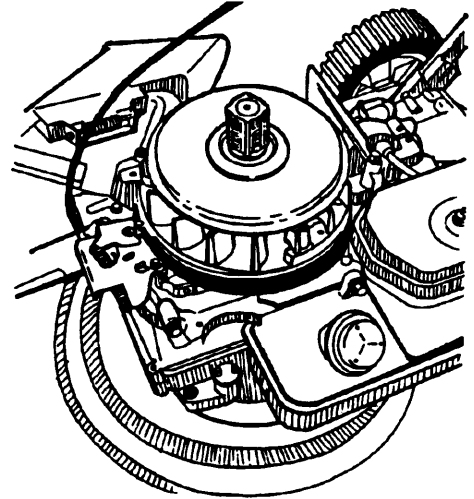


This means the operator must be at the "normal operator's station" for the mower to start and operate. The normal operator's station must be located a safe distance away from the moving blade. The starter mechanism/controls must be within reach only from the operator's station. Regulations require that the operator remain in continuous contact with the controls to keep the blade in motion. When the operator leaves the operator's station and releases the controls, the blade must automatically stop within three seconds.

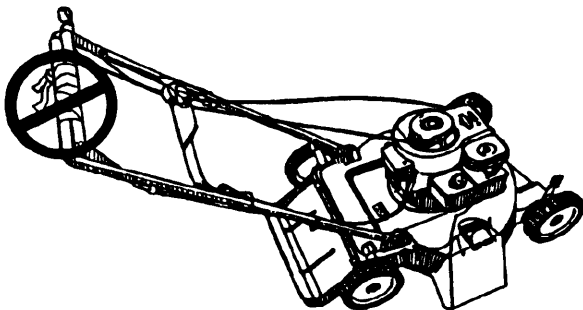
The tip of a rotary mower blade travels up to 200 mph. When a kill switch or throttle lever is activated, it can take five to seven seconds for the engine and mower blade to stop turning. This can allow enough time to leave the operator's station and reach to unplug the grass chute while the blade is still rotating.

Lawn mower manufacturers have designed different types of blade stop mechanisms to meet the three-second blade stop regulation. They include: 1) flywheel engine brakes, and 2) blade brake clutches.

The **flywheel engine brake** works together with an engine ignition kill switch. A **control bail and cable**, which are attached to the mower push handle, control the flywheel brake and ignition kill switch. When the control bail is released, the engine kill switch shorts out the ignition to stop the engine. The flywheel brake stops the rotation of the engine at the same time. Since the flywheel and blade are both fixed to the crankshaft, the blade stops when the flywheel stops. The flywheel brake system is simpler and less expensive. However, the design requires the operator to restart the engine each time the control bail is released.



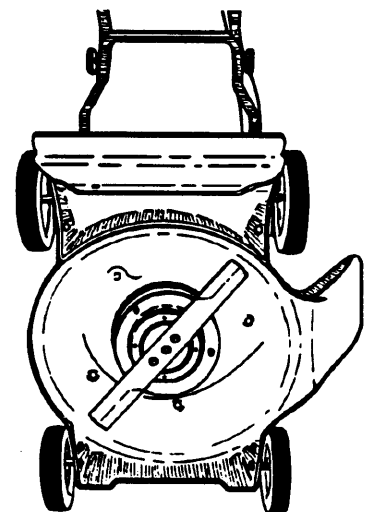
Flywheel Engine Brake



Do Not Tie Down The Control Bail!

Some operators may be tempted to tie or tape the control bail in the engaged position to avoid holding it down while mowing or restarting the engine each time they stop. *This is not* a recommended procedure because it eliminates the purpose of the safety device.

The **Blade brake clutch** design allows the operator to stop blade rotation quickly without stopping the engine. This design uses a similar control bail to operate a clutch and brake mechanism to start and stop the blade. The clutch and brake mechanism is attached to the bottom end of the engine crankshaft under the mower deck. The blade is then attached to an output shaft on the bottom side of the clutch/brake assembly instead of directly to the crankshaft. The blade brake clutch design uses more moving parts and is thus more expensive.



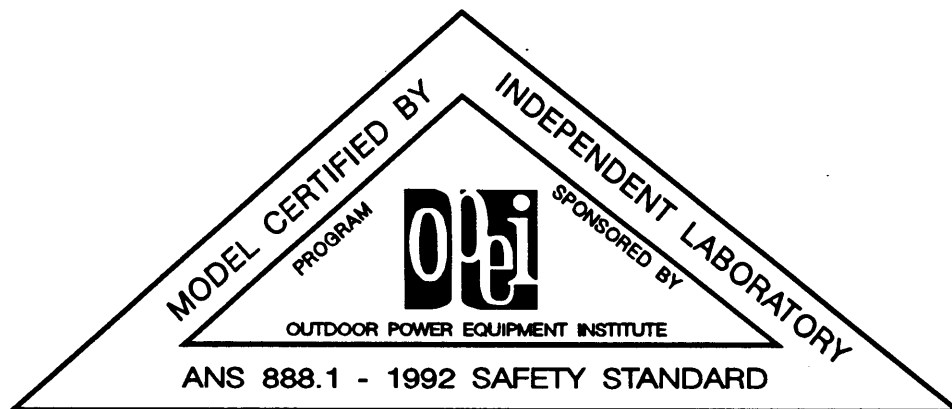
Blade Brake Clutch Assembly Under Mower Deck

OTHER TYPES OF SMALL ENGINE POWER EQUIPMENT SAFETY DEVICES

Many accidents and injuries have also involved consumers using other types of small engine-powered equipment. However, to-date the CPSC has not established federal regulations concerning their design. The CPSC allows the **Outdoor Power Equipment Institute (OPEI)** to set minimum safety standards for other consumer and commercial models.

The OPEI is an industry association of the power equipment manufacturers and service organizations. Together, they voluntarily develop and set safety standards for: rotor tillers, chain saws, riding lawn mowers, lawn and garden tractors, snow blowers, mixers, etc. Member companies voluntarily install additional safety devices and follow self-imposed safety standards when designing other types of equipment.

Only new equipment that meets these minimum standards can have the "OPEI Safety Decal" placed on it. It is recommended that a person purchase only equipment that meets these standards and has a safety decal attached. If companies voluntarily comply, and consumers voluntarily purchase and use safety equipment, the CPSC will probably not be required to mandate additional laws.

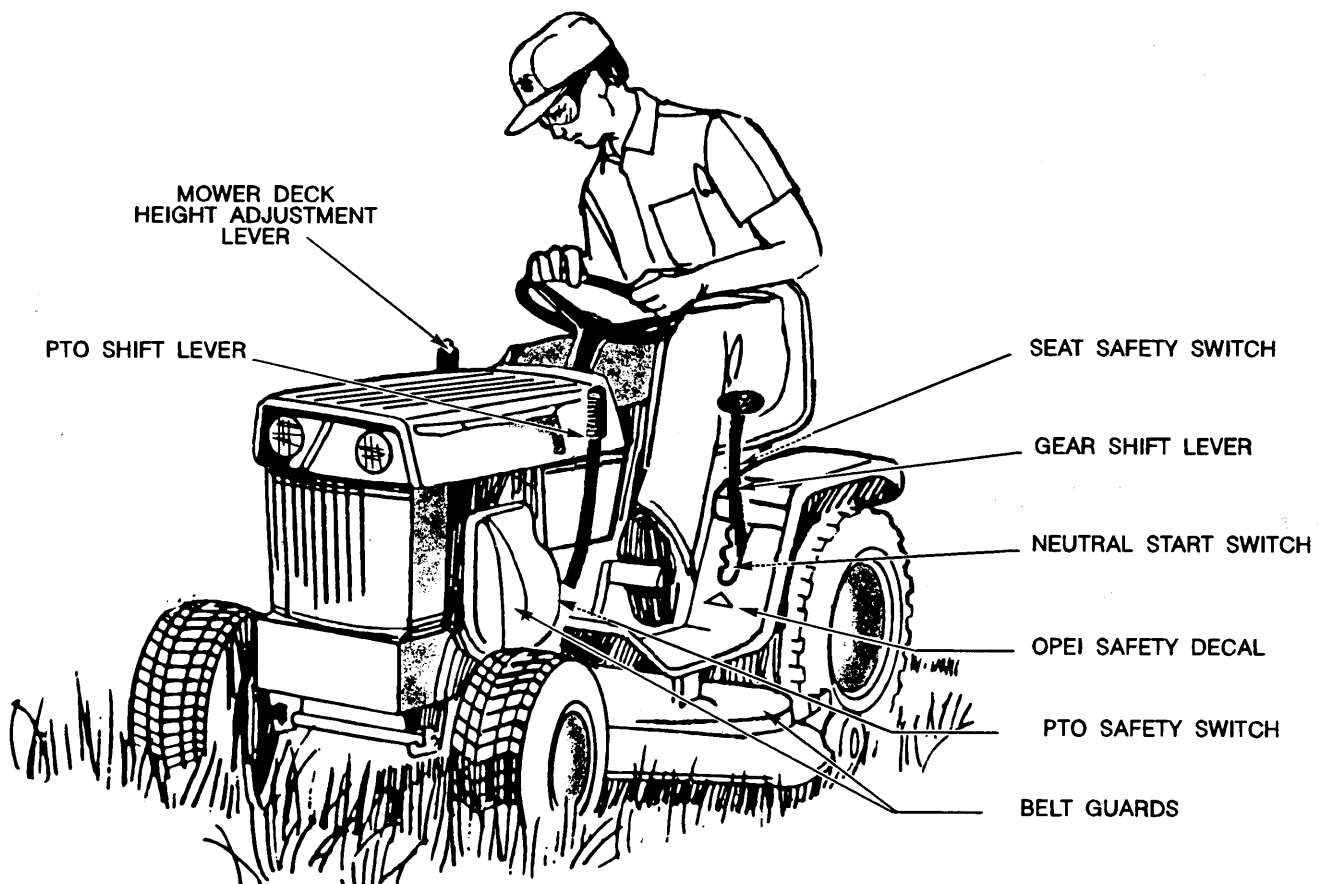


OPEI Safety Decal

Neutral Start Switches - Many types of small engine-powered equipment are now equipped with neutral safety switches. A neutral safety switch is a normally-open contact switch located in the starter circuit. To start the engine, the operator must move the shift linkage into the park or neutral position which contacts and closes the switch. The engine will only start when the shift linkage is in the neutral or park position.

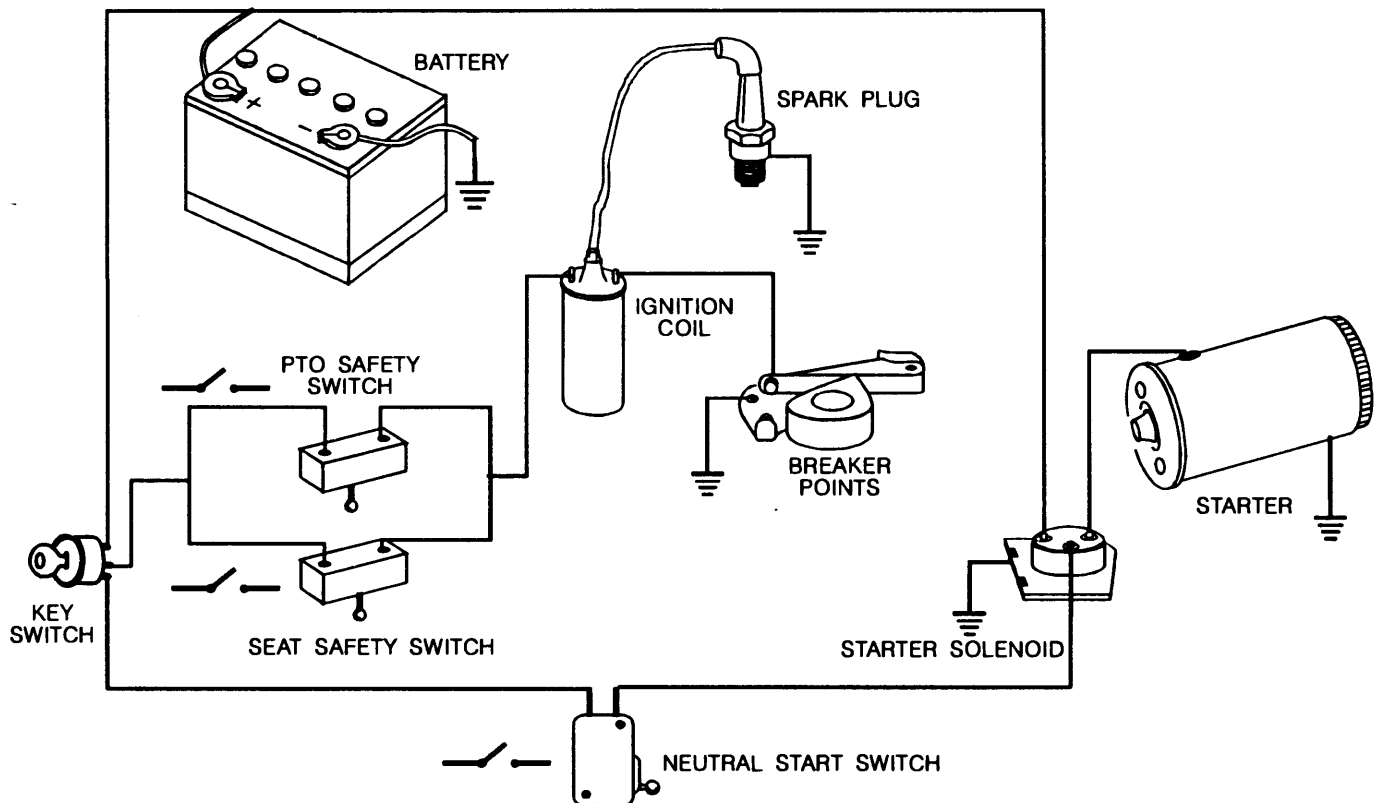
PTO Safety Switches - All garden tractors and riding lawn mowers have some type of PTO and/or belt drive to provide power for the attachments. The PTO shift linkage controls a PTO safety switch in the starter circuit. For the engine to start, the PTO clutch or lever must be disengaged, thus closing the contact switch.

Seat Safety Switches - Lawn and garden tractors and riding lawn mowers are also equipped with a safety switch located under the operator's seat. The seat switch and the PTO switch are usually wired between the key switch and the ignition coil. The PTO switch is a normally-open switch while the PTO is engaged. It is closed when the PTO is disengaged.



Typical Safety Features on a Riding Lawn Mower

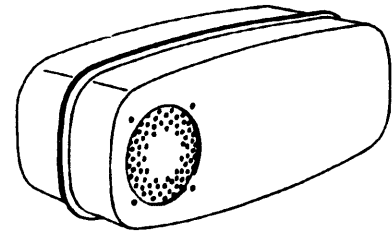
The seat safety switch is a normally-closed contact switch. It closes when the operator sits in the seat. It opens immediately when the operator raises up out of the seat. One of the switches in the series must be closed for the engine to operate. When the operator leaves the operator's seat with the PTO engaged (PTO switch open), the seat switch will open and kill the engine. The engine will then not start with the PTO engaged (PTO switch open) and without the operator being in the seat (seat switch open) because both switches are open. (**Note:** The safety device circuits will vary slightly on equipment equipped with a manual starter and a magneto or an electronic ignition system.)



Typical Wiring Harness for Safety Switches on Riding Lawn Mowers

Chain and Belt Guards - Many injuries to fingers and hands are caused by rotating objects. Exposed drive chains, belts, sprockets, pulleys, and rotating shafts are now covered with safety guards and shields.

Spark Arrestor Mufflers - Newer models of small engine-powered equipment are now equipped with spark arrestor type mufflers. New muffler and muffler attachment designs reduce the chances of exhaust sparks and cinders being blown on the operator. They also reduce chances of starting fires in dry leaves or grass.

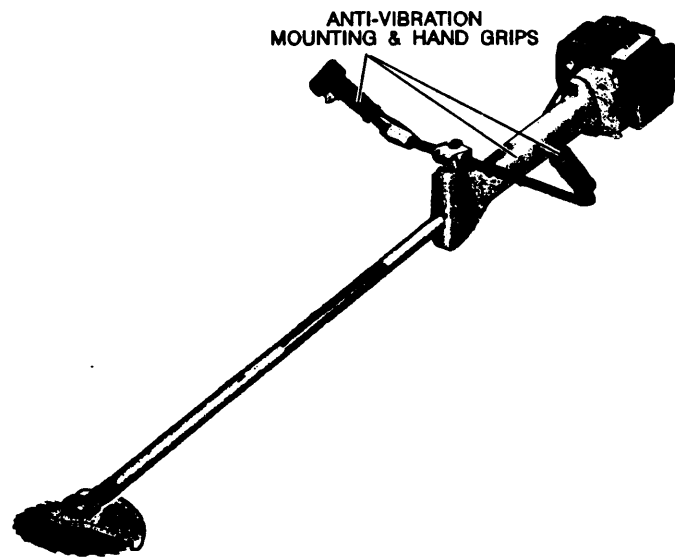


"Lo-Tone" Muffler
Equipped to Receive a
Spark Arrestor

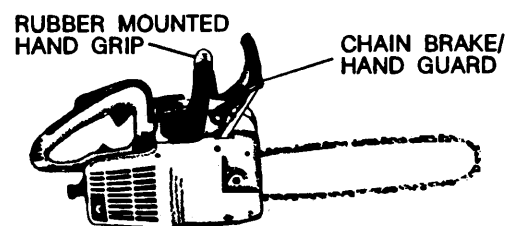
Noise Reduction Equipment - Noise pollution and possible damage to a person's hearing are also a concern. Many types of power equipment produce high-decibel*, high-frequency noise. New designs in mounting brackets, blower fans, mufflers, rotary blades, air fins, etc., help reduce noise to an acceptable level.

Vibration Reduction Systems -

Chain saws, grass trimmers, and blowers are all examples of hand-held power equipment. These and other similar power tools now have the handles, grips and/or engines mounted in some type of rubber mounting. This helps to reduce operator fatigue and the numbing effect caused by continuous, high-frequency vibrations.



Chain Brake - Chain brakes are installed on new models of chain saws to stop the chain in a fraction of a second if a kickback occurs. It reduces the chances of serious injury if the chain saw is "kicked up and back" when the nose of the guide bar accidentally touches another object.



* Underlined words are defined in the Glossary of Terms.

LEGAL CONCERNS

Many consumers think the "safety devices" are a nuisance. They may want to remove or disconnect them. They get tired of having to restart the engine each time they stop to dump the grass bag. They do not want to replace a safety shield each time they make a simple and seemingly safe adjustment or service procedure. They forget about the chances for accidents and the reasons for the safety devices. Others may think the safety devices are the reason an engine will not start and operate correctly. They often start to "tinker with" the safety devices without really knowing what they are doing.

Most small engine repair shops and equipment dealers are members of **State and National Service Equipment Dealer Associations**. They voluntarily send their service technicians to approved service training schools. Employees receive special training on the repair and adjustment of safety equipment and compliance regulations. Equipment dealers and repair shops also agree **not to remove, alter, modify, or bypass any safety equipment**.

Customers often take small engine-powered equipment to these repair shops for service. Customers must agree to have all safety equipment in proper working condition when it leaves the shop. If a customer refuses, the repair shop owner may ask he or she to take the work elsewhere or to sign a special repair order form. The repair order form, in summary states, "The customer fully understands the purposes for the safety devices and requests that they not be repaired." It further states, "The customer assumes full responsibility for any injuries which may result therefrom." This helps to reduce the repair shop's liability for any accidents or injuries caused by improper safety equipment.

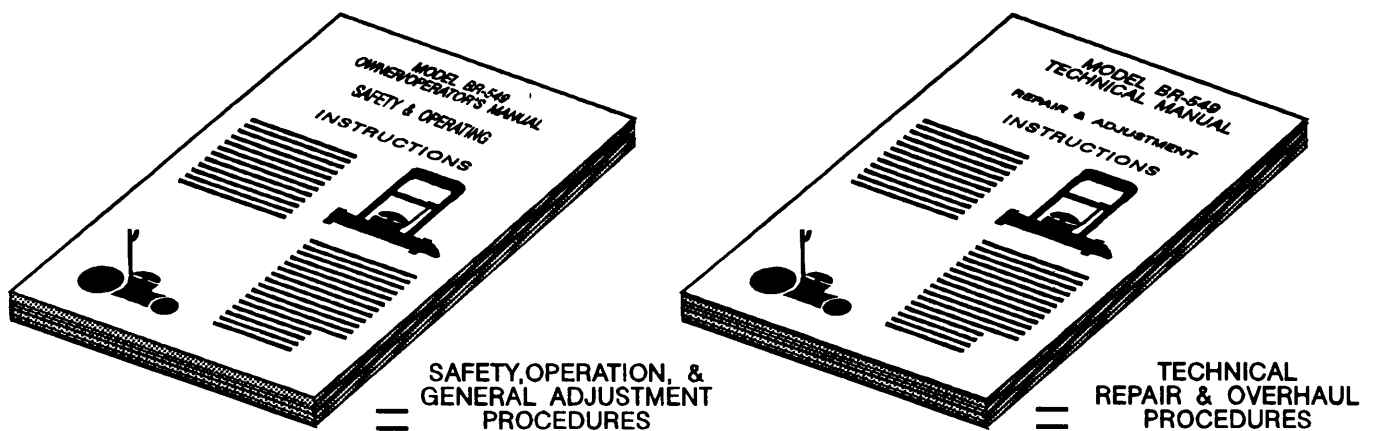
What customers do *after* purchasing new safety approved equipment is *their* responsibility. The customers are personally liable when they choose to remove or modify a safety device or not have it properly repaired. Of course, service dealers should encourage customers to maintain and properly use all safety equipment.

OPERATING, TROUBLESHOOTING, AND REPAIRING SAFETY DEVICES

There are literally hundreds of different makes and models of small engine-powered equipment. Each is equipped with one or more different factory-installed safety devices. Similar type safety devices may be installed on the different makes or models. However, this does not mean that they can all be operated or adjusted the same way.

The operation and general adjustment procedures for a particular make and model are listed in the appropriate owner/operator's manual. The owner/operator's manual is supplied by the manufacturer with each new piece of equipment. If the manual has been lost or damaged, another can be purchased at the equipment dealer. It is important that the person who is operating the equipment *and* the service technician who is making repairs understand the proper operating procedures for a specific model.

Some models have safety devices that require adjustment procedures that should be performed *only* by a qualified service technician. The technician must receive special training and be equipped with precision tools in order to perform these procedures. These specific adjustment and repair procedures are listed in appropriate technical manuals supplied to service dealers by the manufacturer. These technical manuals are not generally available to the consumer. It is beyond the scope of this topic to go into further detail concerning troubleshooting and repairing safety devices.



GLOSSARY OF TERMS

decibel (dB) - a unit of noise measurement.

liability - a legal claim against an individual or company to compensate a second party for a physical or economic loss caused by negligence of the first party.

liable - legally bound or responsible for actions.

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Dealer's Concerns With the CPSC Lawn Mower Safety Standards, Engine Service Association Services Inc, Milwaukee, WI.

Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

TRUE OR FALSE: Circle "T" if the statement is true; circle "F" if the statement is false.

- T F 1. It is a safe practice to temporarily tie the control bail down on a walk-behind rotary lawn mower.
- T F 2. The Consumer Products Safety Commission (CPSC) is a regulatory agency of the county government.
- T F 3. The CPSC has the authority to regulate safety equipment on industrial and commercial models of small engine-powered equipment.
- T F 4. It is a recommended practice for a small engine service dealer or repair shop to remove, alter or modify safety equipment at the customer's request.

- T F 5. Safety devices are installed on small engine-powered equipment only as sales a gimmick and nuisance to the consumer so that he or she will have to hire repair and maintenance work done at a repair shop.
- T F 6. The Outdoor Power Equipment Institute is an industry association of power equipment manufacturers and service organizations.

FILL IN THE BLANK: Place the correct word in the space provided.

- _____ 7. The tip of a rotary mower blade travels up to _____ mph.
- _____ 8. When a kill switch or throttle lever is activated, it can still take _____ to _____ seconds for the engine and mower blade to stop turning.
- _____ 9. The safety devices installed on modern lawn mowers are designed with " _____ controls."
- _____ 10. To comply with CPSC regulations, the blade of a rotary lawn mower must stop within _____ seconds after the control bail is released.
- _____ 11. Decibel (db) is a unit of _____ measurement.

SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph. (Use additional paper when needed.)

12. List and briefly discuss the operation of the two types of blade stop mechanisms.
13. List the four main safety features that walk-behind rotary lawn mowers manufactured since June 1982 must have.
14. Who sets the minimum safety standards for industrial and commercial models of lawn and garden equipment and other types of small engine-powered equipment?
15. List seven examples of the other types of "self imposed" safety devices installed on newer models of chain saws, riding lawn and garden tractors, and other types of small engine-powered equipment.

ADDITIONAL SKILLS AND ENHANCEMENT ACTIVITIES: Perform the following activities or skills as assigned by your instructor.

1. Visit a local small engine repair shop. Discuss with the owner and/or a service technician some of the common adjustment and repair procedures that must be performed on safety devices. Try to determine how many of the procedures are required because the customer "tinkered" with the safety device.
2. Study the operator's manual for a new model of some type of small engine-powered equipment. Determine which service, repair and adjustment procedures are recommended to be performed or checked by the operator.
3. Perform service, repair and adjustment procedures on small engine-powered equipment as outlined in an appropriate operator's manual.

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1992

PLANNING, BUILDING, AND MAINTAINING BARBED AND WOVEN WIRE FENCES

IMPORTANCE OF FENCES

Properly planned and constructed fences are an asset to any operation. Fencing may simply mark boundaries or contain different sizes and types of livestock in certain areas. Cross fences break larger land areas into smaller pastures or fields. By force grazing a smaller area, the grazing capacity can be increased by as much as 25 percent. Fences can also be used to control the movement of wildlife and predator animals.



Proper planning and material selection are necessary to obtain the desired appearance and results. A properly planned fence will save time and money during construction and minimize maintenance costs in the future.

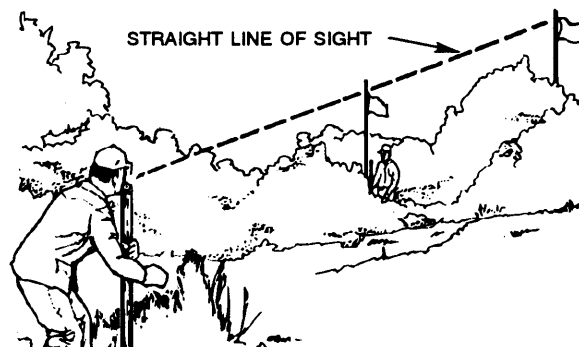
PLANNING AND LAYING OUT A FENCE

When planning a major fencing project, it is helpful to obtain aerial and land capability maps from the Soil Conservation Service. After outside boundary lines are identified and marked, the maps can be used to study the land use and production potential of the land area. The map should show the location of any timber, ponds, streams, gullies, etc.

Fencing the shortest distance between two points is not always the best option. Consider the location of existing fences, barns, lots, roads, etc. when planning fences. The topography of the land and average weather conditions should be considered. For safety and convenience, plenty of gates should be planned. The type of fence selected will depend largely upon the intended use and the type of livestock or wildlife one is trying to keep in or out. Other factors include construction costs, life expectancy of the fence, and maintenance requirements.

After determining the arrangement and type, the new fence line must be laid out. When building fences between different land owners, it is recommended that a professional land surveyor be hired to determine the actual property lines. If the land area is clear and flat, brace posts can be set at each end. To align and mark the line post locations, a wire can be unrolled and stretched between the braces. The wire can be loosened and pulled aside to dig post holes. The wire may then be used as one of the fence wires.

If the land area is rolling or if there is a lot of underbrush, it may be necessary to lay out the fence line in short sections. A person can sight between established points and signal for another person to align stakes using long poles and flags. A builder's level can also be used to lay out fence lines. See student topic # 8147-D for specific procedures.

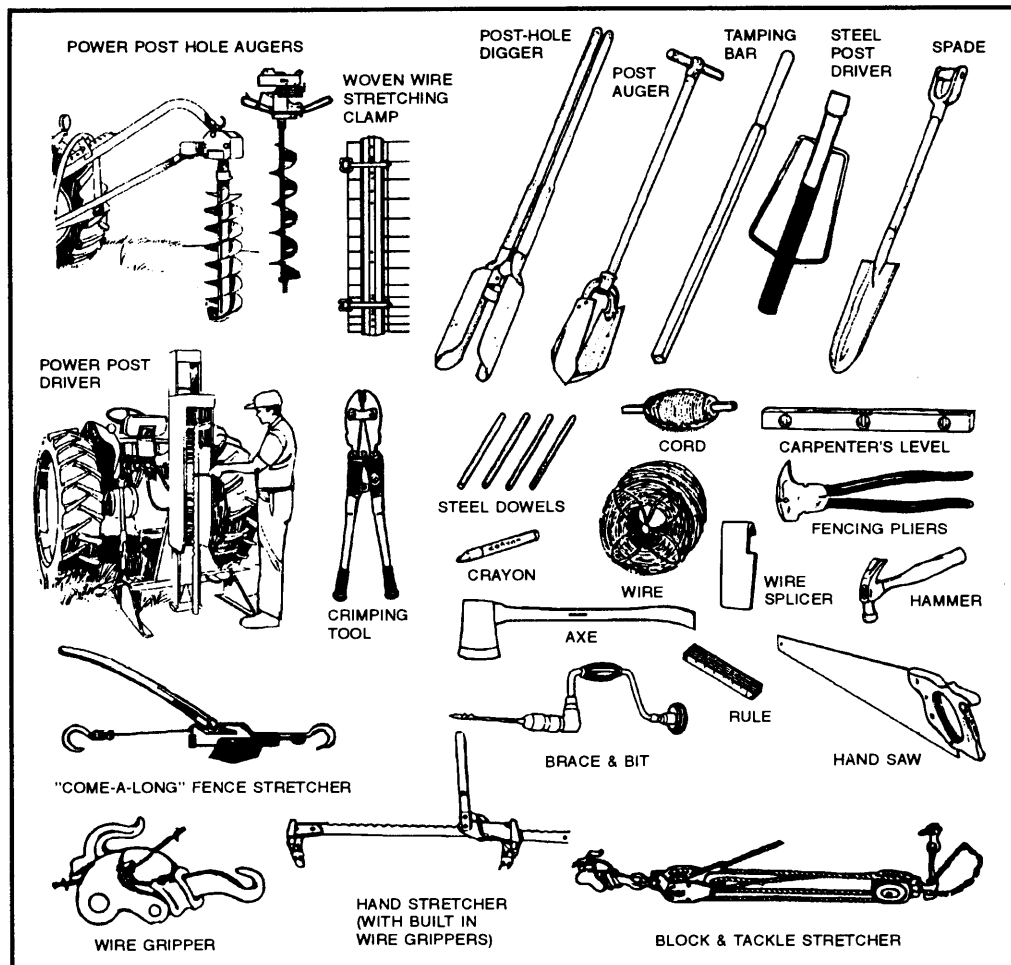


Using Poles and Flags to Lay Out Fence

If timber, under-brush, and/or old fences are in the way, the area must be cleared and leveled. A dozer or tractor can make the task much easier. Any old wire should be removed or buried to prevent livestock, wildlife, and/or people from becoming entangled and injured.

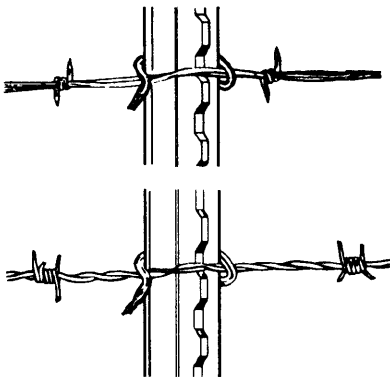
TOOLS AND EQUIPMENT USED IN FENCE CONSTRUCTION

The tools and equipment needed will vary with the type and quantity of fence being built. Both hand and power tools and equipment are available. As with any task, it is safer and quicker to use the correct tools and equipment. Before beginning, make sure they are in good repair. Always make sure you have received proper instructions, especially when operating power tools and equipment.



Common Fencing Tools and Power Equipment

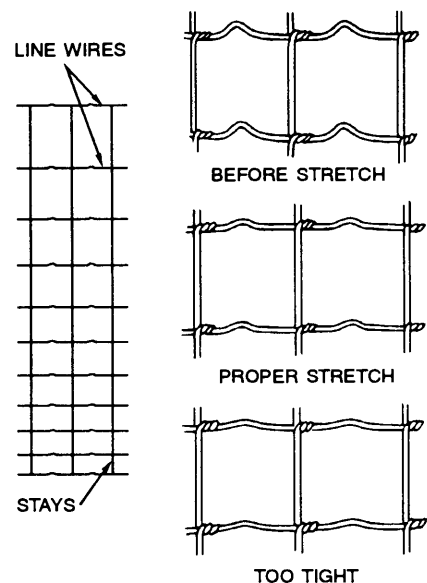
TYPES OF FENCES AND FENCING MATERIALS



Barbed wire is made from two strands of smooth mild steel wire twisted together. Sharp barbs are added to help prevent livestock and wildlife from going "over, under, or through" fences. Barbed wire is available in Standard Steel Gauge 12 $\frac{1}{2}$, 14, and 15 $\frac{1}{2}$ sizes and with two or four point barbs. The smaller the gauge #, the larger the diameter of the wire.

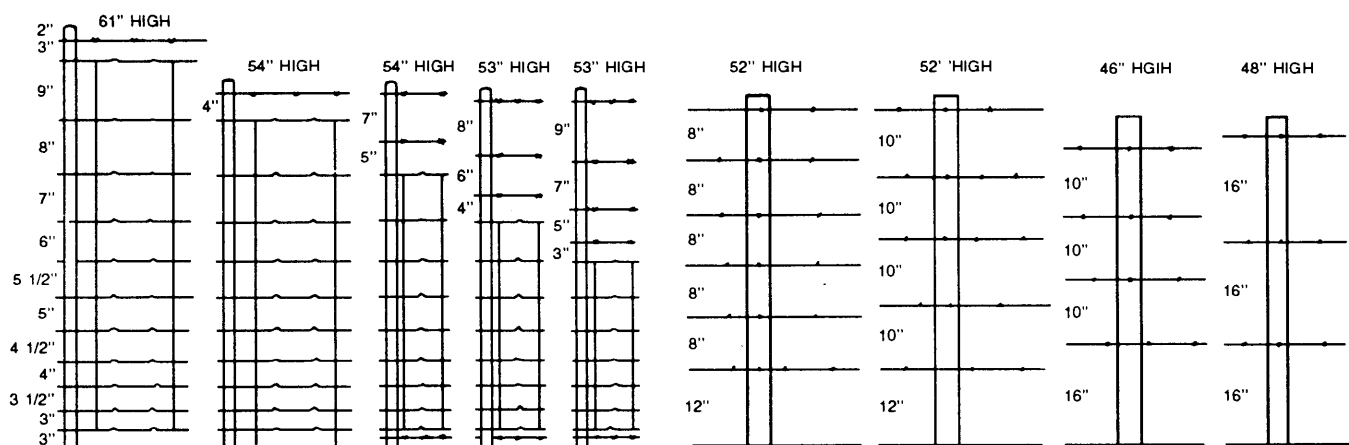
Twisted barbless wire or cable is the same as barbed wire but without the barbs. It is used for constructing braces, gates, horse fences, and in other places where barbed wire might cause injury rather than a gentle prick as a reminder. Barbed wire and barbless cable are normally sold in 80 rod (1/4 mile) rolls. A **rod** is a unit of measure used in land measurement. One rod equals 16 feet, 6 inches; 80 rods = 1,320 feet or 1/4 mile; 160 rods = 2,640 feet or 1/2 mile; 320 rods = 5,280 feet or 1 mile.

Woven wire consists of a number of horizontal lines of smooth wire held apart by vertical wires called stays. The spacing between the horizontal line wires varies from top to bottom. Top and bottom line wires range in size from 9 to 12 ½ gauge while middle line and stay wires range from 10 to 18 gauge. Woven wire for most pasture or field fences is 26 to 48 inches in height and is normally sold in 20-rod rolls. Special purpose woven wire up to 72 inches high is available and is used in such places as for fences in ratitae production.



Woven wire fencing is made with mild steel wire. On some designs, **tension curves** are placed in the line wires. This provides a springing action, which allows the fence to expand and contract due to weather changes. It is important not to over stretch woven wire. The fence is tightened until about one-third of the tension curve has been removed.

Barbed and woven wire are used alone or in combination for different fencing applications. Barbed wire placed above woven wire helps keep larger animals from leaning over the fence and breaking it down. A barbed wire under woven wire may help keep smaller animals such as hogs and sheep from attempting to crawl under. For many cow-calf operations, four to five strands of barbed wire placed 8 to 10 inches apart are usually adequate for most fences as long as cattle are not crowded.

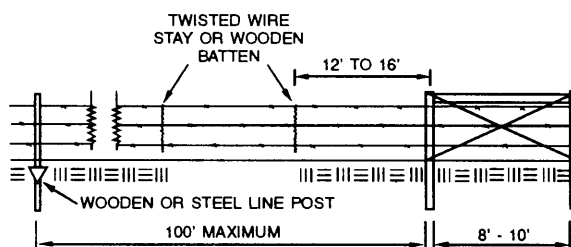


Typical Heights and Spacings for Woven and Barbed Wire Fences

Line post spacing for barbed and woven wire fences will vary with 1) type of fencing, 2) size and type of post used, 3) size of animals, 4) soil types, and 5) the size of the area the animals are confined to. In most conditions, line posts can be spaced 12 to 20-feet apart and set 2 to 2½ feet into the ground. When installing line posts, plan ahead so that wires can be attached to the animal side of the line posts. One exception would be when fencing around a curve.

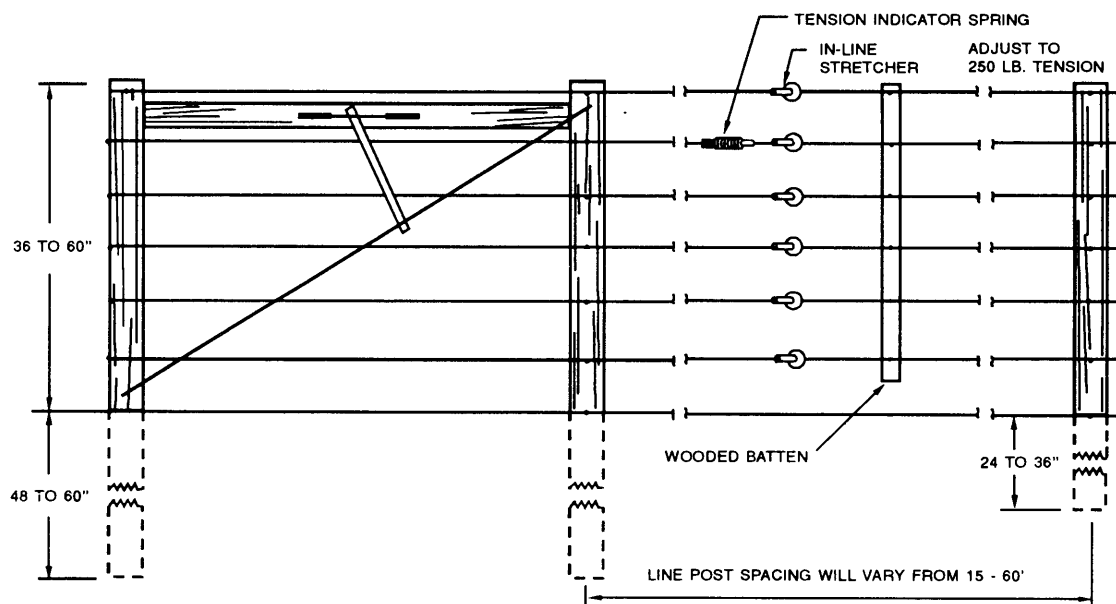
Barbed wire suspension fences

Barbed wire **suspension fences** are common on large cattle ranges. Three to six barbed wires are suspended between line posts spaced up to 100-feet apart. Twisted wire stays or light weight battens are then placed 12 to 16-feet apart, between the line posts.



Barbed Wire Suspension Fence

High-tensile wire fences were introduced into the United States from Australia and New Zealand. This type of fencing has a longer expected life and lower installation cost than many conventional fence designs. Because the high-tensile wire is smooth instead of barbed, it is easier to handle and install. The smooth wire also reduces the chances of injury to livestock.



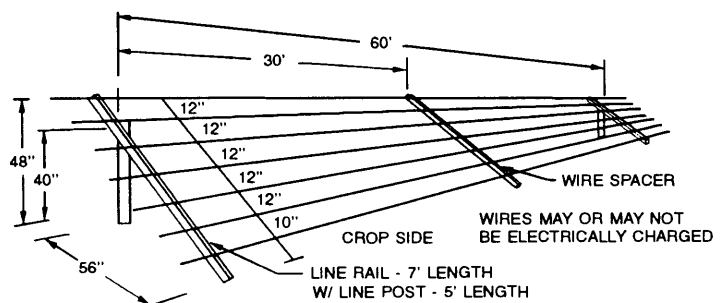
High-Tensile Wire Fence Equipped with In-Line Stretchers and Tension Indicator Spring

High-tensile wire fences are constructed of 12 1/2 to 14-gauge smooth wire with tensile strengths ranging from 170,000 to 200,000 psi. This equals a breaking strength of up to approximately a 1,800 lb pull. Comparable size mild steel wire used in barbed and woven wire has a tensile strength of approximately 25,000 psi with a breaking strength of approximately a 1,000 lb pull. The higher elastic limit of the high-tensile wire reduces the stretching or sagging problems that are common with barb and woven wire fences.

Five double-strand barbed wires would be used for a typical 46 to 52-inch high barbed wire fence. Wires would be approximately ten inches apart with the bottom wire 12 to 16 inches from the ground. A 52-inch combination woven/barbed wire fence might utilize a 9-strand woven wire and three barbed wires. One barbed wire would be installed just below the woven wire and two above it.

In comparison, a 46 to 52-inch tall high-tensile wire fence can be made with 10 single strands of high-tensile wire placed from four to five inches apart. The bottom wire is only three to six inches from ground level. The ten-strand high-tensile wire fence would cost approximately one-third less than the equivalent woven/barbed wire fence.

Various designs of high-tensile fences using from four to ten strands of wire can be constructed to contain different types of livestock. One or more of the wires can be installed on insulators and electrified when needed to give better livestock control. Different designs and wire spacings are also used to effectively control the movement of deer and predator animals. See student topic # 8158-C for additional information concerning electric fencing.

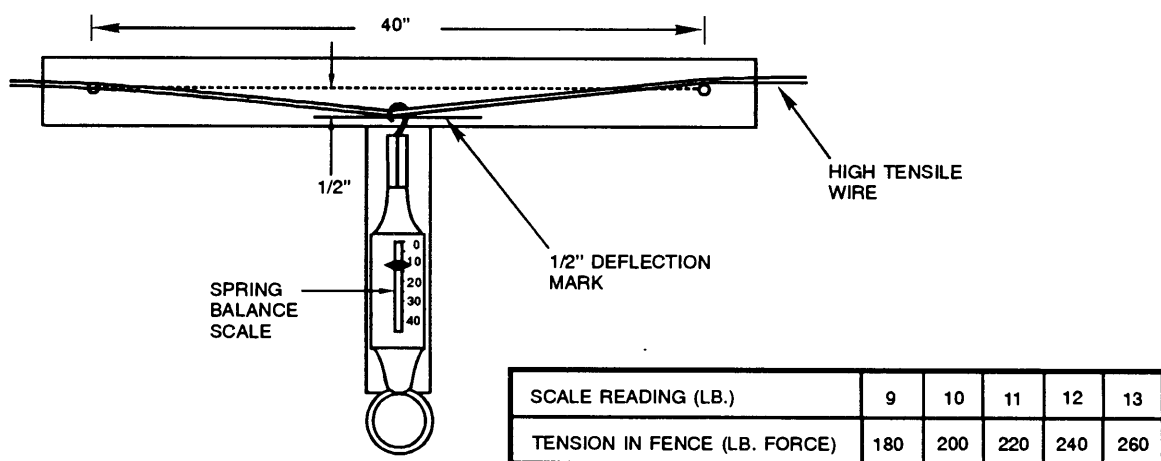


A Slanted High-Tensile Fence Used to Control Deer

A constant 200 to 250 lb tension should be maintained on the high-tensile wires at all times. This can be accomplished with permanently installed **in-line wire tighteners**. Ratchet type tighteners are often used, which can be easily loosened or tightened as needed. A **tension indicator spring** may also be installed in at least one of the wires to monitor the wire tension.

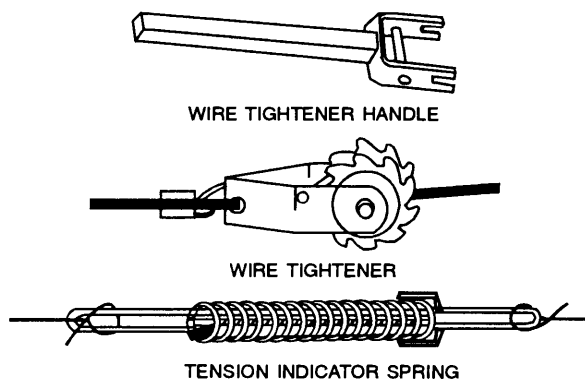
Where there are extreme seasonal changes in the temperature, tension adjustments should be made in early summer and again in late fall.

The same type of line post and post spacings used for barbed and woven wire fences can be used with high-tensile wire fences. However, because of the increased tension on the wires, well-constructed brace and anchor assemblies with the brace posts set 48 to 60 inches deep are needed to provide extra support.



A simple **wire tension meter** can be made of a metal or wooden tee and an inexpensive spring balance scale. The meter is attached to the wire with two hooks positioned 40 inches apart. A spring balance scale is hooked in the middle and pulled until the wire is deflected 1/2 inch. If it takes 12.5 lbs of pull to deflect the wire 1/2 inch, there is approximately a 250 lb tension in the fence wire.

High-tensile, woven, and barbed fencing wire is usually zinc coated (galvanized) to prevent corrosion. The amount of zinc coating is designated as Class 1, 2, or 3. Class 3 has approximately 2 1/2 times more zinc coating than Class 1 and thus should last twice as long before it begins to rust. In average conditions, Class 3 should last 13 to 15 years before rust begins to show through. Once wire begins to rust, its strength decreases rapidly.

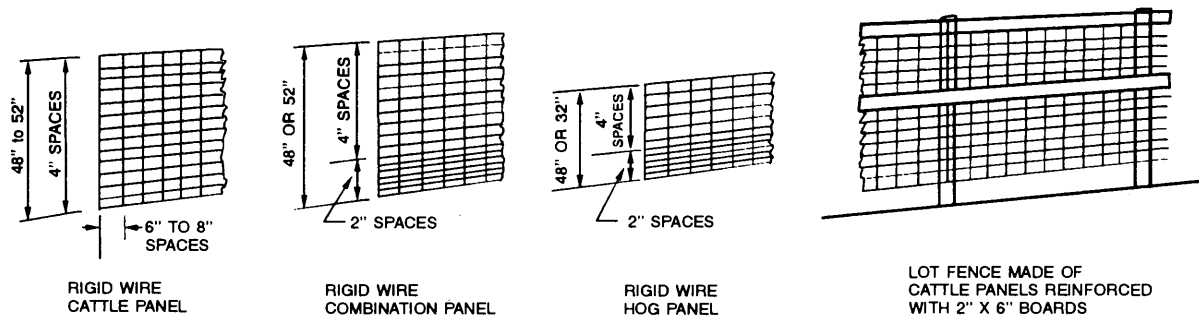


A new type of "fencing wire" is made of a polymer filament. When properly installed, the new **polymer filament fencing** material is strong yet flexible. Some manufacturers claim the new products can be stretched up to 20 percent of their original length and return right back to original shape. A new polymer screen or netting is also available to use in place of woven wire.

The bright colors (white, black, yellow, and orange) help animals to see the fence more clearly. It is ideal for use around pastures and lots where barbed and woven wire could cause injuries if animals should become entangled. The smooth polymer filament wire can be easily installed by threading it through holes drilled into wooden posts. Polymer netting and wire can be attached to wooden posts with conventional staples as long as they are not driven up tight.

Rigid wire panels are often used for fencing where livestock are confined to smaller areas. They may be used to construct corrals, holding pens, lots, and for temporary fencing around barns, hay stacks, etc.

Rigid wire panels are made of stiff wires that are spot-welded together. Panels are available in standard 16-foot lengths with vertical wires spaced six to eight inches apart. Heavy-duty panels are made with $\frac{1}{4}$ inch diameter wire. Lighter duty panels are made with smaller # 4 gauge wire. Rigid wire panels are available in standard 32, 36, 48, and 52-inch heights with 2, 4, and/or 6-inch horizontal wire spacings. Most are galvanized for longer life.



Rigid wire panels are easy to install and do not require stretching. They are often used with steel post as temporary fencing. They can be attached to wooden posts with 2 1/2 inch L-shaped panel staples. When used to construct lots to confine cattle into small areas, welded wire panel fences may be reinforced by running steel pipe or lumber horizontally at the top and middle of the posts.

Types of Fence Post

There are many types of posts available for fence construction. The type and size of brace and line posts used are determined by evaluating factors such as 1) the type of fence being constructed, 2) strength, 3) cost, 4) availability, 5) expected life of fence, 6) expected life of the post, 7) appearance, and 8) how easily the post can be installed and the fencing material attached.

Wooden posts are widely used because they are comparatively low in cost and are available in most regions of the country. **Softwood pine posts** are commercially treated with chemicals, such as cresote, pentachlorophenol, or chromated copper arsenate (CCA), to minimize decay and insect damage. (See student topic # 8229-B) Chemically treated pine posts are available in sizes from 2 ½ to 12-inch diameter tops and in lengths from 5 ½ to 10 feet. Most are guaranteed to last 15 to 30 years.

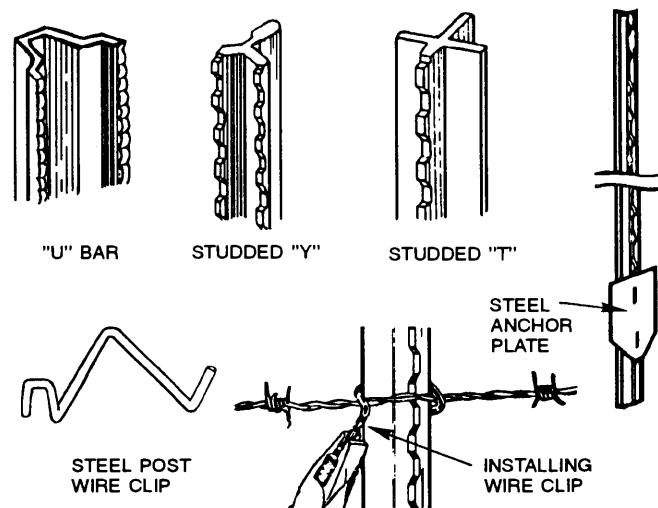
In some areas, other species of soft and hardwood trees are cut locally and used as fence posts. Most are not chemically treated, therefore life expectancy will vary with the local climate. Species such as Osage Orange (Bois d'arc), Red Cedar, and Black Locust have more natural decay and insect resistance, and may last 20 years or longer. Used wooden railroad ties can sometimes be purchased for use as brace posts. They are chemically treated and still have many years of useable service left.

Fencing materials can be attached to wooden line post with nails, staples, and/or by tying them with galvanized wire. Depending upon soil conditions, smaller diameter wooden posts can be sharpened on one end and driven into the ground with power post drivers. However, most are set by digging a hole and tamping soil and/or fine gravel back around the post. One disadvantage of using wooden posts is they will burn should a grass fire occur.

Fiberglass and plastic posts are available in sizes and lengths for use as line posts. They do not need insulators when used with electric fencing. Most fiberglass and plastic posts can be driven into the ground. Spacing and use are comparable to that of smaller wooden or steel posts. Fiberglass posts will not decay, but will burn. They are usually as strong as steel posts, but more flexible and will spring back into position.

Steel line posts can be obtained in different shapes, designs, and sizes. **Studded "T"**, **studded "Y"**, and **"U"** bar designs are most common and are available in 5, 5½, 6, 6½, 7, and 8-foot lengths. They are painted to prevent corrosion. Steel line posts are often constructed with steel anchor plates, which provide extra stability. Most steel line posts can be easily driven into place with the aid of a power or hand post driver. Wire clips are used to attach fence material to steel posts.

One disadvantage of using steel line posts is that livestock may bend or force them out of line by crowding against the fence. However, steel posts are fireproof. They also help ground the fence to the earth and provide protection against lightning if livestock are standing near a fence during a thunderstorm. In some areas, used oil field pipe and structural steel are available at competitive prices. They can be used to construct anchor and brace assemblies, and in some cases, used as line posts.

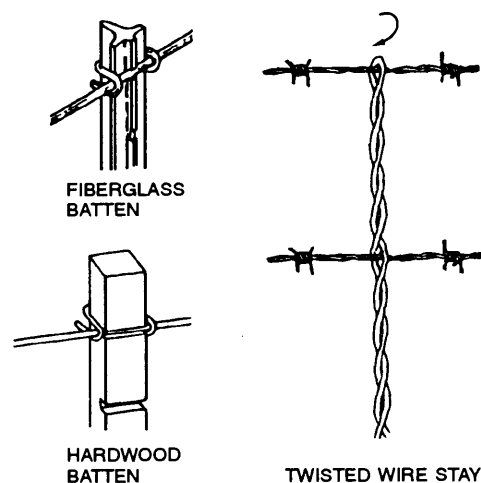


Use of Steel Line Post

Re-cycled rubber "posts" and **"lumber"** are now available in some areas. Utilizing modern technology, used tires and plastic are crumbled and mixed with sawdust and special bonding glues. The mixture is molded into various sizes and lengths of round and square posts, and into several standard size boards. Some rubber posts are sharpened on one end and can be driven into the ground.

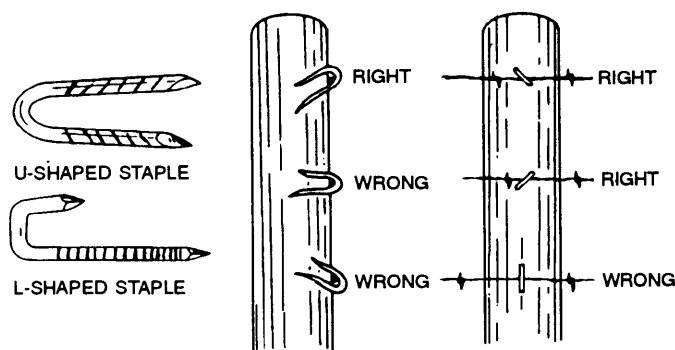
Re-cycled rubber posts and boards are comparable in strength and stiffness to wood and will not splinter. Nails and staples can be driven into the post or lumber without them splitting. The new products are fire resistant and are ideal for use with electric fencing without insulators. They are environmentally safe and some are said to be guaranteed to last 100 years.

With some types of fencing, line posts can be placed further apart to save money. Smaller, lighter, and less expensive **battens** and **stays** are then installed between line posts to 1) maintain wire spacing, 2) act as visual barriers, and 3) help to distribute pressure among all wires. Battens and stays may or may not touch the ground. They can be made of lightweight plastic, fiberglass, or rubber posts; treated or natural decay resistant wood; or twisted galvanized wires. Plastic, fiberglass, rubber, and wood battens are attached using wire clips. Wire stays are twisted onto the fence wires.



Fencing staples are made of 9-gauge wire and are available in several shapes and lengths. Most are galvanized. "U"-shaped staples are available in lengths of 7/8 to 2 inches. "L" or "J"-shaped staples are available in lengths of 1 1/4 to 2 inches. Longer staple lengths will provide better holding ability in softer pressure treated wooden posts while shorter lengths are used for hardwood posts.

Staples provide greater holding power if driven at a slight off-vertical and downward angle so that they straddle the wood grain. Staples should not be driven tight against the wire on line posts. Staples are also available with ringed or grooved shanks for increased holding power.

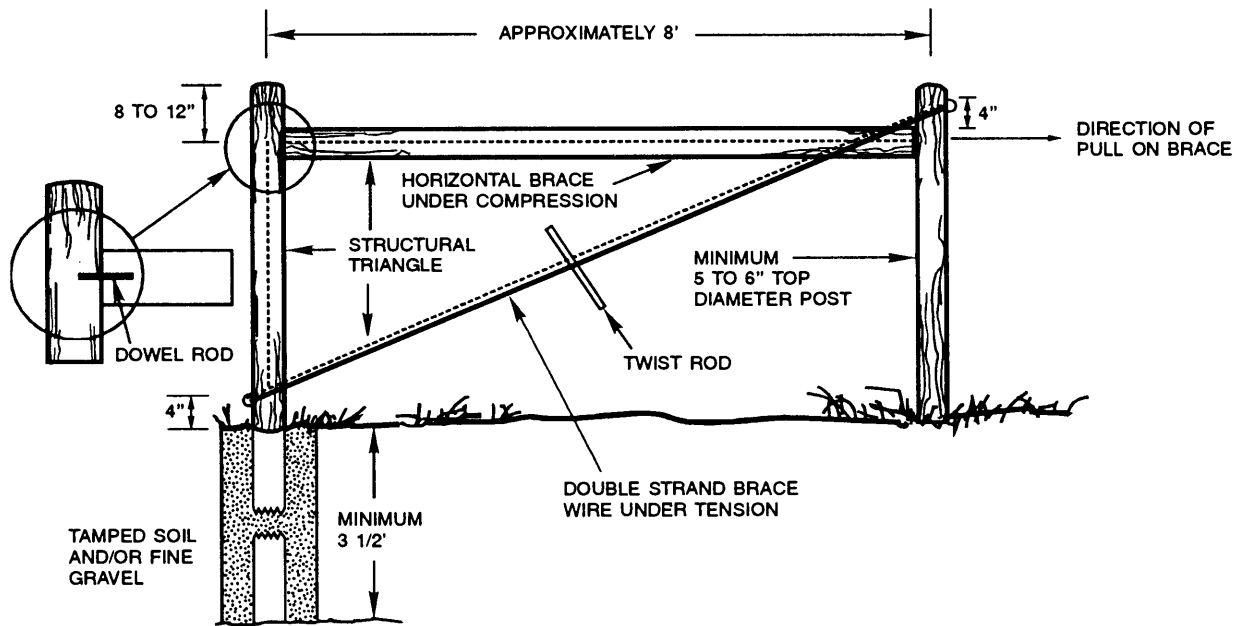


CONSTRUCTING ANCHOR-AND-BRACE ASSEMBLIES

Properly constructed **anchor-and-brace assemblies** or "**braces**" are the foundation for any fence. A common type is an "**H**" **brace** with diagonal wires. It is constructed with wooden brace posts set approximately eight feet apart. The shorter the distance between the posts, the weaker the brace assembly. The horizontal brace is placed 8 to 12 inches from the top of the posts. The diagonal brace wire is installed from the top of one brace post to the bottom of the other. The direction the diagonal brace wire is installed will depend upon the direction of pull on the brace.

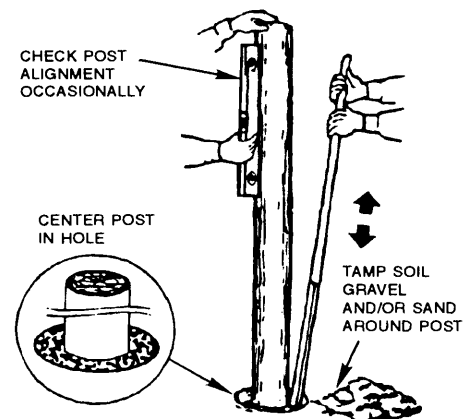
Part of the strength of a brace is provided by the **structural triangles** formed. The horizontal brace is in **compression** while the diagonal brace wire is under **tension**. The brace assembly can remain rigid as long as 1) the brace posts remain firmly anchored in the ground, 2) the horizontal brace that is under compression does not buckle or bow, and 3) the diagonal brace wire under tension does not stretch or break.

Wooden brace posts should be at least five to six inches in diameter at the top, and at least eight feet in length. Brace posts should be set a minimum of 3½ feet deep. Tests have shown that under the same conditions, braces with the posts set 2½ feet deep are only half as strong as braces with posts set 3½ feet deep. In sandy and/or wet conditions, this depth should be increased even more. Allow 4½ feet above ground for most fences.



Typical "H" Brace Made With Wooden Posts

When setting a brace, mark the location of one brace post and dig the post hole. Measure the length of the horizontal brace and mark the location of the other hole so that the brace posts can be set exactly in the center of each hole. Post holes for braces should be at least 12 inches in diameter. This allows enough room for soil and/or fine gravel to be tamped completely around the posts. Usually, one post can be centered and set. The horizontal brace can then be positioned on spikes or dowels, and the second brace post placed into position and tamped.

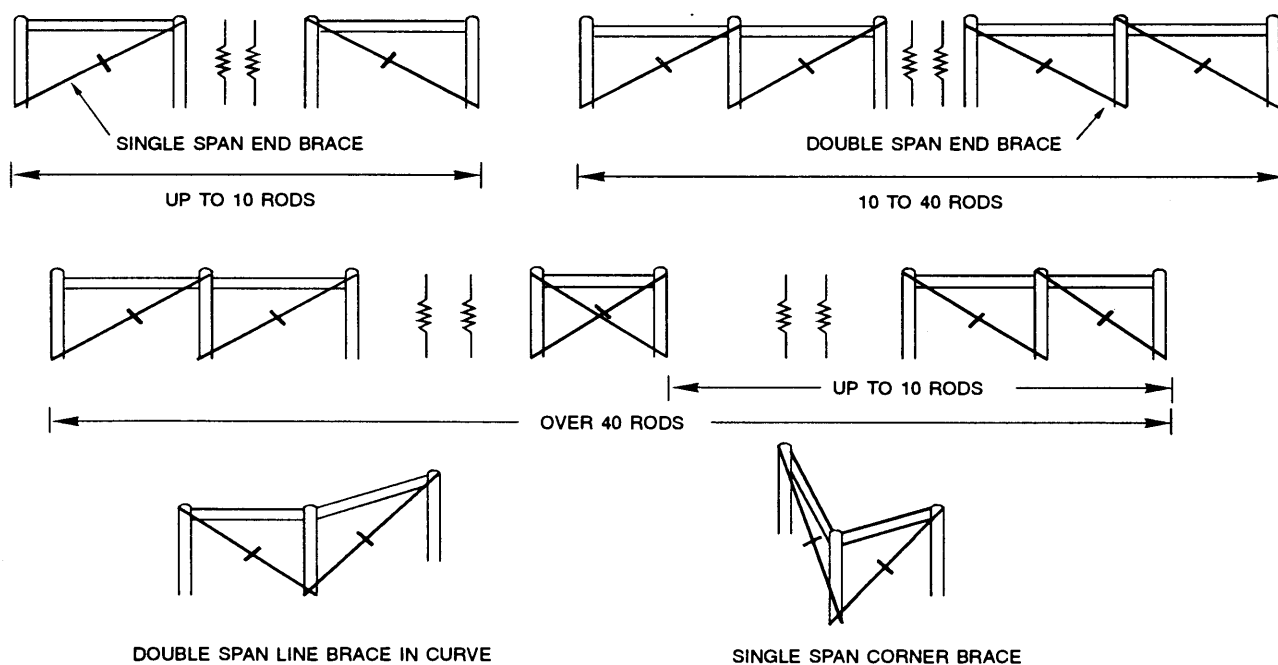


Soil and fine gravel should be added a little at a time and firmly tamped before more is added. If concrete is used to set brace posts, it should be allowed to set three to seven days before any pressure or pull is applied to the brace.

To install the brace wire, a long staple is driven about half its length into the brace post approximately four inches above the horizontal brace member. The first staple is placed on the opposite side from the brace member in the direction the fence will pull. Another staple is placed on the opposite brace post about four inches above ground line. Two wraps of nine-gauge smooth galvanized wire, or two wraps of 12½-gauge barbless cable are threaded through the staples and around the brace posts.

As much slack as possible should be removed and the wire ends securely spliced. A wooden stay or metal rod 18 to 24 inches long can be used to twist the brace wire until the brace assembly is rigid. Do not overtighten the brace wire or distort the brace. Leave the object used for twisting in place. After the brace is tight, add several extra staples to each brace post to secure the brace wire to keep it from slipping up or down.

An **end brace** refers to a brace assembly where the fence pull is from only one direction. A **corner brace** is used when pull is from two or more different angles. A **line brace** is used in the middle of a longer straight fence line where pull will be from two directions. When a line or corner brace is used, it is necessary to install diagonal brace wires in both directions.

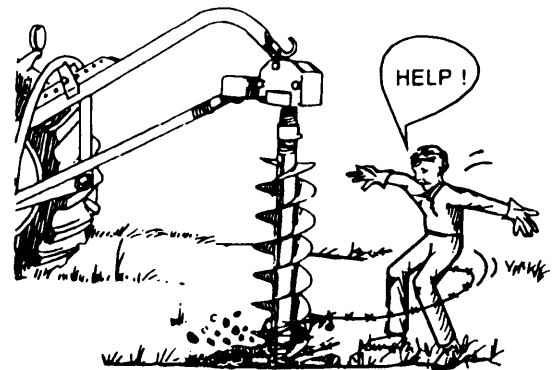


Single span braces with two vertical posts and one horizontal brace member can be used at each end of fences approximately ten rods (165 ') or less in length. By adding another brace post and horizontal member, the strength of a brace assembly can be increased. **Double span braces** are recommended on each end of fences 10 to 40 rods in length. For fences over 40 rods in length, double span line braces can be placed at each end with line braces in the middle as needed, 10 to 40 rods apart. A line brace or larger line post is used where there is a sudden change in elevation of the fence line, or in the middle of a gentle curve. A double span corner brace assembly may be needed where there is a sharper curve in the fence.

FENCE INSTALLATION, REPAIR, AND SAFETY

Building and repairing fences can be dangerous if certain precautions are not taken. Always wear protective gloves, glasses, heavy clothing, and boots. If you are handling treated posts, do not rub your hands or gloves on your face or skin. Some preservative chemicals are toxic and/or can cause skin irritations. Carry staples, nails, and tools in an apron or other container rather than your pockets.

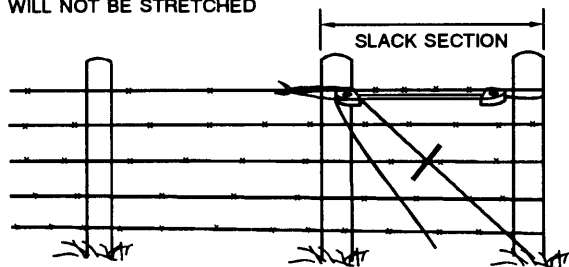
When using power augers or post drivers, exercise extreme caution. **Do not** operate power equipment near wires. Make sure they are moved and secured out of the way. It is easy for wires to become entangled in the moving parts and seriously injure someone.



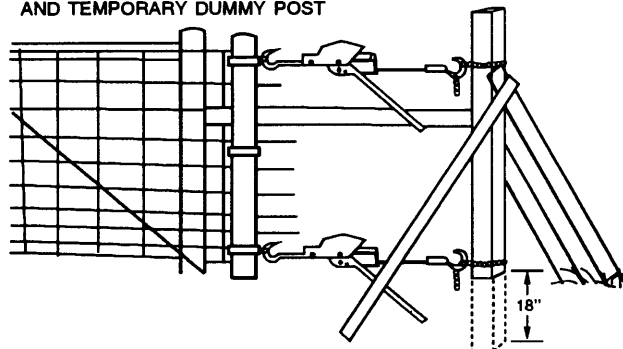
When installing woven wire, lay the roll next to the fence with the narrow horizontal spacing nearest the posts. Unroll a short section of wire. Remove two to three sets of vertical stays from the free end of the roll. Stand the woven wire up and secure to the brace post with several staples. Remember to keep the bottom line wire several inches off the ground. Wrap the line wires around the brace posts and splice them back to themselves.

Unroll the rest of the woven wire. Prop the wire up against the line posts. At the opposite end, attach a **woven wire stretching clamp**. Commercial models are available, or one can be easily made of two 2" x 6" boards and five or six $\frac{1}{2}$ " x 6" bolts with washers and nuts. Holes are drilled in the boards. They are then placed on either side of the woven wire and tightly clamped with the bolts.

BY ATTACHING BLOCK & TACKLE TO
END BRACE POST- SHORT SECTION
WILL NOT BE STRETCHED



STRETCHING WOVEN WIRE WITH
TWO "COME-A-LONG" STRETCHERS
AND TEMPORARY DUMMY POST



Methods of Stretching Fence Wire

Attach stretchers to the woven wire clamp and to a temporary "dummy post" or other secure object located just past the brace assembly. Slowly stretch the fence, making sure the wire does not snag on the line posts or other objects. Monitor the tension curves. When the fence appears to be tight, begin attaching the woven wire to the line posts starting at the opposite end of the fence.

As the woven wire is pulled into position, it may be necessary to tighten or loosen the stretchers slightly. After the wire is attached to the line posts, staple each line wire to the end brace post. The middle line wire can then be cut, the stays removed, and the end wrapped around the brace post and tied back to itself. This procedure is continued on every other line wire until all are tied off.

Barbed wire is attached to the anchor post of the brace in the same way as woven wire. When installing barbed wire, unroll it straight off the roll. Do not unroll it from the side or loop it off, or twists and kinks will occur.

Use only well-maintained wire grippers, stretching clamps, chains, and wire stretchers. Inspect them prior to each use and make sure they are properly attached. Experience will determine where to place the clamp or wire gripper so it does not end up next to the end brace post when the wire is tightened.

When stretching wire, stand on the opposite side of the post or brace. This can provide added protection if the wire slips or breaks. If it is necessary to grab or lift on the wire to free or move it while it is being stretched, use the claw of a hammer or the fencing pliers. Avoid sudden jerks, and release tension on the stretchers slowly. This could prevent serious injury should the wire accidentally break or slip.

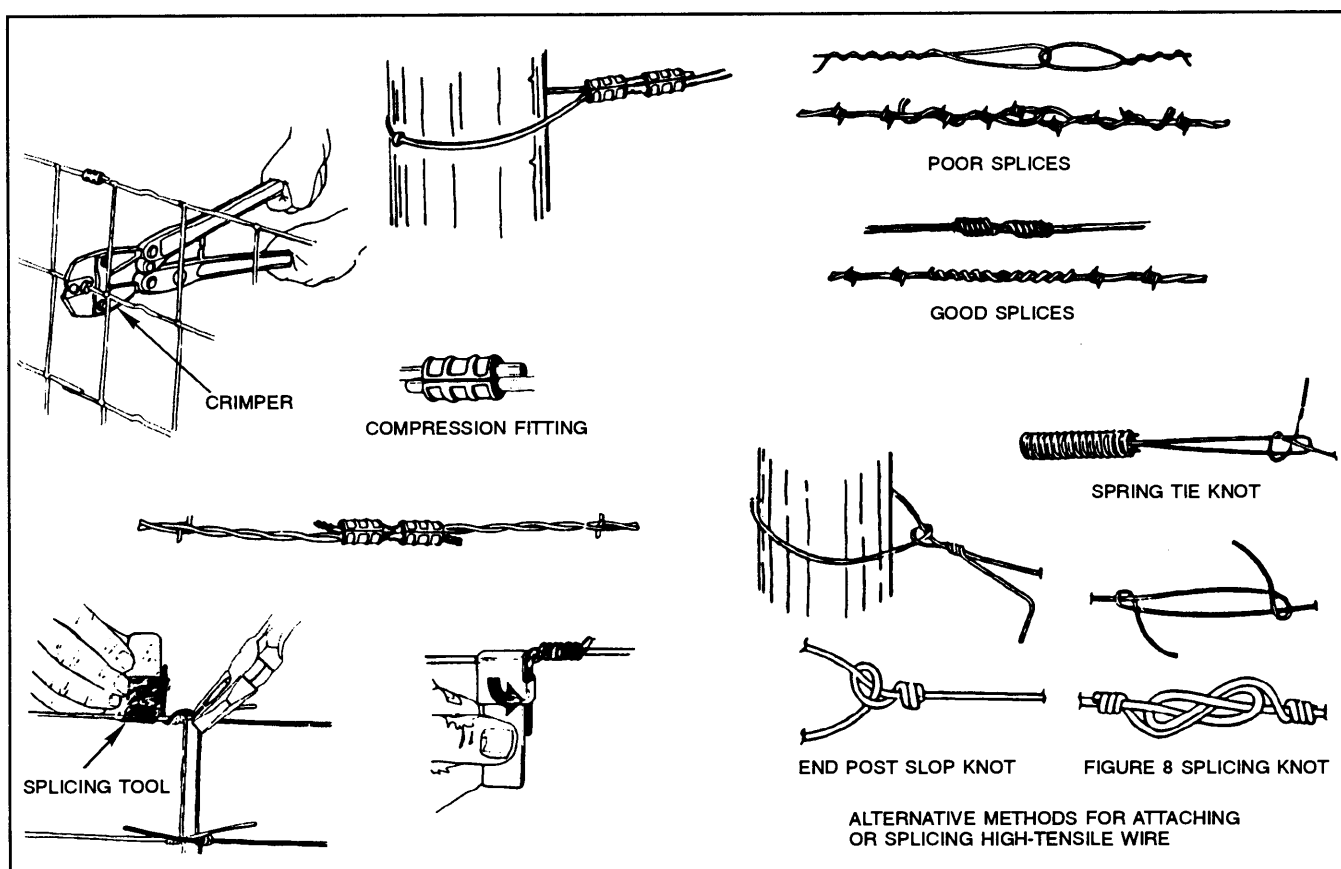
Do not stretch wire with a tractor or truck. It is difficult to "ease-up just-a-little." It is too easy to overtighten and break wires or pull the braces apart. Barbed wire does not have tension curves. Thus, it is difficult to tell how tightly it has been stretched. When stretching any fencing wire, take into account the season of the year. Wire will expand during warm weather and contract during colder weather. If wire is overstretched when installed in the summer, it may contract and break during the winter. Consult an experienced fence builder in your community for advice that has been gained through practical experience.

Some fence builders will attach the stretchers directly to the last brace post. However, this will leave a short section of fence between the woven wire clamp (or wire gripper in the case of barbed wire) and the end post that is not stretched. The fence will "slack off" some when the stretchers are removed.

Splices and points where wires are attached to braces can often be the weakest parts of the fence. Wires may break at the sharp square bends and/or at nicks caused by pliers and wire grippers or clamps. **Mechanical crimp sleeve fasteners** are the recommended method of splicing and tying off high-tensile wires as well as barbed, barbless, and woven wire. When properly installed, they do not slip or weaken the wire.

Because high-tensile wire is more stiff than conventional barbed or woven wire, it is more difficult to twist and tie knots. If mechanical crimp sleeves are not used on high-tensile wires, **end post slip knots**, **spring tie knots**, and **figure 8 splicing knots** are the recommended methods of tying off and splicing. Make loose loops and allow the knots to pull together as the wire is stretched.

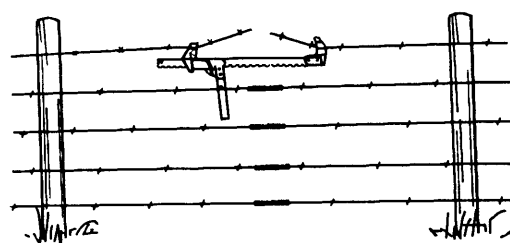
When mechanical crimp sleeves are not used with barbed and woven wire, a type of **western union** splice is generally recommended. Again, avoid making sharp square bends and nicks in the wires with the pliers while trying to bend or wrap wires. A **wire splicer tool** is helpful for forming close tight wraps when making western union type splices.



Methods of Splicing and Attaching Fencing Wire

Caution must be taken when repairing old fences. As fencing wire ages and begins to rust, it often becomes brittle and loses part of its tensile strength. For this reason, do not attempt to restretch any old fence wire as tight as a new fence. A **hand stretcher** with built in wire grippers is a handy tool for restretching and reattaching wires in the middle of the fence line.

Clips and staples can be removed or loosened with the aid of fence pliers from several posts in each direction. Wire ends are attached to the stretcher and slack is removed. A splice can then be made with the stretcher in place.



Using an In-Line Fence Stretcher to Repair Fence

Acknowledgements

Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the information in this topic. Ms. Hannah Kerby, Graduate Assistant, Department of Agricultural Education, Texas A&M University, developed the student activities.

REFERENCES

Structures and Environment Handbook, Midwest Plan Service, Iowa State University, Ames, IA.

Kencove Farm Fence, Blairsville, PA.

Planning Fences, AAVIM, Athens, GA.

Building Fences, AAVIM, Athens, GA.

SUGGESTED STUDENT ACTIVITIES

FILL IN THE BLANK: Place the correct word or phrase that best completes the sentence in the space provided.

- _____ 1. Welded wire _____ are often used for fencing where livestock are confined in small areas.
- _____ 2. _____ consists of a number of smooth horizontal wires held apart by vertical wires.
- _____ 3. _____ fences were introduced into the United States from Australia and New Zealand.
- _____ 4. _____ posts are comparatively low in cost and readily available in most regions of the country.
- _____ 5. Wire _____ are used to secure fence material to steel posts.
- _____ 6. Part of the strength of a "H" brace is provided by the _____ formed with the diagonal brace wire.
- _____ 7. _____ or _____ can be installed between line posts to maintain wire spacing and reduce the number of line posts needed.
- _____ 8. _____ fasteners are the recommended method of tying off high-tensile wires.
- _____ 9. _____ indicate how tightly woven wire has been stretched.

MATCHING: Match the letter of the description with the term it best matches.

_____ 10. suspension fence	_____ 14. end brace
_____ 11. line brace	_____ 15. polymer filament
_____ 12. barbed wire	_____ 16. corner brace
_____ 13. in-line tighteners	_____ 17. western union

- A. Anchor and brace assembly where the pull is from only one direction
- B. Anchor and brace assembly where the pull is from two or more different angles
- C. Maintain the required tension on high-tensile wires
- D. Anchor and brace assembly used in the middle of longer fences where pull will be from two directions
- E. Common on large cattle ranges
- F. Type of splice recommended for use with barbed and woven line wires when crimp sleeves are not used
- G. Made from two strands of smooth mild steel wire twisted together with sharp points attached
- H. Strong yet flexible alternative fencing material with high visibility

TRUE OR FALSE: Circle "T" if the statement is more true than false. Circle "F" if the statement is more false than true.

- T F 18. Fences should always be constructed across the shortest possible distance.
- T F 19. High-tensile fencing costs more to install than other types of fencing but has a longer life expectancy.
- T F 20. Fiberglass and plastic posts can be as strong as steel posts, but will burn in grass fires.
- T F 21. Fence staples provide greater holding power if driven at a downward angle so they are parallel to the grain of the post.
- T F 22. High-tensile and barbed wire fences can be electrified if the proper type of posts and fasteners are used.
- T F 23. Fences will expand or contract according to seasonal weather and temperature changes.

- T F 24. When building fences between different land owners, a professional land surveyor should be hired to determine property lines.
- T F 25. A rod used to measure land is an average of 20-feet long.
- T F 26. The wire used to make high-tensile wire fences has the same breaking strength as the wire used to make barbed or woven wire.

ADDITIONAL SKILLS AND ENHANCEMENT ACTIVITIES: Perform the following activities or skills as assigned by your instructor.

1. Call or write fencing materials supply companies listed in agricultural trade magazines. Request copies of the latest handbooks, videos, etc. on designing and installing different types of fences.
2. Compare the availability, costs, and life expectancies of different types of fence posts used in your community.
3. Contact the local SCS office and obtain an aerial map of land area you or someone you know is planning to build fence on.
4. Plan the specifications for a $\frac{1}{4}$ mile of woven wire fence, a $\frac{1}{4}$ mile of barbed wire fence, and a $\frac{1}{4}$ mile of high-tensile wire fence that might be used in your community. Develop a bill of materials including estimated costs for each. If needed, review topic # 8149-C on Computing a Bill of Materials.
5. Demonstrate the ability to build and repair different types of fences.

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N1993

PLANNING, BUILDING, AND MAINTAINING PRIVACY, RESIDENTIAL, AND COMMERCIAL FENCES

FUNCTIONS OF FENCES

Fences are popular enclosures incorporated into home and business landscapes. They can provide **physical privacy**, **psychological privacy**, and **security**. Fences are also built to **confine** pets, livestock, and/or people to a limited area.



Physical privacy fences are constructed to restrict or limit vision. This type of fence may also be used for security and confinement reasons. Usually, privacy fences are tall and solid. They obstruct the line of sight onto and off a particular area.

Psychological privacy fences provide a piece of mind by simply marking borders or boundaries. Psychological privacy fences may be as simple as a row of rocks or a rail fence which can easily be seen through and stepped over. A psychological privacy fence is often constructed only as a psychological barrier or reminder and serves little or no security or confinement purpose.

Security fences add protection and prevent intrusion into, or escape from, a site. A tall chain link fence constructed around a home or business is an excellent example of a security/confinement fence.

Many fence designs are constructed to also provide a **transition** between visual planes **for landscape purposes**. In addition, some designs may also provide **protection** from the wind and/or **shade** from the sun. Different fence designs can be constructed to provide one or more of these functions at the same time.

MATERIALS USED IN RESIDENTIAL AND COMMERCIAL FENCES

There are many designs and types of fences constructed today. The most popular materials used are: 1) **wood** and 2) **chain link**. Other materials, such as native stones; bricks; concrete blocks; plastic, fiberglass, or steel pipe; or wrought iron panels, are also used.

Galvanized wire fabric (chain link) and wooden materials should be compatible with the other building materials used. Weather conditions and ground contact may have an adverse effect on building materials in some areas. Fencing and building materials should be compatible with the landscape and visual appearance of the surrounding area.

Contact local building material suppliers for additional information on fencing material choices, material compatibility, and recommended installation procedures. Commercial fencing specifications and installation procedures are also normally available upon request.

Chain Link

Chain link fences are constructed primarily for security or confinement needs. Chain link material may be covered with galvanized coating before *or* after it is woven into the fabric-type mesh structure. Materials coated prior to weaving often have a more uniform protective coating than those dipped after weaving. This provides better rust protection necessary in damp climates.

For various residential and commercial needs, chain link wire fabric is available in different heights, in several wire gauge sizes, and with different amounts of galvanized (**zinc**) coating. Class-III, zinc-coated, 11½ gauge chain link wire is recommended for normal, commercial, light-duty, or residential installations.

Wood Products

Various wood products are used in fence construction. Natural insect and decay-resistant **redwood** and **cedar** lumber are often preferred. However, in most cases these are more expensive. Some hardwood lumber may provide added life expectancy, but it is also expensive. Softwood species such as pine are less expensive, but are not as decay and/or insect-resistant. They are commonly used when cost is a major construction consideration.

Pressure-treated wood products are available with extended life expectancies. Less expensive softwood lumber is treated with chemical preservatives to minimize weathering and insect damage. A preservative commonly used is **chromated copper arsenate (CCA)**. Softwood lumber is placed in large, enclosed containers. Preservative chemicals, which are injected under pressure, soak into the wood fibers.

APPLICATION	RETENTION Lbs./Cu.Ft. (pcf)	USES
Above Ground	0.25	decking, fenceboards, sills, etc.
Ground Contact	0.40	posts, landscape timbers, etc.
Fresh Water Contact	0.60	retaining walls, piers, docks, etc.
Permanent Wood Foundation	0.60	all weather wood foundations, full basements, crawl spaces, Plen-Wood Systems, etc.
Utility Poles	0.60	telephone, electrical distribution and barn poles
Piles-Ground or Fresh Water Contact	0.80	standard and foundation piles
Salt Water Contact	2.50	piling, bulkheads, timbers, etc.

Recommended Wood Preservative Retention Levels

Pressure-treated lumber is classified or rated by the amount of chemical preservative that is retained in the lumber after treatment. Common ratings for CCA treatment range from 0.25 to 2.50 pounds of chemical per cubic foot (pcf) of lumber. The more preservative chemical retained, the longer the lumber should last in adverse conditions. Lumber that is used for above ground decking and fencing should have a minimum retention rating of 0.25 pcf. Boards, posts, landscape timbers, etc., that are exposed to direct ground contact or damp conditions should have a minimum rating of 0.40 pcf for adequate protection. Lumber exposed to continuous water contact should have a minimum rating of 0.60 pcf. Consult local suppliers for specific recommendations in your area. (See student topic #8229-B for additional information.)

Softwood lumber treated with CCA is often referred to as "Wolmanized" lumber. This is misleading. Wolmanize is actually a trade name for one company's CCA preservative treatment process. Many other brands of CCA pressure-treated lumber are also available.

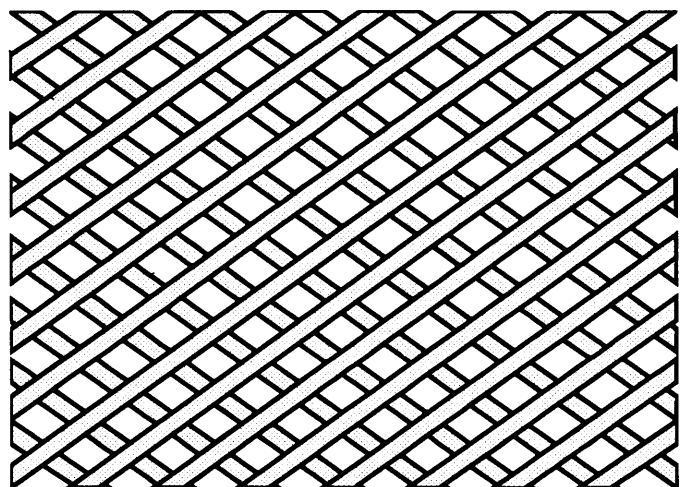
Note! CCA and other chemical preservatives such as creosote and pentachlorophenol (penta) have recently been classified and listed as **restricted use pesticides**. These chemicals can now only be purchased and applied by individuals and companies who have a **certified pesticide applicators license**.

Treatment with CCA or similar preservatives often gives the lumber a light pale-green color. This is not to be confused with damp or freshly cut "green" lumber that has not yet been kiln dried.

Pressure-treated pine lumber is commonly recommended for many types of wooden fence construction. If untreated lumber is used, paint or a water repellent preservative (WRP) should be applied. Some people may still prefer the "natural look" of unfinished lumber; however, the fence may not last as long. Even when pressure-treated lumber is used, fresh cut board ends and saw kerfs should be treated with an approved WRP.

Fence designs may be limited by the availability of wood materials in some areas. The demand for wood products in other types of construction has increased lumber prices. New processed wood products are available and are rapidly gaining in popularity.

Lattice panels are wooden slats stapled and glued together. They are available in four-by-eight foot panels with different grades and thicknesses. Pressure-treated lattice panels are also available. Fences constructed with these panels are often limited to patio fences or transition areas between other fence designs or structures.



Typical Wooden Lattice Panel

FENCE CONSTRUCTION AND CONSIDERATIONS

Proper planning is essential to any fence construction. The type of fence constructed usually depends on needs and personal preference. Fence location and material planning are very important.

Important considerations must be taken when developing a "bill of materials" or shopping list. **Actual** and **nominal** material sizes are not the same. Consult local suppliers for actual lengths, measurements, and specifications when developing working plans. Properly planned and constructed fences can add value and beauty to any business or home.

In some cases, local building codes may restrict the height of certain fences, the types of materials used, and "**set back**" requirements from streets, sidewalks, etc. Property lines are often used as fence lines. Obtain the neighbors' permission if any portion of the fence or concrete footing is to be placed on their property. Certain communities also have codes that restrict the use of fences in alleys or utility right-of-ways. In some areas, a building permit may be required prior to starting any fence construction.

TOOLS

Fence construction is accomplished with the use of common tools. Post hole diggers, pliers, saws, string, a hammer, stretching devices, a level, and measuring tapes are often needed. End wrenches and concrete tools are optional. Safety equipment, such as gloves, clothing, eye-wear, boots, and ear protection, is also required.

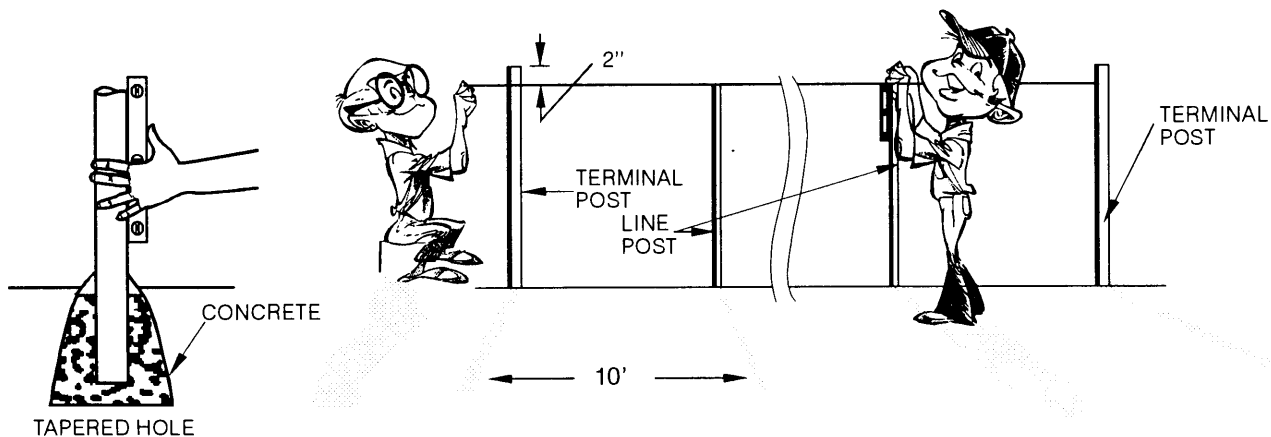
CHAIN LINK FENCE CONSTRUCTION

To construct a chain link fence, stake the property line, the desired location of the fence, and the proposed gate locations. Stretch a string between the stakes and mark post placement. **Terminal posts** are posts that are used at corners, gates, or where the fence will end. All terminal posts should be set two inches inside the property line.

Common post sizes for residential chain link fences are 2 3/8" for terminal posts and 1 5/8" for line posts. Commercial fences are often built to specifications using 3" terminal posts, 2" line posts, and 4" gate posts. Commercial fences for security purposes may require the use of barbed or spiral wire material at the top for added protection.

Standard walk-through gates are 35½" wide. The gate posts should be set 39" apart, measured from the inside to allow for gate hardware. Standard double drive-through gate posts are set ten feet apart (inside measurements). Line posts go between the terminal posts and are spaced no more than ten feet apart.

Line posts are usually set two inches below the height of terminal post to allow for the top rail and line post caps. Two people may be needed to lay out the fence line; one person to "sight" the posts and the other to adjust individual line posts. A level is used to align the posts vertically. Post holes are usually six to eight inches in diameter. Terminal post holes may be slightly larger. Holes may be tapered out at the bottom with a hand digger for extra strength and support footing. The outside surfaces of line posts should be in line with the outside surfaces of the terminal posts.

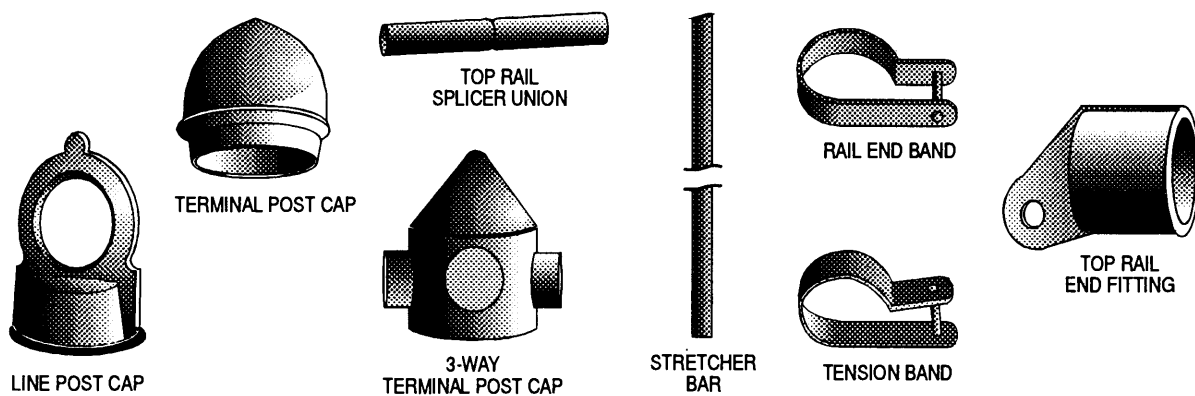


Post Alignment for Chain Link Fences

Concrete is used to set posts permanently in place. A good mixture for setting posts is 1-part cement, 2-parts sand, and 4-parts gravel. Add just enough water so the mixture will pour easily. Too much water weakens concrete, and causes cracking.

Be sure to keep the ingredients clean and eliminate any foreign matter. It is recommended that the concrete be allowed to cure at least two to four days before attempting to stretch the chain link. It is *not* recommended to pour concrete when the temperature is below freezing.

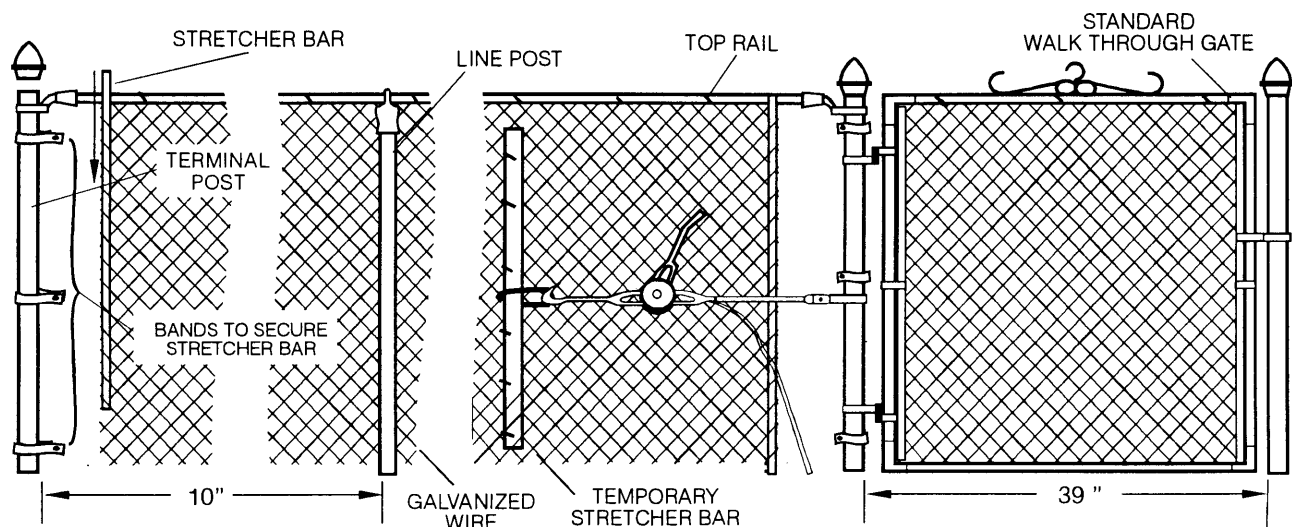
After posts are secured, fittings are placed on the posts. **Tension bands** are spaced approximately 15 inches apart on each terminal post and are used to secure the stretcher bar. Since the fabric is installed on the outside of posts, tension bands should be installed on the terminal posts with the straight side of the clamp toward the outside. There are a wide variety of fittings used for rail ends and line post caps. Bolt heads used in tension clamps and rail ends are installed with their heads toward the outside of the fence.



Typical Chain Link Fence Fittings

Terminal **post caps** are available in 3-way, in-line, and 4-way cross type constructions. Some **top rails** may be manufactured with one end swedged for easy connection. Others are jointed with the use of **splicer unions**. A heavy gauge **galvanized wire** is often stretched between terminal posts at ground level to which the bottom of the chain link fabric can be attached.

The chain link fabric is rolled out along the outside of the fence line. A **stretcher bar** is inserted into one end of the chain link and attached to the terminal post using the tension bands.



Chain Link Fence Installation

The fabric should be stretched by hand toward the next terminal post to help remove kinks. The fabric is then loosely attached at intervals to the top rail to hold it upright during final stretching. A temporary stretcher bar is inserted through the fabric approximately 18" to 24" from the ending terminal post. A wire stretcher is connected between the stretcher bar and terminal end post or another secure object.

The chain link fabric is slowly tightened with the wire stretcher. Occasionally raising and lowering the fabric will ensure that it is not hanging. When the chain link fabric is tight, another permanent stretcher bar is inserted next to the last terminal post and secured with the tension bands.

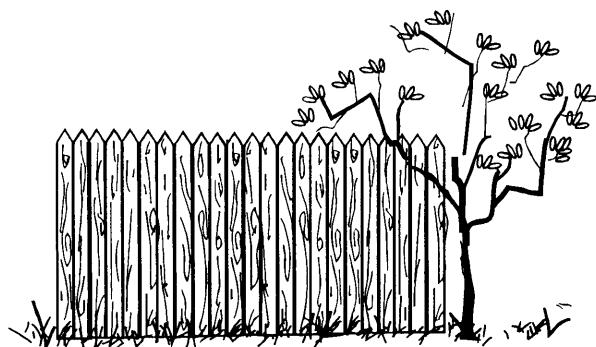
The chain link fabric is then permanently attached to the line posts, top rail, and to the wire placed at ground level with galvanized or aluminized wire clips. The temporary stretcher bar can be removed after the fabric is firmly secured.

Any excess chain link fabric can be easily removed by twisting a single strand out of position in a counterclockwise manner. Sections of chain link fabric can also be spliced together by twisting a single strand in a clockwise direction, back through the loops of the ends.

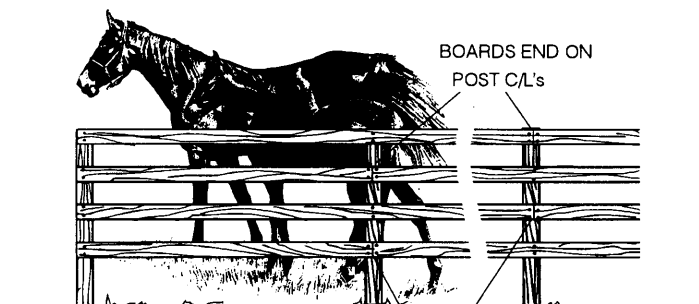
Gates are installed so that they are level with the top rail of the fence. Clamp-on hinges are secured to gate posts with the top hinges pointing down and the bottom hinges pointing up. The hinges and gate latch are adjustable for proper operation.

WOOD FENCE CONSTRUCTION

There are a wide variety of wooden fence designs. Two basic designs that will be discussed in this topic are: 1) **corral**, and 2) **vertical slat**.



VERTICAL SLAT WOOD FENCE



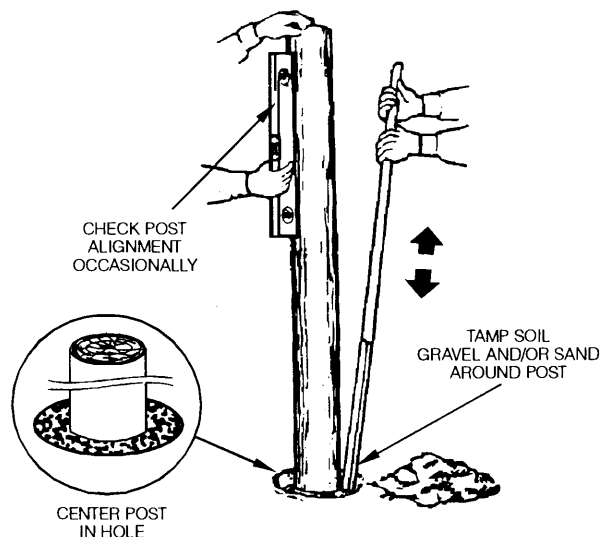
CORRAL TYPE WOOD FENCE

Corral Fence Construction

Corral type fences are used primarily as a psychological privacy and/or a confinement fences. Corral fence lines are staked and marked in much the same way as other fence designs. Wooden posts are used to support a variable number of horizontal boards or rails. The length and strength of the boards or rails usually determines the spacing between posts.

Corral type fences can be constructed with round, half-round, 4" x 4" square, landscape timbers, or split posts as desired. For longer life, penta or CCA pressure-treated posts should be used. Posts should be set approximately 2½ feet deep.

When the containment of livestock is not a consideration, fences may be constructed with the boards on the outside of the fence for appearance reasons. Posts should always be placed in the center of the hole with the desired nailing surfaces facing the correct direction. The posts are set by firmly tamping soil, small gravel, and/or sand around them.



Tamping a Post

Small amounts of fill material should be placed in the hole and tamped all the way around the post before more is added. Posts may also be set in concrete if desired.

The size and grade of the lumber used for horizontal boards or rails will depend upon the budget allowed, the desired appearance, and the type of animals to be contained, if any. The larger the lumber size and the better the grade selected, the stronger the fence and the longer it should last.

Pressure-treated lumber is recommended for most applications. All saw kerfs should be retreated with an approved preservative treatment to decrease decay. If untreated lumber is used, an acceptable WRP or paint can increase fence life.

It is often wise to obtain longer lengths of lumber or decrease post spacing slightly so that rough ends, splits, and end cracks can be removed. **For example:** If 8' and 16' lumber is used, posts can be spaced on 7'6" to 7'9" centers. Bad ends can be removed and joints can then be staggered to decrease warping and increase overall fence strength.

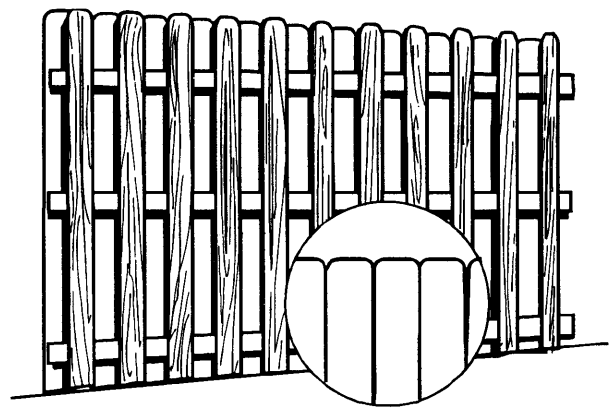
Board or rail ends are squared, cut to length, and secured to posts. The horizontal boards or rails should be cut to allow for ends to meet at the center of line posts and to the outside edges of terminal or gate posts

Use galvanized fasteners to prevent rust stains and extend fastener life. Use 10d or larger ring-shanked nails, or lag screws. Galvanized drywall screws, commonly referred to as "deck screws" are rapidly gaining popularity in wood fence construction. These fasteners provide excellent strength and "pull out" resistance.

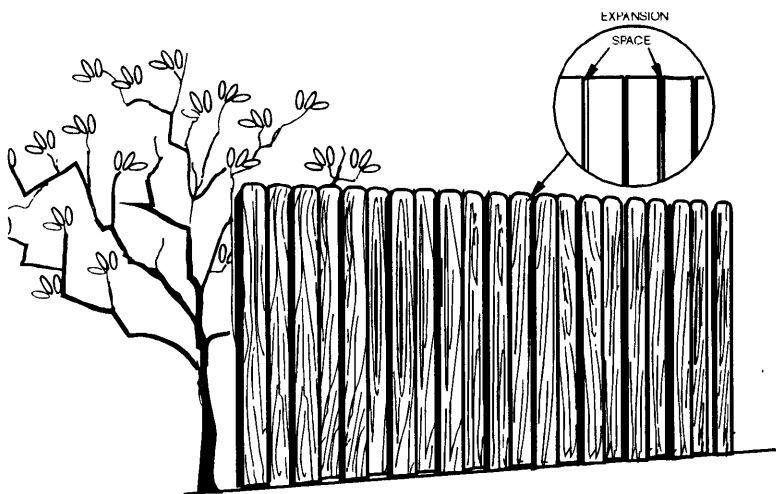
VERTICAL SLAT FENCE CONSTRUCTION

Many different designs of vertical slat wood fences can be constructed to satisfy personal preference and specific needs. "One-by" (1" nominal thickness) treated pine, cedar, or redwood lumber that is 4, 6, 8, 10, or 12 inches wide (nominal width) can be used as vertical slats. In drier climates, untreated pine may be used and left to naturally age.

The top edges of the slats may be "dog eared" or trimmed for an added appearance and security. It is more difficult to climb over a fence with rough, irregular edges than a smooth surface. Depending on availability, cost, and preference, choose a **select grade** of lumber. **Rough sawn** lumber may be used. However, **surfaced lumber** will often require less preparation if painting or staining is desired.

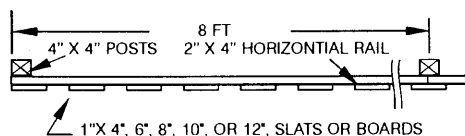


"Dog Eared Vertical Slats"

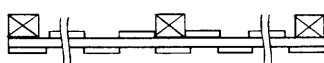


Allow Space for Expansion

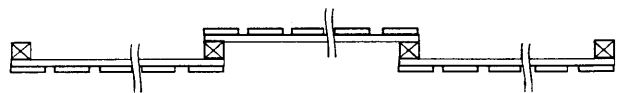
Typical vertical slat fences are six feet high. Even when complete privacy is desired, some space should be allowed between the slats for expansion and contraction due to seasonal changes. When vertical slats are placed up to six inches apart, some designs allow air movement while still providing limited privacy, security, and confinement. Designs may be altered for specific needs or purposes.



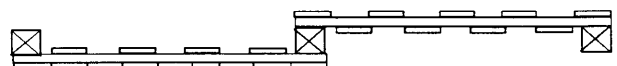
STRAIGHT PANEL



ALTERNATING SLAT



ALTERNATING PANEL



ALTERNATING SLAT / ALTERNATING PANEL

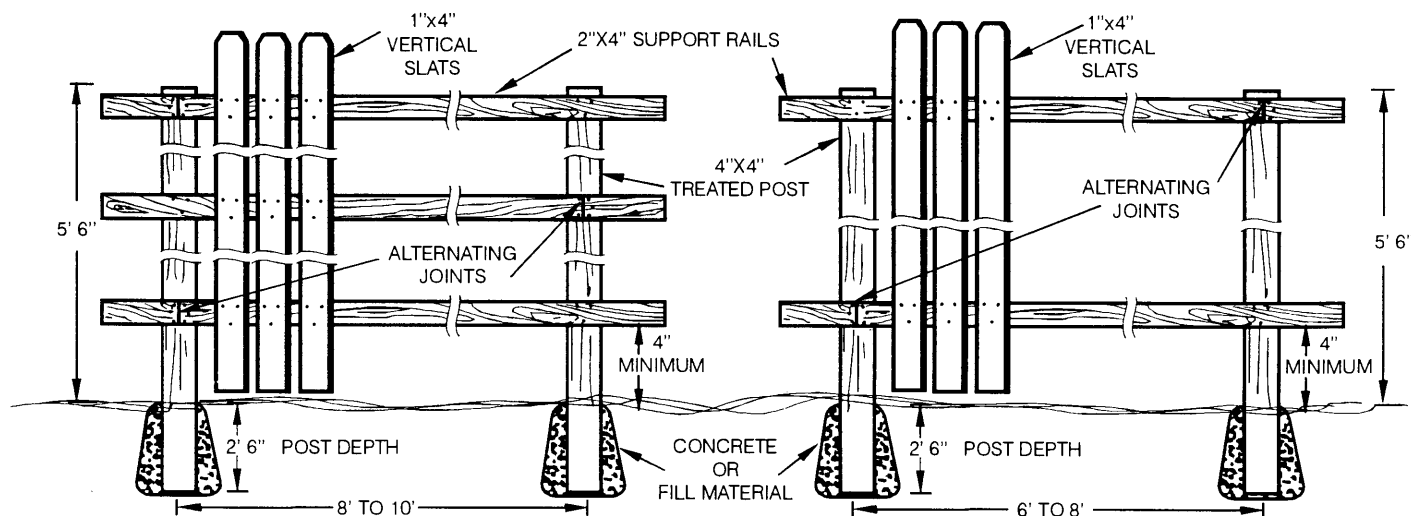
Various Vertical Slat Wood Fence Designs (top view)

Typical vertical slat fences are constructed using eight foot posts set two and one-half feet deep. Four-inch square posts and landscape timbers are commonly used. Round posts can also be used, but it is difficult to splice horizontal rails on the round, irregular surfaces. The posts selected should be matched with the appearance and life expectancy of the lumber used for the horizontal rails and vertical slats

Posts are normally set six to eight feet apart when only two horizontal rails are used. If three 2" x 4" rails are used for added strength and support, longer spans may be possible. When softer lumber such as treated yellow pine is used for rails, a shorter span with three 2" x 4" rails is still recommended. As with corral type fences, posts for vertical slat fences may be set with concrete or firmly tamped with sand, soil, and/or small gravel.

Horizontal rails used to support the vertical wood slats are usually made of 2" x 4" treated lumber. Except on terminal or gate posts, all horizontal rails should end on post center-lines to provide an adequate nailing surface for joints. If possible, alternate rail joints to provide extra stability and strength.

Galvanized nails, lag screw, and deck screws should be used to fasten vertical slats and support rails. If cracking or splitting is a problem, "blunt" the sharp points of the nails or use pilot holes. Hardware for wood fence gates and other accessories is available at lumber yards and fencing supply stores.



Common Support Rail Designs with Alternating Joints

MATERIAL AND TOOL SAFETY

Care should be taken when working with pressure-treated materials due to their toxic nature. Avoid direct skin contact and frequent or prolonged inhalation of sawdust from treated wood. *Always* wear a dust mask, eye protection, gloves, and proper clothing during construction procedures. Follow manufacturer's recommended procedures for application. Do not burn scrap CCA treated lumber. Dispose of all waste materials in an approved trash collection or burial site.

Always select the proper tools. Improper tools and construction methods may result in serious injury or mar the work. Keep all tools clean and free from rust. Inspect all power equipment and tools for frayed or damaged cords. Caution must always be taken when working with cutting tools or nail guns. All electrical equipment should be properly grounded. An approved GFCI should be used at all times when working outdoors or in damp environments.

Always remember to obtain proper building permits. It is also recommended that all local utility companies be contacted prior to any digging or construction. Underground service lines (electric, gas, telephone, sewer, cable tv, etc) may be easily damaged with hole digging tools and equipment. Utility companies can usually send a customer service representative to the construction site immediately to mark the exact location of underground utility lines.

REFERENCES

Planning Fences, American Association For Vocational Instructional Materials, Athens, GA.

Building Fences, American Association For Vocational Instructional Materials, Athens, GA.

Pressure Treated Wood, Chemical Specialist , Inc., Charlotte, NC.

Acknowledgments

Mr. Donald G. Krobot, Intern, Department of Agricultural Education, Texas A&M University, and Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the information in this topic. A special thanks to local fencing contractors and building material suppliers for information and current industry trends.

SUGGESTED STUDENT ACTIVITIES

LISTING: Respond to the following items in the spaces provided.

1. List the functions different fence designs can provide.

1. _____	2. _____
3. _____	4. _____
5. _____	6. _____

2. List the two most popular types of materials used to construct fences.

1. _____	2. _____

3. List two common wood fence designs.

1. _____	2. _____

SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph. (Use additional paper when needed).

4. Explain why cedar and redwood lumber are often preferred for wood fence construction.

5. Briefly describe what "pressure-treated" lumber is and explain why it is increasing in popularity.
6. What should be done before digging post holes or performing any fence construction?
7. List the ingredients for a concrete mixture that is good for setting posts. List two considerations for this mixture.
8. Pressure-treated lumber that is purchased for use as fencing boards that are placed above ground should have what minimum pcf chemical retention rating? Give answer in pounds per cubic feet.
9. What minimum pcf chemical retention level rating should lumber, posts, landscape timbers, etc. that are placed in direct contact with the ground and/or used in continuously damp conditions have? Give answer in pounds per cubic feet.
10. Standard walk-through chain link fence gates are 35½ in width. What is the ideal inside measurement between gate posts to allow for gate hardware?

ADDITIONAL SKILL AND ENHANCEMENT ACTIVITIES: Perform the following as assigned by instructor. Report your findings to the class.

1. Visit a local lumber yard and hardware store. Inspect the different types and grades of treated and untreated lumber used for fence construction. Determine which types are commonly used in your area. Compare the price and life expectancies of each.
2. Inspect several chain link and wood fences in your area. Observe the fence fittings and hardware used. Compare the different designs with the probable function(s) the fences provide.
3. Visit with a local commercial fence contractor. Determine local fence construction specifications and set-back requirements, if any. Specifically inquire about safety requirements, types of materials used, and fence heights. Determine which restrictions apply to commercial and/or residential fences.
4. Calculate a bill of materials for a fence you or someone you know is planning to build. Determine the overall length of each fence section. Calculate the post spacing required so that posts are uniformly spaced.
5. Assist in the planning and construction of a wood or chain link fence.

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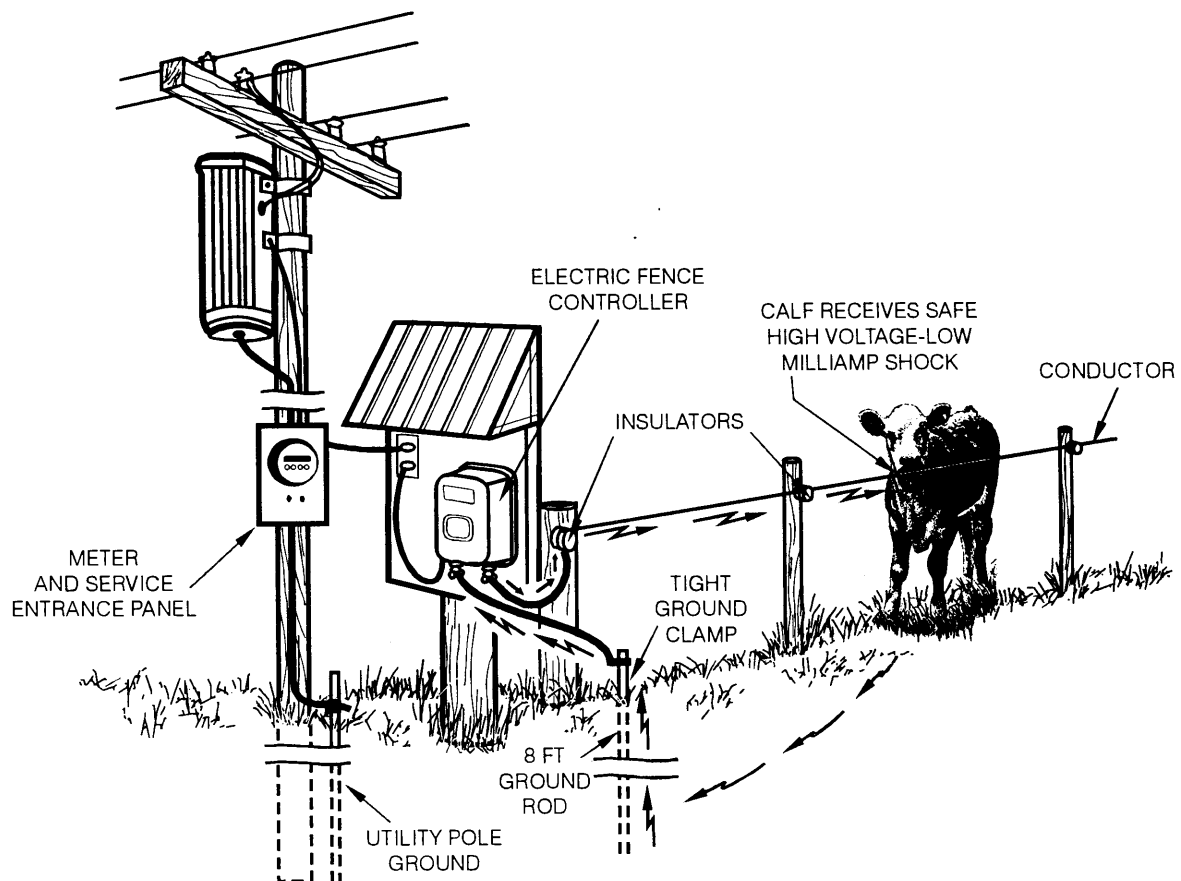
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N1992

PLANNING, BUILDING, AND MAINTAINING ELECTRIC FENCES

Electric fences are used as an alternative to traditional barbed, woven, and high-tensile wire fences. They are used to effectively manage livestock, and utilize forage resources. Electric fences are also used to train livestock to avoid fence contact, thus protecting traditional existing fences from damage. The primary purpose of an electric fence is to provide a mild "shock" to animals that come in contact with it. Animals learn to "respect" the wire and avoid direct contact.



ELECTRIC FENCE USES

Electric fences are used to contain livestock or wildlife. One common use is to set up temporary pastures for grazing. Permanent existing fences can be protected from damage by fighting bulls or other animals. Electric fences are also used to separate cows from calves during weaning time. Portions of existing barbed and high-tensile wire fences may also be electrified for livestock containment. The advantages of using an electric fence are as follows:

- * low, initial cost and ease of construction
- * easily maintained and economical to operate
- * easily moved to a new location when necessary
- * provides protection from predator species
- * protects and extends usefulness of existing permanent fences
- * easily moved to allow fence rows to be cleaned and cleared
- * allows grazing of all areas no matter how large or small

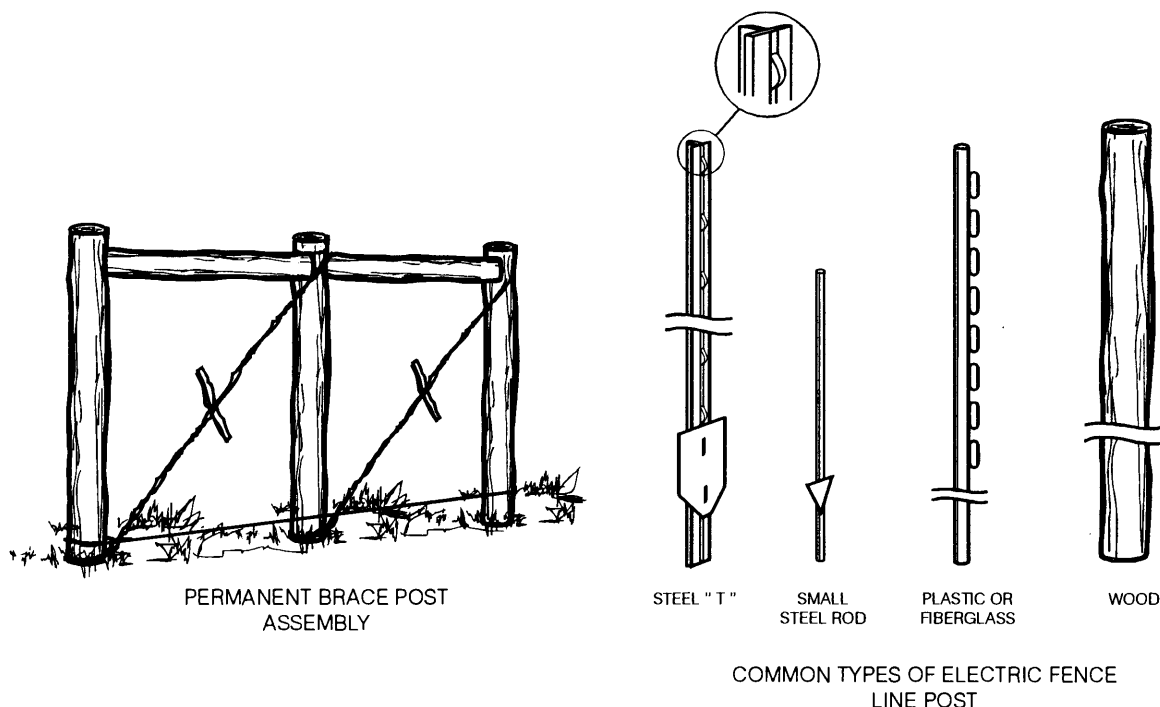
An electric fence does have some distinct disadvantages: 1) livestock require training when it is first used, 2) must be energized or kept in operation at all times to be fully effective, 3) is not effective in dry environments without a return ground wire, and 4) electric fence equipment is dangerous if altered or installed improperly.

The essential parts of a complete electric fence are: 1) **posts** [steel, fiberglass, plastic polymer, or wood], 2) **conductor** [bare wire, smaller gauge barbed-wire, high-tensile wire, or approved tape or twine type conductors], 3) **insulators**, 4) **electric fence controller**, 5) **grounding rod(s)**, and 6) **power supply** [battery or line voltage].

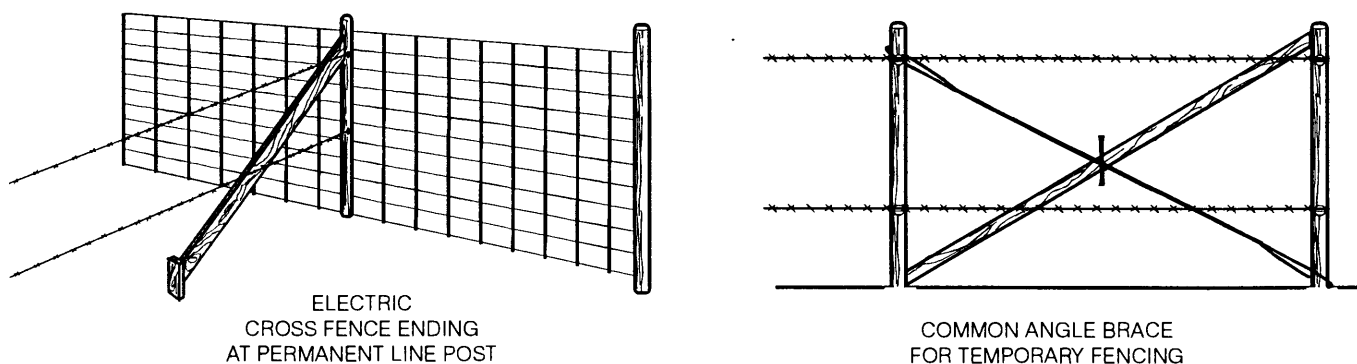
POSTS

Steel, fiberglass, plastic polymer, and wooden posts are commonly used as electric fence line posts. The same types of posts can be used for both permanent and temporary electric fences. However, new light-weight plastic polymer, fiberglass, or small steel posts are more commonly used for temporary fences.

Posts are usually driven into the ground with a hand-held post driver, hammer, or with the aid of tractor power. Some smaller wooden posts may be sharpened on one end and driven into the ground. However, some soil conditions may require the use of post holes for proper post placement. Electric fences can be built with fewer and lighter line posts. Most installations require a post spacing ranging between 30 to 50 feet.



All ends, corners, and gate posts for permanent electric fences should be braced. For permanent electric fences, construct **brace-post assemblies** similar to those used for barbed and woven wire fencing. Wooden brace assemblies are more common, however, other materials may be used.



Temporary Electric Fence Braces

When constructing wooden braces, the brace bar and posts are secured in place with wire and nails. A heavy gauge wire is stapled to posts in a diagonal position and twisted to strengthen the brace assembly. Even when temporary electric fences are constructed, some type of angle bracing for end posts is recommended.

For temporary electric cross-fences, wooden line posts in existing permanent fences offer a good starting point for brace assemblies. Decide on the general location of the electric fence and select the nearest existing line post. The existing fence line post is used as the temporary brace assembly anchor post. Stretch a wire or string from one temporary brace-post assembly to the next to mark the remaining line post locations.

CONDUCTORS

To deliver an adequate "shock," all conductors must be able to conduct electrical current with a minimum of resistance. Small **14 or 15½ gauge galvanized barbed wire** (double-strand twisted) and **12½ to 14½ gauge single-strand, high-tensile steel wire** are commonly used as electric fence conductors. However, smaller **16 and 17 gauge single-strand galvanized or aluminized wire** can be used for short-distance temporary fences.

Badly rusted wire and larger gauges of galvanized barbed or high-tensile smooth wire are not normally recommended for electric fencing because of their higher resistance. Consult the owner's manual supplied with the controller for specific wire requirements and applications.

All splices in wire conductors must be secure so that continuity is not lost. Splices made by loosely twisting wire ends together *are usually not* adequate. Properly made "western union type splices" or crimp-on metal sleeves should be used to create more secure, low-resistant splices in wire conductors.



POOR SPLICE



WESTERN UNION TYPE SPLICES



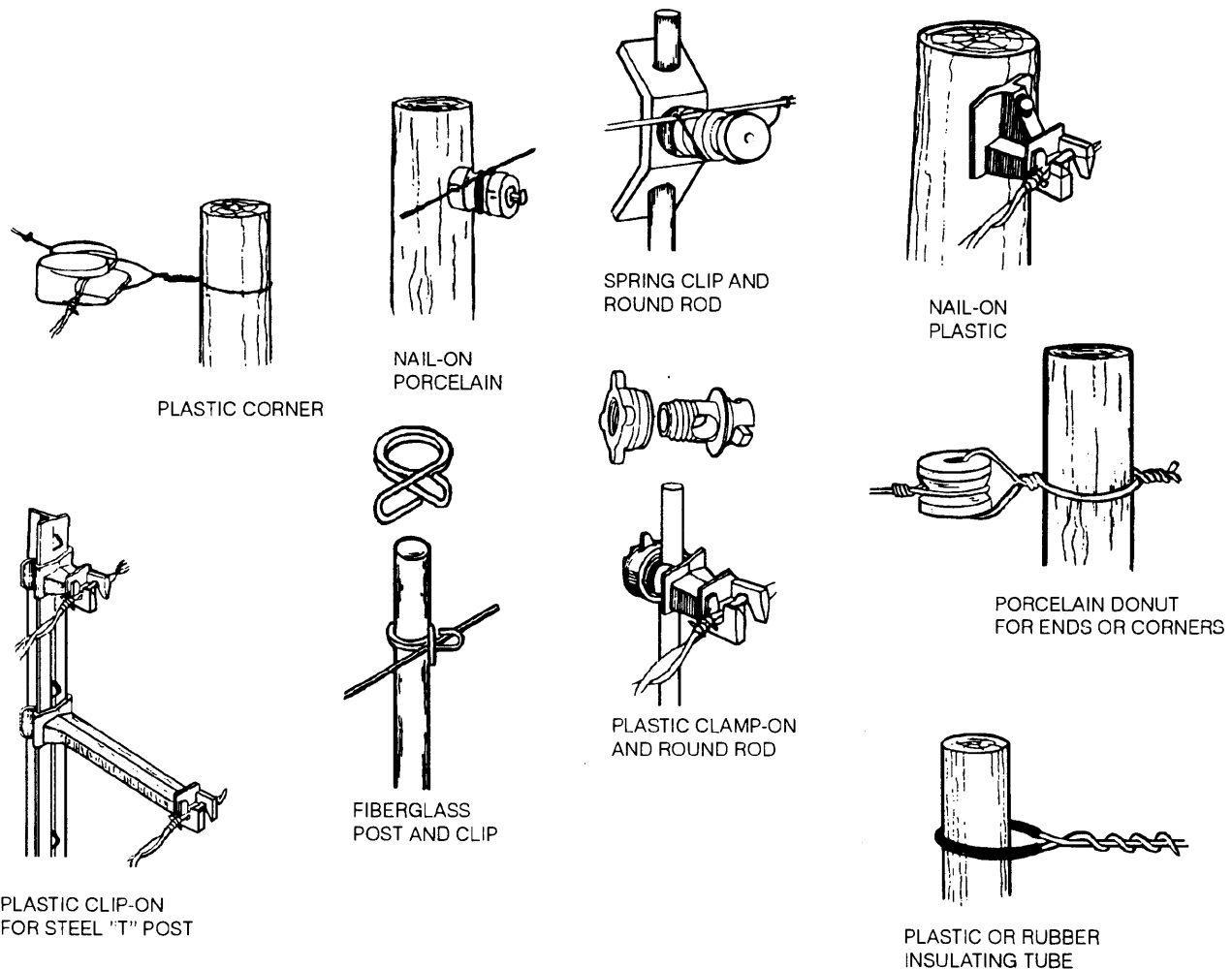
CRIMP-ON METAL SLEEVE

A new low-cost electric fence conductor is made of **special high-strength plastic polymers** and very **small gauge wires**. Thin strands of the plastic polymers are woven together with several strands of small stainless steel wire. The brightly colored plastic polymer strands provide strength, support, and excellent visibility. The smaller wires conduct the electrical current. Materials of this type are available in braided tape, twine, or netting form. They are easily spliced by simply tying tight knots.

Permanent barbed and high-tensile wire fences are often converted to electric fences by insulating and "energizing" one or more strands of existing wire. Insulators are used so that electrified strands do not touch other wires or posts. This application proves very useful for maintaining existing fences.

INSULATORS

The proper use of good insulators is essential for proper electric fence operation. Most insulators are made of plastic polymers or ceramic materials. Choose insulators that are compatible with the post and wire types used. Insulators must: 1) secure the conductors and 2) prevent accidental grounding. Insulators are secured to wooden posts with the use of nails or staples. Quality galvanized fasteners should be used where applicable.



Common Types of Electric Fence Insulators

Insulators for use with steel T-posts clip or slide into position. Some T-post insulators are extra long for offset fencing. Other designs which clamp around steel rods are available. Some styles of plastic polymer and fiberglass posts have clips or loops molded directly into them as standard features.

CONTROLLERS

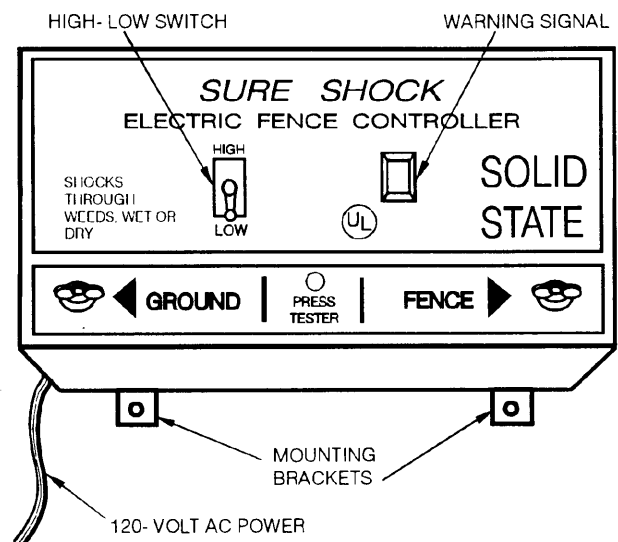
Electric fence controllers are also referred to as "fence chargers" or "fence energizers." All models should be **UL** safety approved and have fused protection devices. Special controllers can supply an adequate electrical charge for long lengths of conductors. Most models are now solid-state devices which have lower impedance (lower resistance) and produce higher voltage.

Solid State Controllers

Solid state controllers are more expensive, but are usually safer. Some models may be able to energize 10 to 50 miles of electric fence. Controllers use a transformer to increase voltage. The increased voltage may range from 1,000 to 10,000 volts. At the same time, the current is reduced to a safe level of only 0.025 to 0.040 amps. The higher voltage models are normally recommended to contain larger animals and to control predators and wildlife.

Solid state controllers can produce 45 to 65 electrical pulses per minute. Each pulse is very brief; usually only a small fraction of a second in length. Any object, animal, or plant that comes in contact with the conductor material produces a load on the controller. Weeds and brush growth should be kept to a minimum near electric fences to prevent accidental grounding.

Newer controller models are often referred to as "weed burners." They can provide enough voltage to "burn" and kill the growth-buds or new growth of small bushes, grass, or weeds. **Note!** The controller does not actually ignite the plant so that it burns, but prevents new growth of the plants from constantly touching the fence and shorting it out. Some models are equipped with a built-in **meter** or **warning light** to check operation and monitor maintenance needs.



"Electric Fence Charger"

The make and model of controller used will depend on: 1) personal preference, 2) type of animals to be contained, 3) number of conductors energized, and 4) the length of fence. Both indoor and outdoor models are available in 6-volt DC, 12-volt DC, or 110-volt AC models. Most 6 and 12-volt models can be used with an optional solar panel to recharge the storage battery.

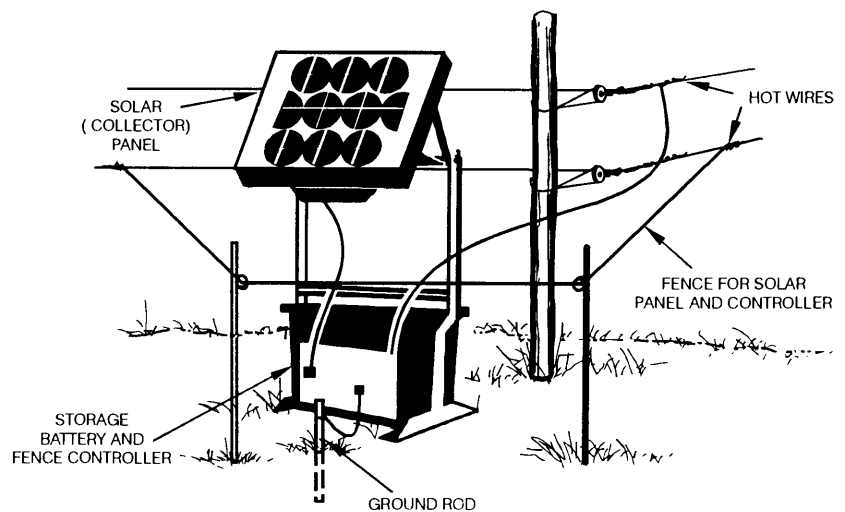
Twelve-volt controllers commonly use a wet-type storage battery as a power supply source. For this type of application, a heavy-duty, 12-volt marine type battery is recommended. These batteries are designed to withstand a deep discharge before recharging. Marine type batteries are also constructed with heavy-duty materials and are designed for more frequent recharging. When a 6-volt controller is used, choose a deep-cycling heavy-duty battery for best results.

Indoor and Outdoor Controllers

Fence controllers can be purchased in both **indoor or outdoor models**. All indoor controllers *must be* installed inside of a protective building to keep them dry.

Outdoor controllers are available in shock and weather-proof molded cases. These models are often used in remote areas where the only practical electrical power source is a storage battery. Battery life can be prolonged with good charging practices or with the aid of a "solar panel" recharger.

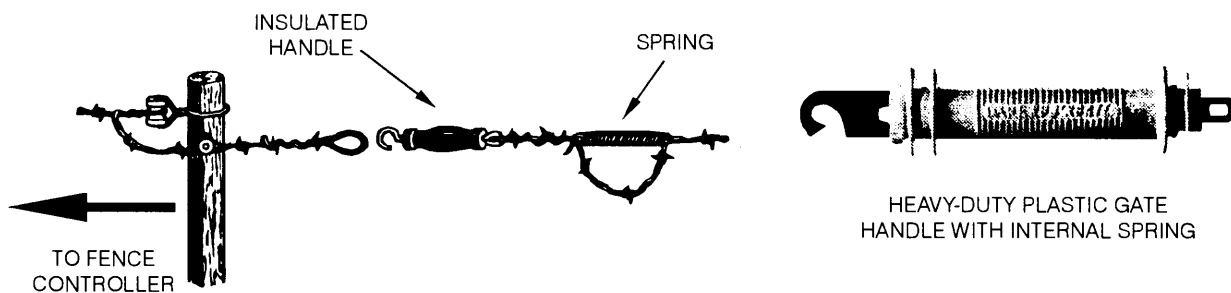
Outdoor models should be installed in a secure place and protected from livestock. To prevent unnecessary damage, a loop of wire is often used to create a "short section of fence" around the controller and battery area. Even though outdoor models are designed to be used without protective enclosures, it is wise to provide some sort of additional protection from the weather.



Self Contained Solar Powered Electric Fence Controller

ELECTRIFIED GATES

Gates and passages may also be electrified if desired. An insulated handle and a spring can be used to make an electric fence gate. Special gate fixtures and optional accessories are available at fencing supply stores. When installing an electric fence gate, the gate handle should be installed in the section of fence opposite the controller connection.



Electric Fence Gate

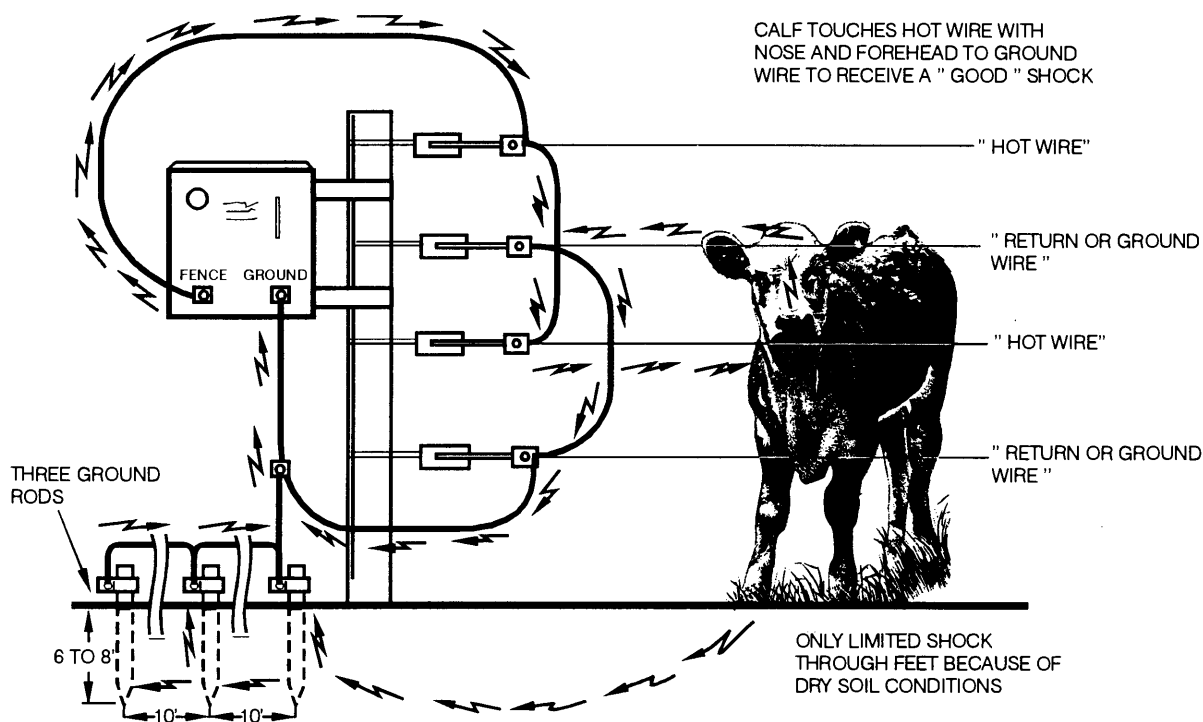
This will ensure that the fence will not be shorted out when the gate is opened and dropped to the ground. All connections must be maintained to ensure that the circuit is not open, broken, or shorted.

ELECTRIC FENCE HEIGHT RECOMMENDATIONS

Insulator height should be adjusted so that conductors are approximately two-thirds the height of the animals to be contained. Conductor location should be approximately 30" to 36" from the ground for most cattle. Placement for large hogs should be from 14" to 16", while installation for smaller pigs is from 6" to 8". Sheep should be contained with two conductors placed at 8" and 22" above the ground level.

PERMANENT ELECTRIC FENCES

Permanent electric fences are constructed using two to twelve smooth wires secured to strong, long-lasting posts. Corner and gate posts are constructed and braced in a similar manner as barbed and woven wire fences. Permanent electric fences can provide a 30 to 50% savings over conventional barbed or woven wire fences.



A Permanent Electric Fence with Two Hot Wires and Two Return Wires

Instead of using the earth as the return path for the ground as in temporary fences, one or more wires also serve as a grounded return to the fence charger. This provides a return circuit for the electrical current flow even when soil conditions are dry. Solid state electric fence controllers are available in models that provide power for large plots over 1,000 acres.

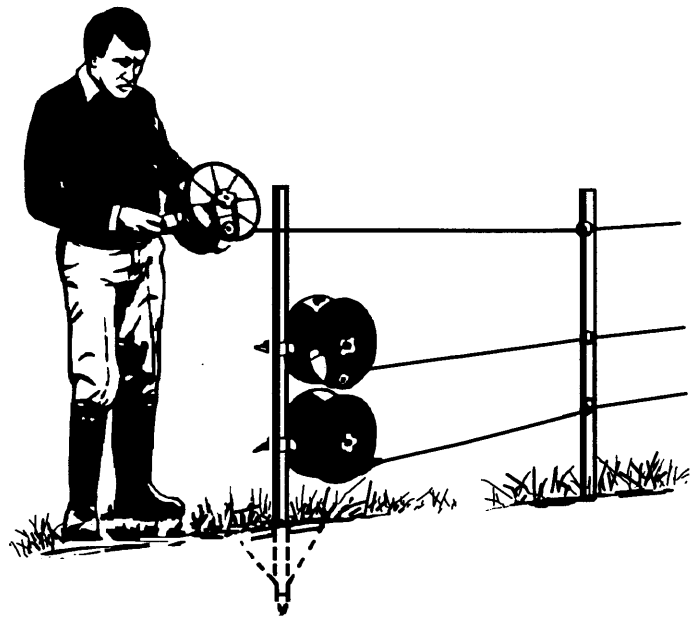
TEMPORARY AND PORTABLE ELECTRIC FENCES

Temporary fences are used to provide livestock control as the need arises. The moist earth is used to complete the electrical circuit and provide the shock. An indoor or outdoor controller is used to energize the conductor(s). Corner or end post often require a minimum of bracing, especially when short lengths of single conductors are used.

Smaller line posts, spaced further apart can often be used for temporary electric fences. When using temporary electric fences for cross fencing, the electric fence often starts and stops at a traditional or permanent fence line post. Care should be taken to ensure adequate protection from accidental grounding. Training of animals to respect the temporary fence is essential.

Temporary electric fence designs constantly change as new materials are introduced. New post and conductor designs allow for quick installation and removal of temporary electric fences. They are light-weight and easy to set up. These materials have gained popularity for portable applications.

Excess conductor materials can now be stored on **insulated storage reels** to prevent cutting and splicing. Portable temporary electric fences are often used to protect haystacks, waterways, gardens, etc. These inexpensive fences are easy to install and can be quickly rolled up and moved to create additional pastures or confinement areas.

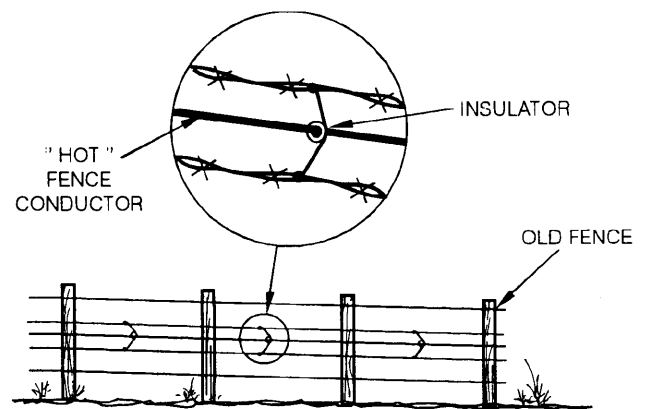


Temporary Fence Using Insulated Conductor Storage Reels

OFFSET ELECTRIC FENCES

Offset electric fences are used in some areas to protect existing permanent fences or to salvage old fencing. Often, the fences on rented or leased pasture land are in need of major repair. Existing fences or posts can be re-utilized with the use of an offset electric fence.

Offset brackets are installed to existing posts and/or wires. The brackets are equipped with an insulator. A new electric fence wire is then installed through the insulators. The brackets and insulators hold the new electric fence wire (conductor) approximately six to eight inches away from the old fence. This provides a cost effective alternative to repairing or replacing the entire fence. Offset electric fencing is also widely used to protect existing permanent fences from animal damage.



Offset Electric Fence Attached to an Old Permanent Fence

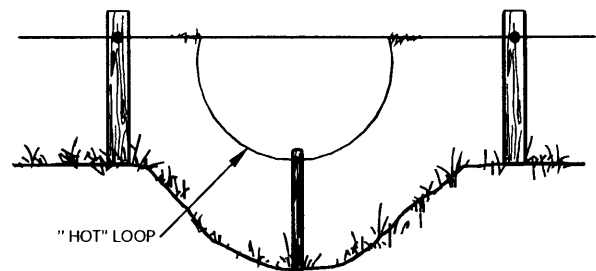
WILDLIFE AND PREDATOR FENCING

Specially designed and installed electric fences are useful as **wildlife and predator control barriers**. The height, wire spacing, and wire placement for these types of fences have been specially designed based upon animal behavior. When properly installed with the correct type of controller, these fences are highly effective for controlling deer and other types of wildlife.

LIVESTOCK TRAINING

Animals must be trained to respect an electric fence if it is to be effective. This is particularly true if only one or two strands of wire or approved conductor is used. Most animal can easily go over or under electric fences if not trained to respect them. When fences span ditches or gullies, install extra loops of wire to prevent animals from going under the main wire.

Training for most animals is done by placing a small quantity of feed on the opposite side of the fence just out of their reach. It is best to allow them to discover the feed on their own rather than try to drive them to it. The "lesson" is usually learned within one or two hours. This is an important consideration and should be used when initially setting up **all** electric fences, especially a temporary fence which encloses a small area.



"Hot Loop" Placed in Gully or Ditch

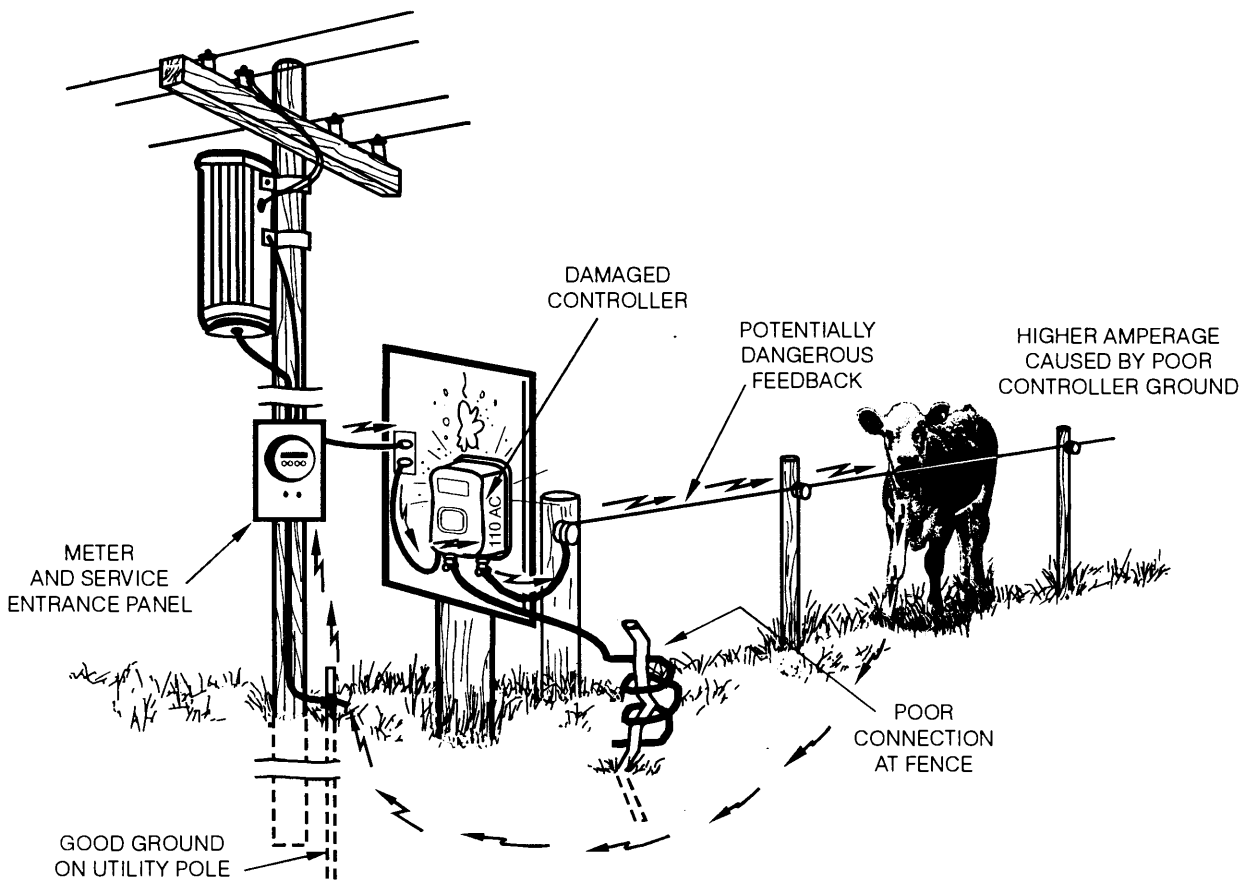
It is more difficult to give goats and sheep a shock through the wool or hair on their necks and backs. Therefore, they must touch a more sensitive area (their nose) to the conductor to receive an adequate shock. To train goats or sheep, attach an ear of corn, block of hay, or brightly colored objects to the conductor.

Because of curiosity, they will generally touch the fence with their noses and receive a mild shock. Some animals may gradually forget their training or learn to not touch the wire with a sensitive area. For this reason, electric fences may not be as effective in controlling sheep or goats as with other animals.

GROUNDING FOR ELECTRIC FENCES

For proper operation and safety, all 110-volt AC fence controllers should be used *only* on circuits equipped with an **equipment safety ground conductor** (third-prong ground). In addition, the fence controller *must* be grounded for proper fence operation. If the fence controller is not properly grounded, the electric fence may try to ground itself back through the power supply ground and neutral leg of the power supply circuit.

There is a chance the controller could become damaged. This could cause a potentially dangerous feedback through the power supply, controller, and electric fence. The feedback current could be of sufficient amperage to cause a serious electric shock or electrocution instead of a mild shock for only a fraction of a second. Always make sure controllers are properly grounded and power supply circuits are protected with the proper size fuse or circuit breaker.



Controller Damaged by Feedback Through Power Supply Circuit Due to Poor Connection at Fence Ground.

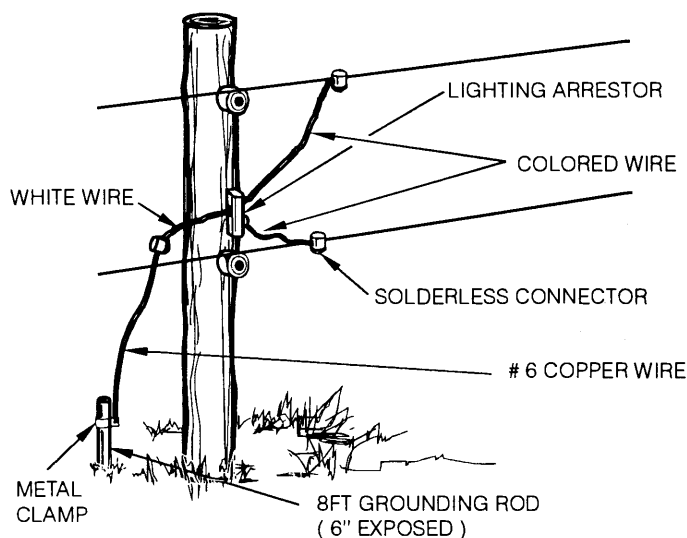
Proper controller grounding for 6 and 12-volt DC models is equally important. However, the potential from feedback damage is not as great. At least one ground rod should be driven into moist earth to provide adequate protection. Galvanized or copper-coated steel grounding rods driven into the earth six to eight-feet deep are recommended.

When connecting the ground wire to the ground rod, high-quality clamps should be used to prevent loose connections and reduce corrosion. Simply wrapping the ground wire around the ground rod is not adequate. Most controllers can be purchased with approved clamps and accessories for grounding.

Many controller manufacturers now recommend three ground rods installed 10 feet apart for adequate protection in dry soil conditions. *Do not* install controller ground rods within 10 feet of any utility, building, or barn electrical ground system. Always follow manufacturer's suggestions when installing any permanent or temporary electric fence grounding system.

LIGHTNING PROTECTION

Electric fences should be installed with approved lightning protection. **Lightning arrestors** are devices that allow excessive surges of voltage from lightning to jump a narrow gap and go directly to the earthen ground. If fences are not protected, surges will often damage controllers and/or injure livestock that may be standing next to the fence during a thunderstorm. Lightning arrestors should be used on *all wire fences*.



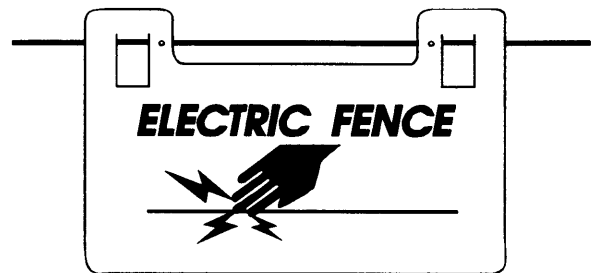
Lightning Protection for Electric Fencing

Arrestors should be installed at approximately every 300 feet along the fence line. Some models of controllers are equipped with built-in voltage surge protectors for additional protection from lightning.

ELECTRIC FENCE SAFETY

Electrified wire, especially barbed wire, is dangerous. If an animal becomes entangled, repeated shocks could result in serious injury or death. Electric fence chargers are designed to operate safely at specific amperages and voltages. Always follow owner's manual suggestions and *do not* attempt to alter, repair, or adjust a controller. An electric fence *should not* be installed beneath or in close proximity of overhead power lines.

Electric fences should be clearly marked at regular intervals. A sign not less than 4 by 8 inches should be used every 200 feet. In some states, this is required by law. Even if it is not required in your state, it is a good practice. Signs should be highly visible with letters one inch in height or larger. The words "Electric Fence" should be printed in black lettering on both sides.

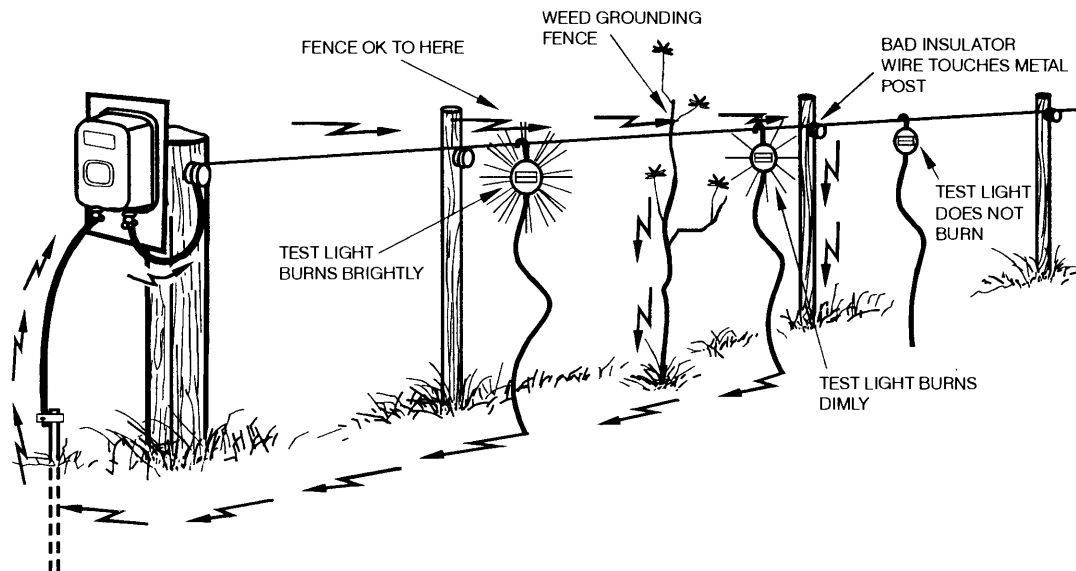


"Electric Fence" Warning Sign

Due to new technological advances in electronics, newer models are designed to decrease the risk of dry grass or brush catching fire. However, do not use flammable liquids when clearing fence lines of brush or weeds.

MAINTAINING AN ELECTRIC FENCE

Proper maintenance of an electric fence is required for proper operation. A **digital volt meter** capable of measuring up to 10,000 volts can be used to check the exact controller output. The voltage should be measured at the controller and at various locations along the fence. As voltage decreases, a person can isolate the location of bad insulators or points where weeds or grass may be grounding out the fence.



Using a Test Light to Check Electric Fence Operation

Less expensive **electric fence test lights** can also be used. Most testers are equipped with small neon light bulbs. The test light is hooked on the electric fence wire or conductor. The wire lead with a short metal test probe is inserted into the moist earth. If the light bulb burns brightly, the fence is "hot." The brighter the bulb burns, the more voltage or the "hotter" the electric fence. When the light bulb does not burn or burns dimly, the fence is grounded somewhere between the controller and point where the test is being made.

It may be necessary to periodically walk the fence and check for damaged posts or insulators, or to see if grass, weeds, or brush have grown up into the conductor. It may also be necessary to clean and tighten connections at the controller and at the grounding rods to maintain proper operation.

SUMMARY

All electric fence controllers *must be* grounded at the ground rod for proper operation. All 110V AC controllers must be grounded both at the power supply cord and at the grounding rod for proper operation. Lightning arrestors should be used on several line posts in each span of fence. If the controller is an indoor type, place it in a ventilated area and keep it clean and dry.

Battery operated units should be checked and cleaned routinely. A dangerous condition can result when a short or spark is allowed near a battery. When wet-type storage batteries are being discharged or charged, they release a highly flammable hydrogen sulfide gas. Always wear gloves and approved eye protection when working near battery operated fence controllers. Always follow controller operator's manual or consult local suppliers for specific information.

REFERENCES

Kencove Farm Fence, Blairsville, PA.

Parmak Electric Fencers - Installation and Operating Instructions, Parker McCrory Mfg. Co., Kansas City, MO.

Building Fences, American Association For Vocational Instructional Materials, Athens, GA.

Planning Fences, American Association For Vocational Instructional Materials, Athens, GA.

Acknowledgements

Mr. Donald G. Krobot, Intern, Department of Agricultural Education, Texas A&M University, and Dr. Joe Muller, Curriculum Specialist, Instructional Materials Service, developed and organized the information in this topic.

SUGGESTED STUDENT ACTIVITIES

TRUE OF FALSE: Circle "T" if the statement is more true than false. Circle "F" if the statement is more false than true.

- T F 1. Livestock training is not important when initially setting up an electric fence.
- T F 2. Indoor controllers should only be installed in a protected dry area.
- T F 3. Cross bracing is not recommended for permanent electric fences.
- T F 4. Electric fences can be electrified by lightning which may injure livestock or damage the fence controller.
- T F 5. Insulators are used so that electrified conductors do not touch other wires, posts, or other materials and cause accidental grounding.

FILL-IN-THE-BLANKS: Complete the following statements by inserting the correct word(s) in the blanks provided.

- _____ 6. _____ fences are used to protect existing fences from damage by livestock and wildlife.
- _____ 7. Fence controllers must be _____ for safety and proper operation.
- _____ 8. An electric fence should not be installed beneath or close to _____.
- _____ 9. A sign, _____ (size) should be used to mark electric fences every 200 feet.
- _____ 10. A _____ or neon test light can be used to check fence controller output.

SHORT ANSWER: Answer the following items in a sentence, phrase, or short paragraph.

11. Briefly explain why 110-volt electric fence controllers must be properly grounded and connected to a circuit equipped with a equipment safety ground conductor (third-prong ground).
12. Describe how to "train" livestock to respect an electric fence.
13. Describe how the "shock" is transferred to the animal and back to the "ground" when an electric fence is used.

14. Explain why rusty or large gauges of wire are not recommended for use as conductor material.
15. Describe how solar panels are used with electric fence controllers.
16. Describe the materials that are commonly used as conductors for electric fences. (Give examples.)

-NOTES-

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