

Unit I – Common Power Tools

Lesson I: Safe Use and Maintenance of Power Tools for Woodworking

Many woodworking tasks in agricultural mechanics are done with power tools because their speed and efficiency can make woodworking tasks much quicker and easier. Before using power tools for woodworking, it is essential to be familiar with the parts and functions of the tools and to know how to operate them safely. This lesson identifies some common power tools (portable and stationary) and discusses safety precautions and maintenance procedures related to these tools.

Basic Procedures for Shop Safety

Each year many agricultural workers incur injuries while working with power tools. Unsafe use of power tools can result in injuries ranging from minor cuts and bruises to severe lacerations, finger amputations, and eye punctures from flying objects. Massive bleeding from severe injuries and electrocution can cause death. Tool operators sometimes add to the hazards by taking shortcuts to save time, disregarding warnings, not knowing how a tool works, and not using safety precautions appropriate for each tool.

The following are general safety procedures for working in a shop area. Safety precautions for specific tools are discussed later in this lesson.

- Adhere to instructions.
 - Read labels and warnings on containers and tools.
 - Follow the manufacturer's recommendations for use and maintenance of a specific tool.
 - Pay attention to signs posted in the work area.
 - Follow the instructor's directions.
- Wear safety glasses at all times in the shop.
- Wear protective gear such as gloves, earplugs, and safety shoes if appropriate.
- Do not wear loose-fitting clothing that could get caught in a moving part.
- Wear a hair net to prevent long hair from getting caught in a tool.
- Keep work areas clean and free of clutter.

- Inspect each tool before using it to make sure it is working properly.
- Tell the instructor about any damaged tool.
- Do not use a tool that is not working properly.
- Return each tool to its proper place of storage.

Common Sources of Power for Woodworking Tools

Power tools used in agricultural mechanics are powered by various means. Electricity, including battery packs, and compressed air (pneumatic power) are common sources of power for woodworking tools. In addition to the general safety precautions listed above, there are specific safety precautions for each of these types of power.

Safety Precautions for Electric and Pneumatic Power Tools

Electric and Battery-Powered Tools

- Always unplug a tool or disconnect it from its battery before inspecting it and making adjustments.
- Only use a tool that is double insulated or has a grounded plug.
- Always plug a tool into an outlet with a ground-fault circuit interrupter (GFCI or GFI). A GFCI will shut off the power if a short occurs. If an outlet is not equipped with a GFCI, a portable GFCI can be plugged into a grounded outlet.
- Do not stand on wet ground or a wet surface while operating an electric tool.
- Make sure stationary power tools are anchored to the floor.
- Make sure all guards and shields are in place and vents are clear of debris before turning on a tool.
- Do not bend the power cord sharply, do not use the cord to pull the plug from the outlet, and do not use the cord to carry the tool. Such actions could break the cord. A broken power cord could cause an electrical shock.
- Use only the battery specified by the manufacturer for the tool being used.
- Use only the type of recharger designed for the batteries being used.

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- Always store battery packs safely so that no metal can come in contact with the terminals. This can short-circuit the battery and cause sparks, fire, or burns.

Pneumatic Power Tools

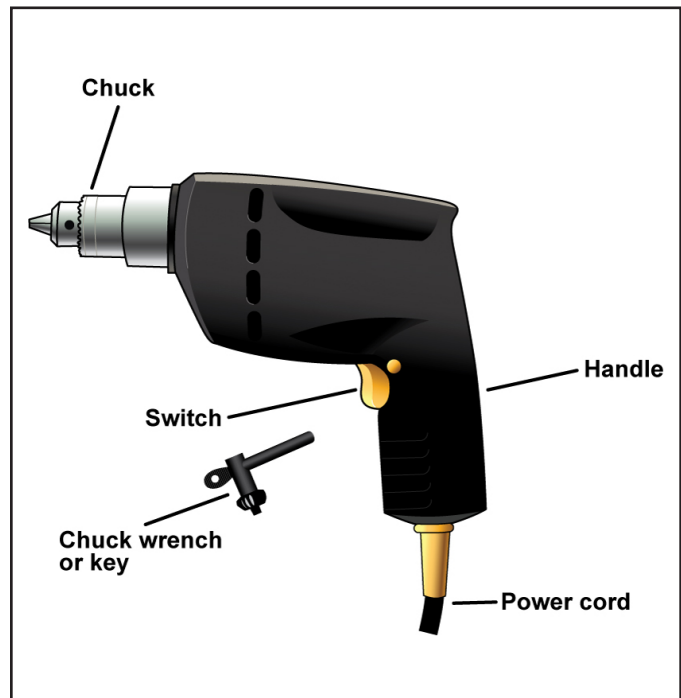
- Disconnect pneumatic tools for all inspections and adjustments.
- Do not join or separate quick-disconnect couplings on high-pressure lines when bystanders are nearby.
- Do not use compressed air for cleanup if the air pressure is 30 lb per sq in. (psi) or greater.
- Do not point an air stream at anyone. High-pressure air can drive dust into the eyes, damage eardrums, or cause other injuries.
- Check couplings and air lines for evidence of wear and damage.
- Make sure air tanks and lines are free of moisture and appropriate filters are in place.
- Follow the manufacturer's recommendations for hose size and maximum air pressure.
- Oil pneumatic tools regularly according to manufacturer recommendations.

Portable Drills

Portable power tools, such as a drill, are particularly useful because they can easily be taken to the job site, do not require extensive setup, and are relatively affordable. Main parts of a portable drill include an on/off switch, power cord, handle, chuck (the part that holds the drill bit), and chuck key. See Figure 1.1. A chuck key is used to loosen and tighten the chuck. Portable drills are used to do various woodworking jobs, such as drilling and boring, driving and removing screws, and operating hole saws. Drills can also be used for sanding and polishing wood.

Portable drills come in different sizes. The size of a drill is based on the maximum size of drill bit that the chuck will hold. For example, with a 1/4-in. drill, the chuck holds a bit with a shank that is no larger than 1/4 in. Some drills have only one motor speed while others have different speeds. Variable-speed drills are useful for driving screws. Screws can be removed by using the reverse setting.

Figure 1.1 – Portable Drill



Safety precautions for a portable drill include the following:

- Choose the right drill bit for the job. For example, do not put a square-shank bit in an electric drill.
- Make sure the bit is tight in the chuck. Use the key in each hole of the chuck to tighten the bit. Be sure to remove the chuck key before starting the drill to avoid throwing the key.
- Make sure work is held securely in place. Use a clamp or vise to hold a small piece of work.
- Hold the drill perpendicular to the work to avoid binding the bit.
- Remove the bit from the drill after completing the job.

Basic maintenance procedures for a portable drill include the following:

- Keep parts lubricated according to the manufacturer's instructions.
- Sharpen or replace dulled drill bits.

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Portable Circular Saws

Portable circular saws are available in different sizes. Main parts of a circular saw include an on/off switch, power cord, angle scale (used for setting the depth of the blade's cut), base, angle adjustment lock, handle, blade guard, and blade. See Figures I.2 and I.3. The size of a circular saw is determined by the diameter of the largest blade it will hold.

Figure I.2 – Portable Circular Saw

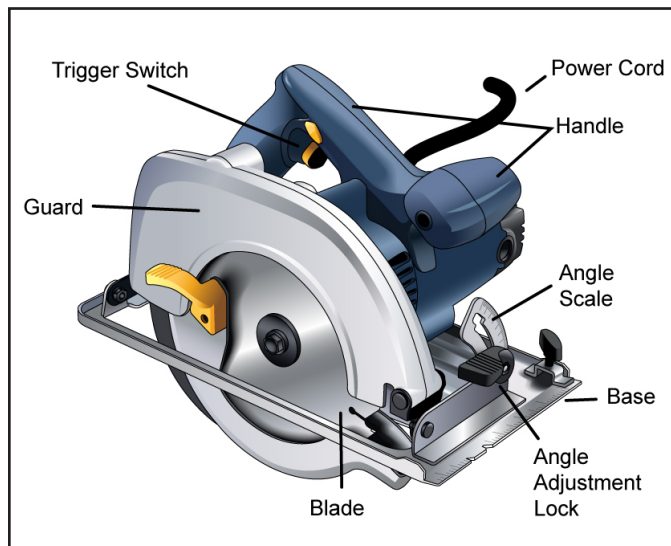


Figure I.3 – Using a Circular Saw



As the saw's name suggests, the blade of a circular saw is round and it spins in a circle during cutting. Circular saws are commonly used for making rip cuts, crosscuts, bevel cuts, and angle cuts for mitering. Different types of blades are used for different kinds of cuts. For example, a blade with large teeth may be chosen for fast, rough cutting and a blade with small teeth may be chosen for finer cutting. The blade can be adjusted to cut at different depths. Because the blade rotates upward, splintering occurs on the topside of the piece. For this reason, the best side of the piece should be placed face down when sawing with a circular saw.

Safety precautions for a portable circular saw include the following:

- Choose the right blade for the cut.
- Make sure base and angle adjustments are correct for the cut and are tightly in place.
- Back the saw slightly away from the work before turning it on.
- Allow the saw to reach full speed before beginning to cut.
- Cut only in a straight line to avoid binding the blade.
- Wait until the blade stops moving before setting the saw down.

Basic maintenance procedures for a portable circular saw include the following:

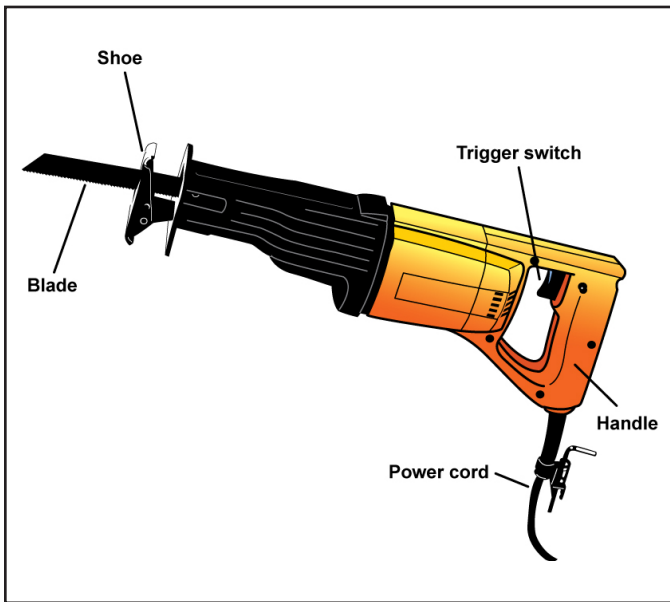
- Make sure the blade guard always moves freely. Small pieces of wood can become caught in the blade guard, preventing it from covering the blade properly when the saw is not in use.
- Clean, sharpen, or replace blades that are gummy or dull.

Reciprocating Saws

A reciprocating saw is another common portable power tool that is useful for work in close areas where it would be difficult to operate a circular saw. Main parts of a reciprocating saw include an on/off switch, power cord, handle, shoe, and blade. See Figure I.4. With this saw, the blade moves up and down. The shoe is placed against the work for stability. The shoe can be adjusted in or out to

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Figure 1.4 – Reciprocating Saw



Basic maintenance procedures for a reciprocating saw include the following:

- Follow the manufacturer's recommendations for regular service.
- Inspect and replace blades as needed.

Band Saws

A band saw is a large machine that must be anchored to the floor. Main parts of a band saw include an on/off switch, upper and lower wheels and wheel guards, table, upper and lower blade guides, and arm. The wheels, guards, and blade guides are located above and below the table. See Figure 1.5. The blade is thin and forms a continuous loop that runs over the two wheels and through the two blade guides.

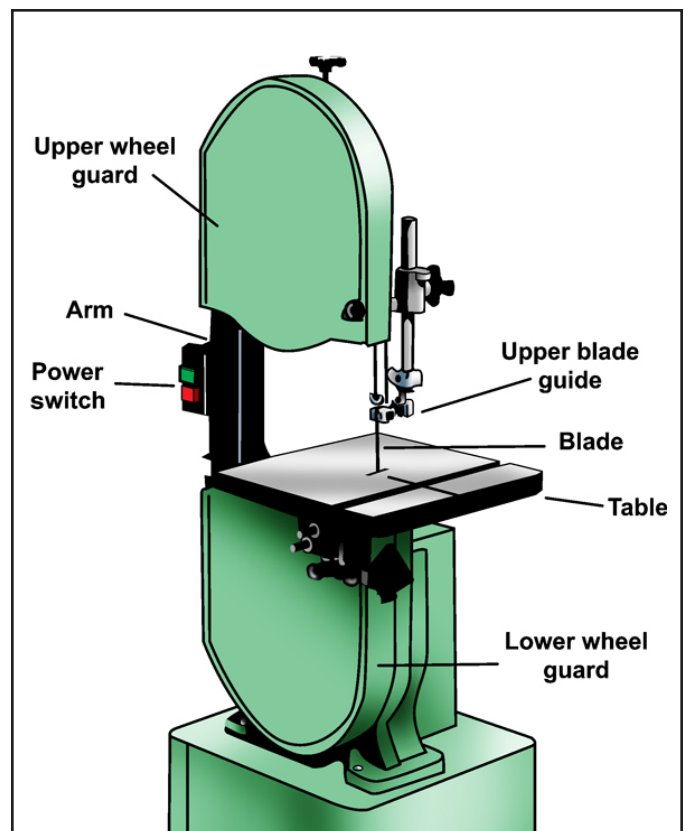
control the depth of the cut. Different kinds of blades can be used to make different types of cuts.

This heavy-duty saw can be used to make relief cuts, irregular cuts, crosscuts, and pocket cuts. Relief cuts are made in the waste portion of a piece, almost to the actual cutting line. Relief cuts can be a helpful step for creating curved edges in a piece. Pocket cuts are made at the edge of a piece to form a three-sided indentation, or pocket, at the edge. The blades for a reciprocating saw have a narrow and straight shape and are available in different types for cutting wood, metal, plastic, and plaster.

Safety precautions for a reciprocating saw include the following:

- Choose the right blade for the cut.
- Choose the right speed for the cut. Use a low speed to cut dense, hard material and a high speed to cut softer material.
- Make sure the saw is at working speed before cutting.
- Hold the shoe against the work at all times.

Figure 1.5 – Band Saw



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The size of a band saw is determined by the diameter of its wheels. For example, a 14-in. band saw has 14-in. wheels. Band saws can be used for making straight and irregular cuts, arcs, curves, and bevels. Band saw blades vary in width, thickness, teeth size, and teeth spacing. A narrower blade has fine teeth and is used for cutting sharp curves. A wider blade has coarse teeth and is used for cutting large curves.

Safety precautions for a band saw include the following:

- Use the right blade for the cut. Teeth should be pointing downward.
- Make sure the blade tension is tight.
- Place the guide within 1/2 in. of the work.
- Take special care in planning the cut, making sure that both the work piece and the waste piece of wood can be controlled so neither one hits the arm of the saw.
- Turn off the saw immediately if the blade “clicks” or breaks. A clicking noise could mean that the blade is cracked.
- Turn off the saw before backing out of a cut.

Basic maintenance procedures for a band saw include the following:

- Maintain proper blade tension.
- Maintain proper blade tracking. The blade should stay in the center of the wheels.
- Repair or replace broken blades.

Table Saws

A table saw works similarly to a portable circular saw, but it is much larger and is anchored to the floor. Main parts of a table saw include an on/off switch, blade height adjustment wheel, rip fence, miter groove, blade guard, table, and blade angle adjustment wheel. See Figure 1.6. This stationary saw is equipped with either a tilting table or a tilting arbor, which can be adjusted for making angle cuts. The blade is mounted in the tilting arbor. The rip fence acts as a guide for making straight cuts. A push stick is used for making rip cuts in narrow or short pieces. See Figure 1.7.

Figure 1.6 – Table Saw

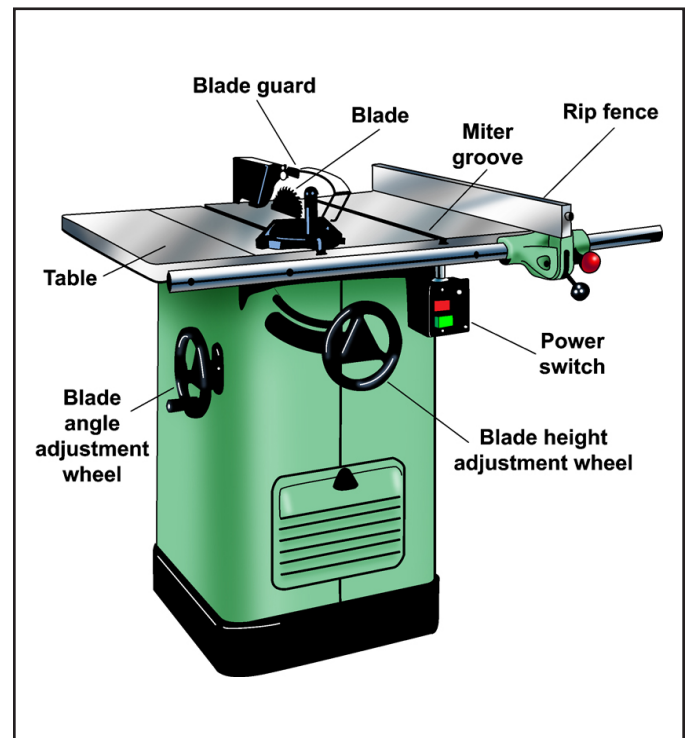
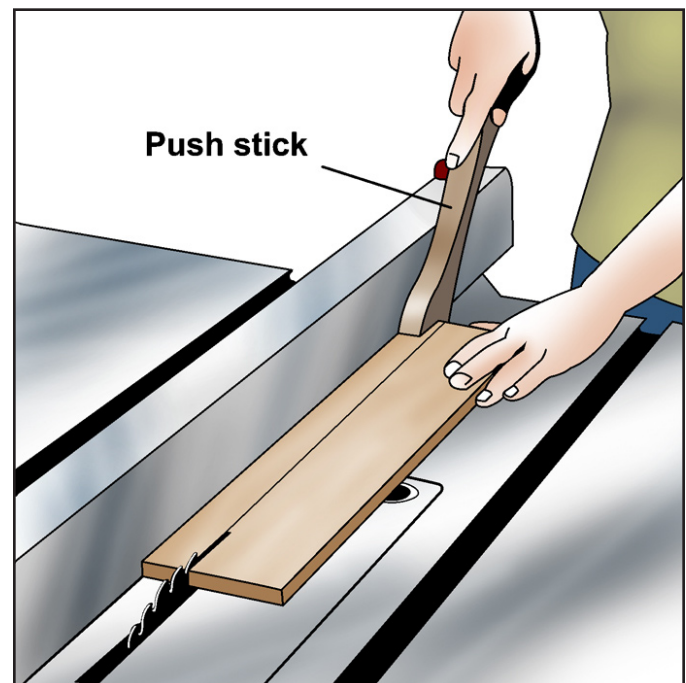


Figure 1.7 – Using a Push Stick When Cutting With a Table Saw



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Different types of blades are used for ripping, crosscutting, mitering, beveling, and joint making. Certain types of blades can perform special functions such as cutting dados. The size of a table saw is determined by the largest diameter of blade it can hold. An 8-in. saw is useful for cutting small pieces and a 10-in. or 12-in. saw is useful for cutting large pieces or making rough cuts.

Safety precautions for a table saw include the following:

- Check the blade. Make sure it is right for the cut and make sure the teeth point in the direction of the blade's rotation.
- Adjust the blade to the correct angle and height for the cut.
- Stand to the side of the blade and do not reach across the table.
- Keep hands at least 6 in. from the blade.
- Use a push stick for guiding small pieces.

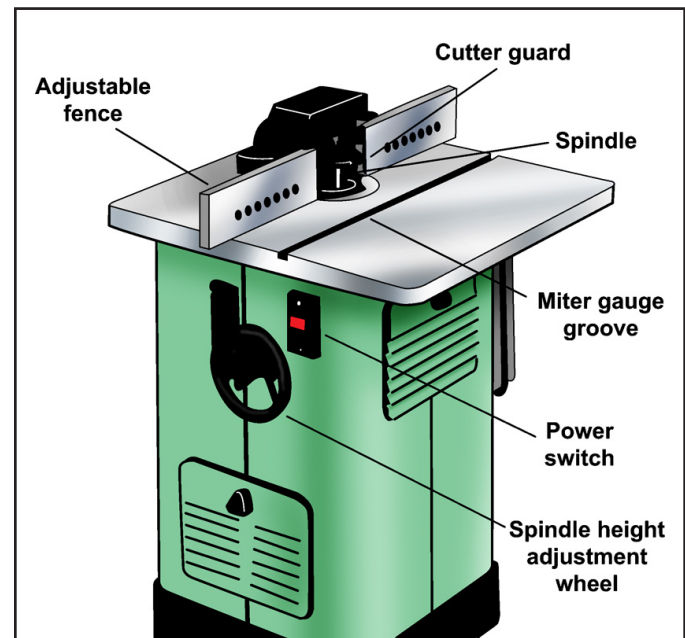
Basic maintenance procedures for a table saw include the following:

- Check the blade to be sure it is not warped.
- Regularly remove sawdust. A collection of sawdust could cause the motor to overheat.
- Use silicone or powdered graphite, not oil, on screw threads to keep them moving freely. With oil, screw threads could become gummed up with sawdust.
- Remove rust on unpainted parts with oiled steel wool.
- Remove excess oil after cleaning with steel wool and coat the area with paste wax.

Shapers

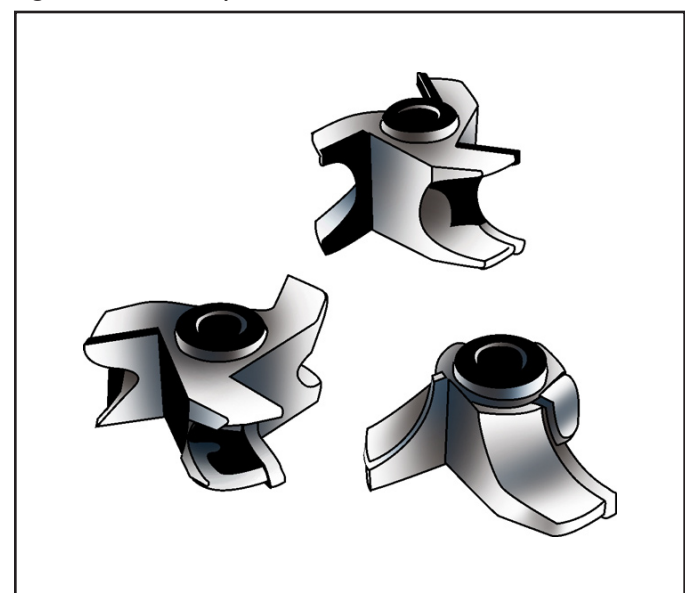
A shaper is a stationary power tool that is used for shaping edges, making moldings, and cutting joints. Main parts of a shaper include an on/off switch, spindle height adjustment wheel, miter gauge groove, spindle, cutter guard, and adjustable fence. See Figure 1.8. The spindle holds the cutter. The adjustable fence is used as a guide for straight cuts.

Figure 1.8 – Shaper



Cutters come in different shapes for making cuts of different patterns, including decorative edges. See Figure 1.9. The size of the shaper is determined by the diameter of the spindle.

Figure 1.9 – Examples of Different Cutters



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Safety precautions for a shaper include the following:

- Check all adjustments and locking nuts before using the machine.
- Check the rotation of the cutter and feed the work into the cutter opposite the direction of rotation.
- Make sure the piece has no warps or cracks that could cause it to be thrown.
- Always use proper guards and clamps.
- Use a holder or a push stick to guide the work when the piece is less than 1 ft in length.

Basic maintenance procedures for a shaper include the following:

- Follow the manufacturer's recommendations for lubrication. Oil is generally a good lubricant for areas where sawdust does not collect. Silicone is good for areas where sawdust collects.
- Inspect belts and follow the manufacturer's specifications for proper tension.

Jointers

Jointers come in different sizes and do functions similar to those of a hand plane. Small jointers are portable and large jointers are stationary. Main parts of a jointer include an on/off switch, infeed table adjustment levers, infeed table, tilting fence, cutter guard, cutterhead, and outfeed table. See Figure 1.10. The three main adjustable parts are the infeed table, tilting fence, and outfeed table. The outfeed table must be set at the same height as the cutter edges at the highest point of their rotation. See Figure 1.11. This adjustment is important to avoid tapering or biting the surface.

Jointers are used for planing edges and surfaces and for cutting bevels and chamfers. The jointer is equipped with a cylinder that holds knife blades. This cylinder is called the cutterhead. The length of the knife blades determines the size of the jointer and the maximum width of board it will cut.

Figure 1.10 – Jointer

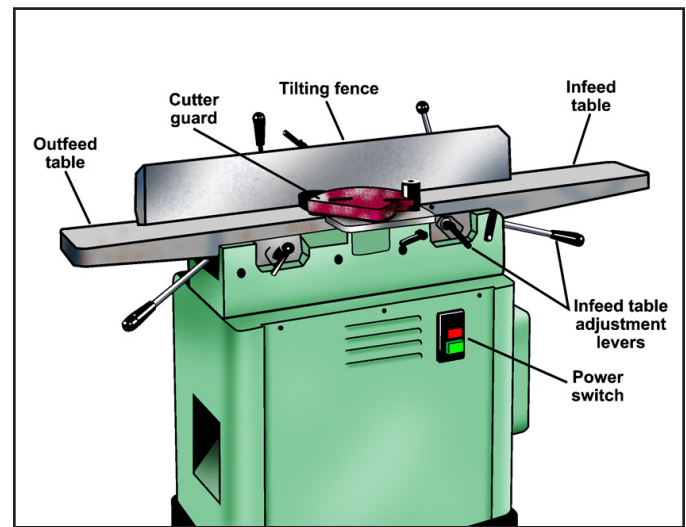
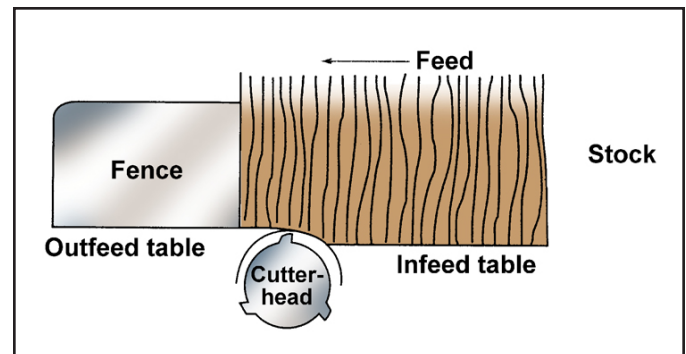


Figure 1.11 – Proper Adjustment of Outfeed Table on Jointer



Safety precautions for a jointer include the following:

- Make sure the table and fence adjustments are correct for the job. Do not exceed the recommended maximum cuts.
- Do not use the machine to work on a piece that is less than 12 in. long or less than 3/8 in. thick.
- Cut with the grain of the wood.
- Make sure the piece is free of knots and splits.
- Keep hands at least 6 in. from the cutterhead.
- Use a push stick and feather board when necessary.

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Basic maintenance procedures for a jointer include the following:

- Keep knives sharp. Dull knives can cause kickback.
- Follow the manufacturer's recommendations for lubricating the machine. It may be necessary to take some of the machine apart to reach places that require lubrication.
- Replace sealed bearings when they are worn.

Summary

Power tools can help make woodworking tasks quick, but they are dangerous. To prevent injury, users must follow general safety precautions and specific safety measures for each type of tool. Electricity, batteries, and compressed air are common sources of power for woodworking tools and there are general safety measures for electric and pneumatic power tools. Common portable power tools include portable drills, circular saws, and reciprocating saws. Larger stationary machines include band saws, table saws, shapers, and jointers.

Credits

Agricultural Construction: Volume II. University of Missouri-Columbia: Instructional Materials Laboratory, July 1989.

Becker, W.J. *Safety with Hand and Power Tools.* University of Florida. Accessed January 28, 2002, from <http://www.cdc.gov/niosh/nasd/docs/as02400.html>.

Brodhead Garrett Tools for Teaching. 2002 Catalog.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Electric Tools – Basic Safety. Canadian Centre for Occupational Health and Safety, 1998. Accessed May 2, 2002, from http://www.ccohs.ca/oshanswers/safety_haz/Power_tools/saf_elec.html.

Exploring Agriculture in America. University of Missouri-Columbia: Instructional Materials Laboratory, June 2000.

Feirer, J.L. *Furniture and Cabinet Making.* Peoria, IL: Bennett Publishing Company, 1983.

Margentino, M.R., Malinowski, K. *Farm Machinery and Equipment Safety Part I: Recognizing and Understanding the Hazards.* Rutgers Cooperative Extension. Accessed January 29, 2002, from <http://www.cdc.gov/niosh/nasd/docs2/as16700.html>.

Umstattd, W.D., Davis, C.W. *Modern Cabinetmaking.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Wagner, W.H., Kicklighter, C.E. *Modern Woodworking.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1996.

Wagner, W.H., Smith, H.B. *Modern Carpentry.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Zimmerman, F.W., McWard, L.J. *Exploring Woodworking: Fundamentals of Technology.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1999.

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Lesson 2: Safe Use and Maintenance of Power Tools for Metalworking

Many of the machines, tools, and buildings used in agriculture are made of metal and thus a thorough knowledge of power tools for metalworking is essential when working in agricultural mechanics. Before using power tools for metalworking, it is essential to be familiar with the parts and functions of the tools and to know how to operate them safely. This lesson will identify some common power tools (portable and stationary) and discuss safety precautions and maintenance procedures related to these tools.

Basic Procedures for Shop Safety

Each year many agricultural workers incur injuries while working with power tools. These injuries range from minor cuts and bruises to severe lacerations, finger amputations, and eye punctures from flying debris. Massive bleeding from severe injuries and electrocution can cause death. Tool operators sometimes add to the hazards by taking shortcuts to save time, disregarding warnings, and not using safety precautions appropriate for each tool.

The following are general safety procedures for working in a shop area. Safety procedures for specific metalworking tools are discussed later in this lesson.

- Adhere to instructions from the following sources:
 - Labels and warnings on containers and tools
 - The manufacturer's recommendations for use and maintenance of specific power tools
 - Signs posted in the work area
 - Directions given by the instructor
- Wear safety glasses in the shop at all times.
- Wear protective gear, such as gloves, earplugs, and safety shoes, if appropriate.
- Do not wear loose-fitting clothing that could get caught in a moving part.
- Wear a hair net to prevent long hair from getting caught in a tool.
- Keep work areas clean and free of clutter.
- Inspect each tool before using it to make sure it is working properly.

- Tell the instructor about any damaged tool.
- Do not use a tool that does not function properly.
- Return each tool to its proper storage place.

Common Power Sources for Metalworking Tools

Electricity, including battery packs, and compressed air (pneumatic) are two of the most common sources of power for metalworking tools. In addition to the general safety precautions listed above, there are specific safety considerations for each of these types of power.

Safety Precautions for Electric and Pneumatic Power Tools

Electric and Battery-Powered Tools

- Always unplug a tool or disconnect it from its battery before inspecting it and making adjustments.
- Only use a tool that is double insulated or has a grounded plug.
- Always plug a tool into an outlet with a ground-fault circuit interrupter (GFCI or GFI), which will shut off the power if a short occurs. If an outlet is not equipped with a GFCI, a portable GFCI can be plugged into a grounded outlet.
- Do not stand on wet ground or a wet surface while operating an electric tool.
- Make sure stationary power tools are securely anchored to the bench or floor.
- Make sure guards and shields are in place and vents are clear of debris before turning on a tool.
- Do not bend a power cord sharply, do not use a cord to pull the plug from the outlet, and do not use a cord to carry the tool. Broken power cords can cause an electrical shock.
- Use only the battery specified by the manufacturer for the tool being used.
- Use only the type of recharger designed for the batteries being used.
- Always store battery packs safely so that no metal can come in contact with the terminals. This can short-circuit the battery and cause sparks, fire, or burns.

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Pneumatic Power Tools

- Disconnect pneumatic tools for all inspections and adjustments.
- Do not join or separate quick-disconnect couplings on high-pressure lines when bystanders are nearby.
- Do not use compressed air for cleanup if the pressure is 30 lb per sq in. (psi) or greater.
- Do not point an air stream at anyone. High-pressure air can drive dust into the eyes, damage eardrums, and cause other injuries.
- Inspect couplings and air lines regularly for evidence of wear and damage.
- Make sure air tanks and air lines are free of moisture and appropriate filters are in place.
- Follow the manufacturer's recommendations for hose size and maximum air pressure.
- Oil pneumatic tools regularly according to the manufacturer's recommendations.

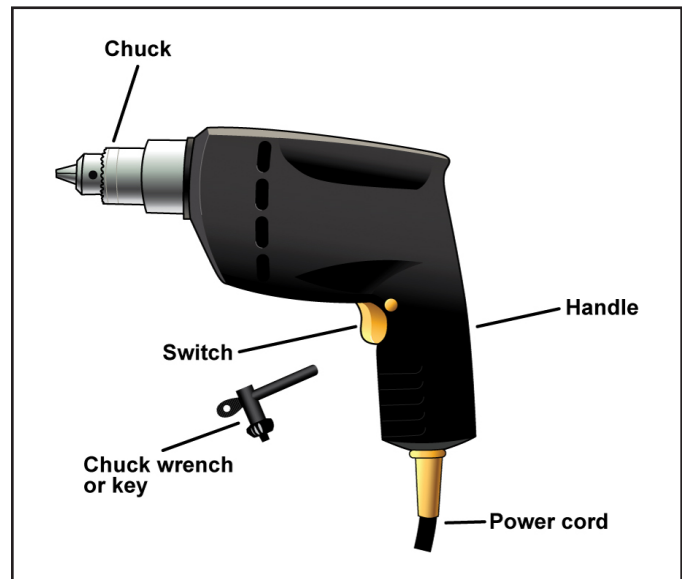
Portable Drills

Portable power tools, such as a drill, are particularly useful because they are easy to take to the job site, do not require extensive setup, and are relatively affordable. Main parts of a portable drill include an on/off switch, power cord, handle, chuck (the part that holds the drill bit), and chuck key. See Figure 2.1. A chuck key, or wrench, is used to loosen and tighten the drill bit in the chuck. In metalworking, the word "drill" is often used to refer to a drill bit.

Depending on the type of drill bit, portable drills are used for many tasks in metalworking, including drilling and boring, driving and removing screws, sanding, polishing, and powering hole saws. Portable drills come in different sizes. The size of a drill is determined by the maximum size of drill bit the chuck will hold. For example, a 1/4-in. drill will hold a bit with a shank no larger than 1/4 in. Many specialized metalworking drills are also available.

The basic drill bit used in metalworking is a general-purpose one that can be used on a number of materials and in a variety of situations. Drill bits used in metalworking are commonly made of carbon steel, high-speed steel, and cemented carbide. Of these three materials, carbon steel

Figure 2.1 – Portable Drill



is the weakest and cemented carbide is the strongest. High-speed steel withstands higher speeds and lasts longer than carbon steel. Cemented carbide withstands very high speeds and outlasts high-speed steel and carbon steel.

Some drills have only one motor speed while others have different speeds. Variable-speed drills are useful for driving screws. Screws can be removed by using the reverse setting.

Safety considerations for a portable power drill include the following:

- Choose the right drill bit for the job. For example, do not use a square-shank bit in an electric drill.
- Make sure the bit is tight in the chuck. Use the chuck key in each hole of the chuck to tighten the bit. Be sure to remove the key before starting the drill to avoid throwing the key.
- Use a center punch to mark stock when working with metal. The indentation helps guide the bit.
- Make sure the work is held securely in place. Use a clamp or vise to hold a small piece.
- Hold the drill perpendicular to the piece to avoid binding the bit.
- Remove the bit from the drill after completing the job.

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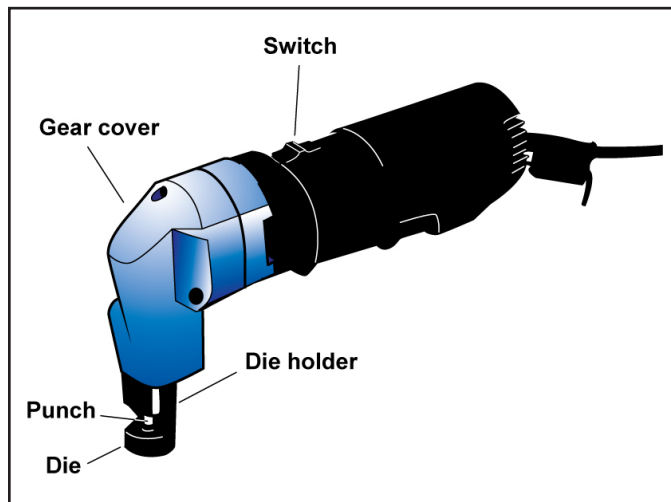
Maintenance considerations for a portable power drill include the following:

- Keep parts lubricated according to the manufacturer's instructions.
- Sharpen or replace dulled drill bits.

Portable Power Nibblers

Portable power nibblers are convenient for taking to the work site to cut sheet metal quickly and efficiently. Main parts of a power nibbler include an on/off switch, gear cover, punch, die, and die holder. See Figure 2.2.

Figure 2.2 – Portable Power Nibbler

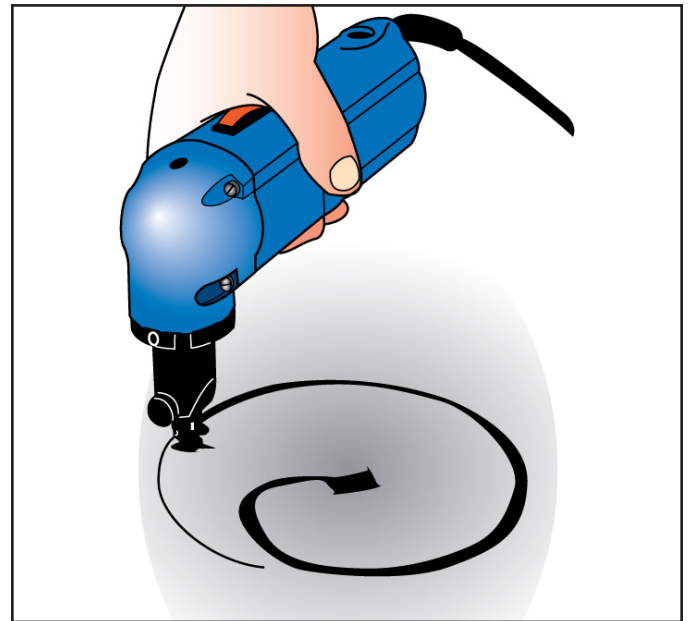


A power nibbler performs functions similar to those of hand shears or snips, but it is more versatile and gets the job done quicker. A power nibbler can make straight, curved, and interior cuts. It can cut thin metal that is bent or formed. Interior cuts are made in metal by using a hollow punch or other tool to make a small hole at the center of the planned cut. The power nibbler is then used to cut the desired shape. See Figure 2.3. Power nibblers are designed to eject metal cuttings down and away from the operator, which is a good safety feature of this tool.

Safety considerations for a portable power nibbler include the following:

- Wear eye protection when doing metalwork.
- Wear gloves when handling metal with sharp, cut edges.

Figure 2.3 – Power Nibbler Making an Interior Cut



- Do not use compressed air or the hands to remove metal chips and cuttings.

Maintenance considerations for a portable power nibbler include the following:

- Make sure the chip-ejection hole is clear of debris.
- Follow the manufacturer's recommendations for regular service.

Cold Circular Cutoff Saws

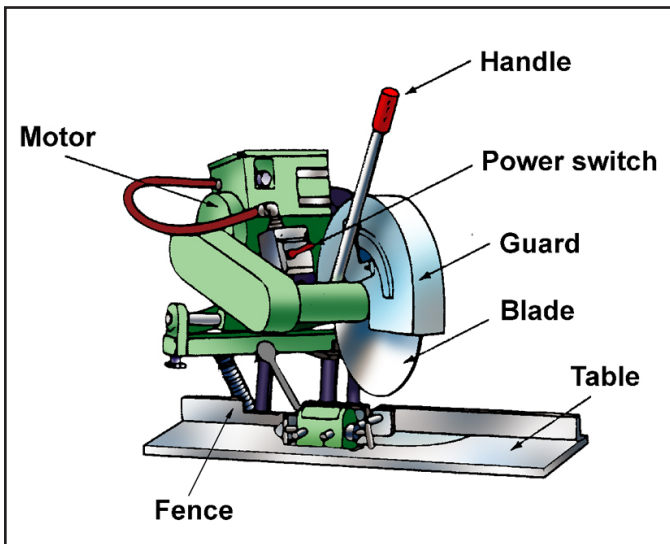
A cold circular cutoff saw has a flat, round blade and is used for cutting metal to length, making straight or miter cuts, and cutting soft or unhardened metals. Larger models of this type of saw are stationary, similar to the table saw used in woodworking. (See Unit I, Lesson 1 for information about a table saw.) Main parts of a cold circular cutoff saw include an on/off switch, table, blade, guard, handle, motor, and fence. See Figure 2.4. The circular saw can be used on materials such as aluminum, copper, machine steel, and stainless steel.

Safety considerations for a cold circular cutoff saw include the following:

- Wear eye protection when doing metalwork.

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Figure 2.4 – Cold Circular Cutoff Saw



- Wear gloves when handling metal with sharp, cut edges.
- Do not use compressed air or the hands to remove metal chips and cuttings.

Maintenance considerations for a cold circular cutoff saw include the following:

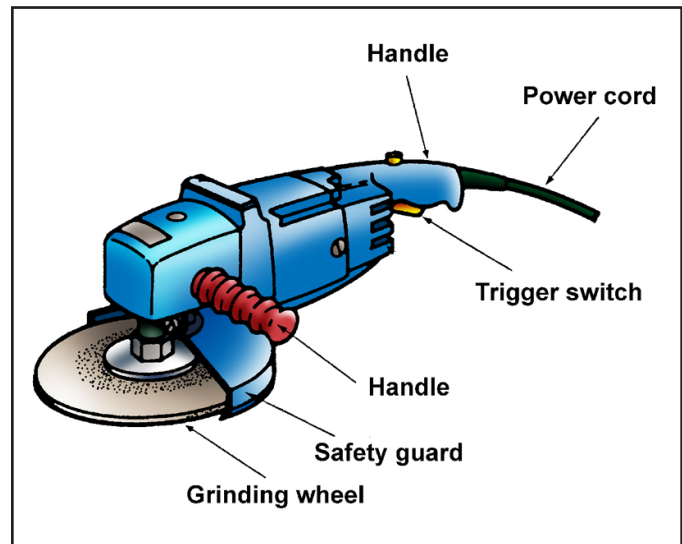
- Follow the manufacturer's recommendations for regular service.
- Clean, sharpen, or replace dull blades.

Portable Grinders

A portable grinder is a lightweight tool for grinding, shaping, and cleaning metal. It is useful for performing resurfacing work, such as removal of rust and paint. Grinders work by abrasion, which means the surface of the grinding wheel acts like a cutting tool to remove unwanted material. Main parts of a portable grinder include an on/off switch, grinding wheel, safety guard, handle, and power cord. See Figure 2.5. Some models are equipped with flexible sanding wheels for sanding wood and metal.

Grinding wheels are available in different textures of abrasive material. A wheel with a coarse texture is used for shaping metal and preparing metal for welds, whereas a wheel with a medium texture is used for sharpening

Figure 2.5 – Portable Grinder



tool blades. Grinders can also be used with wire brushes to remove rust.

Safety considerations for a portable grinder include the following:

- Wear appropriate face and eye protection.
- Wear additional protective clothing, such as a dust mask or respirator, if needed.
- Choose the right wheel or disc for the job. It should be rated to turn at speeds higher than the machine will produce.
- Secure small pieces in a clamp or vise.
- Examine the work area to identify areas where sparks might fall and make sure there is no fire hazard. Do not grind metal near combustibles.

Maintenance considerations for a portable grinder include the following:

- Inspect grinding wheels regularly. Do not use wheels that are damaged or out of round.
- Do not use wheels that are less than half of their original diameter.
- Remove the wheel or disc after use.
- Store the grinder and accessories in their proper place.

Unit I – Common Power Tools

Bench Grinders

A bench grinder does work similar to a portable grinder, but it is a stationary machine mounted on a bench. Main parts of a bench grinder include an on/off switch, grinding wheels, safety shields, and adjustable tool rests. See Figure 2.6. The adjustable tool rests are used for supporting and guiding small objects for grinding. See Figure 2.7.

Figure 2.6 – Bench Grinder

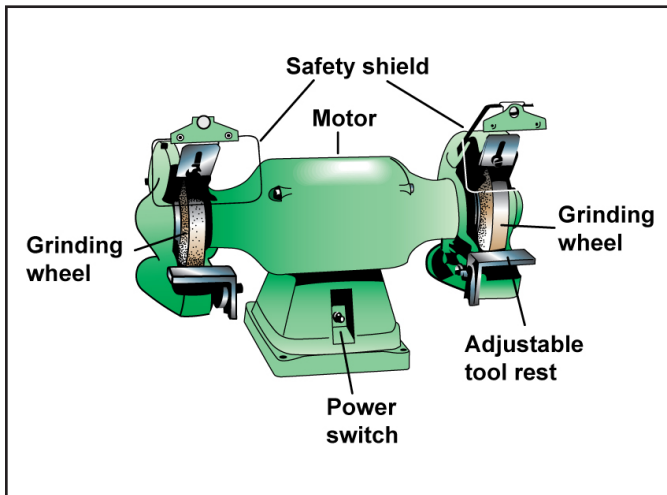
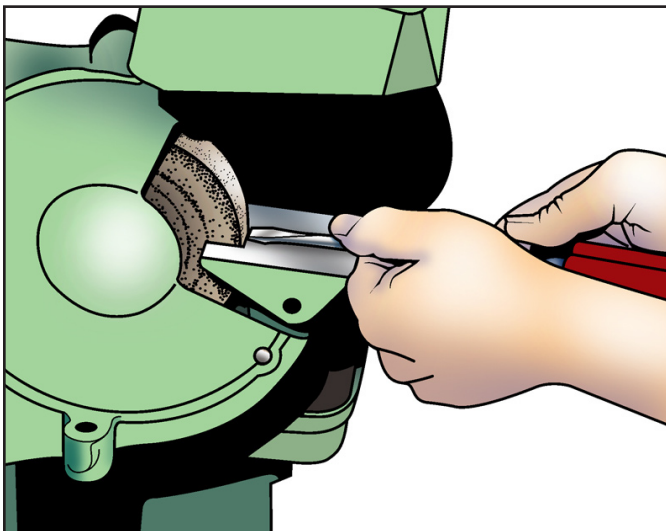


Figure 2.7 – Reconditioning a Screwdriver on a Bench Grinder, With Tool Supported by the Tool Rest



Bench grinders are used for sharpening and reconditioning tools and for shaping and cleaning metal. Another type of stationary grinder is called the pedestal grinder. It is similar to a bench grinder but is larger and is anchored to the floor. Both a bench grinder and a pedestal grinder have a double-shafted motor, which allows a wheel to be mounted on each side. Usually one wheel is coarser in texture and is used for removing material from the surface of the piece. The other wheel is finer in texture and is used for finishing work.

Safety considerations for a bench grinder include the following:

- Wear appropriate eye and face protection.
- Wear additional protective clothing, such as a leather apron or an appropriate filter or respirator, if needed.
- Adjust the tool rest for the job.
- Stand to the side of the wheel when starting the grinder and let the wheel run for a short period before using it. Wheels that are going to break usually do so within the first minute of use.
- Move the work slowly back and forth across the face of the wheel to avoid overheating the metal.
- Do not force work into the grinding wheel. Allow the speed and grit of the wheel to do the work.

Maintenance considerations for a bench grinder include the following:

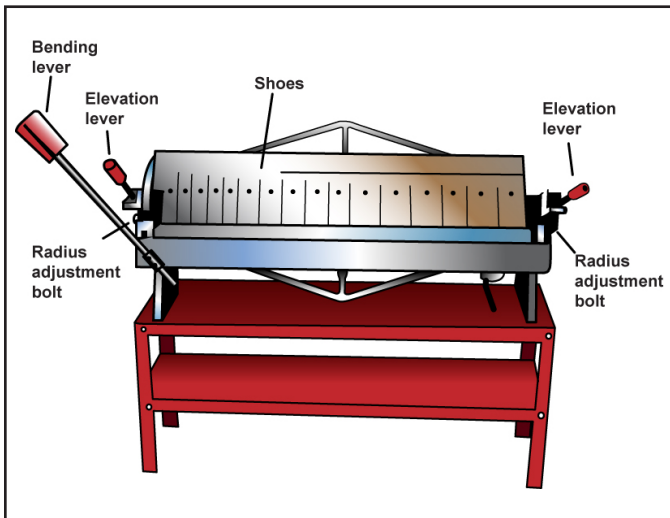
- Do not use the wheel to grind soft metals, such as copper and aluminum. They quickly clog the grinding wheel. For soft metals, use an abrasive belt grinder.
- Inspect wheels frequently. A good wheel makes a ringing sound when it is suspended by a string and tapped lightly. A wheel that does not make such a sound should be replaced. (Mounted wheels cannot be tested this way.)
- Recondition used wheels to restore their abrasive work surface and bring them back into round. This is called dressing. Receive proper instruction and permission before dressing a wheel.

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Sheet Metal Brakes

Many small repair jobs in agricultural mechanics, such as bending metal, are performed by hand, but machines like folders and brakes can do larger jobs better and faster. Hand-operated sheet metal brakes are available in a variety of sizes, from smaller bench-mounted models to industrial-sized brakes. Main parts of a brake include radius adjustment bolts, bending lever, elevation levers, and shoes. See Figure 2.8.

Figure 2.8 – Sheet Metal Brake



Sheet metal brakes are used for making angle and radius bends, seaming, flattening, and punching. These brakes increase work force by using cams and levers and can exert thousands of pounds of pressure.

Safety considerations for a sheet metal brake include the following:

- Keep fingers clear of the working mechanism.
- Leave bending machines closed when not in use.

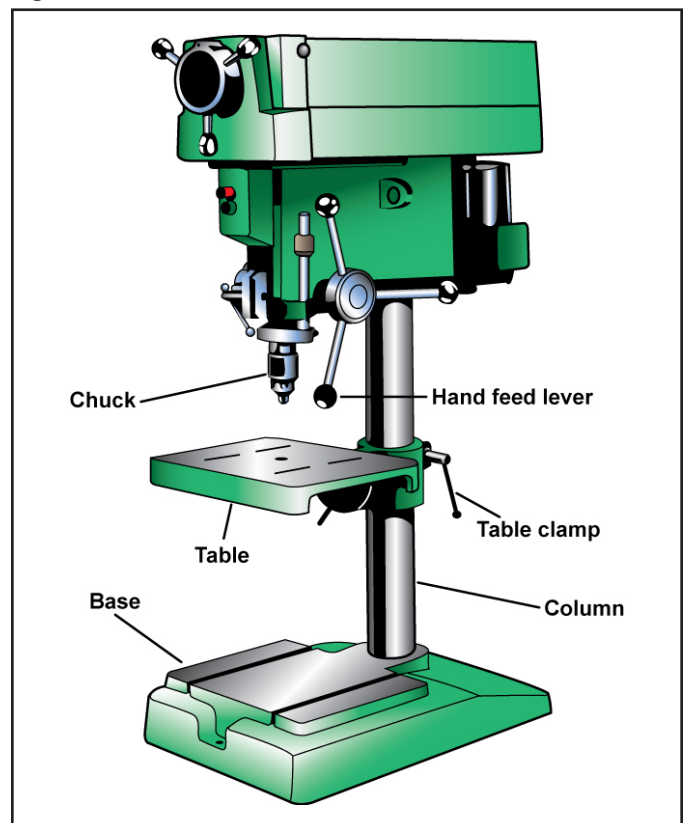
Maintenance considerations for a sheet metal brake include the following:

- Follow the manufacturer's recommendations for regular service.

Drill Presses

A drill press performs operations similar to those of a portable drill, but it is a large stationary machine capable of heavier work. Common uses for drill presses are drilling or boring holes and countersinking (making a recess where a screw can be driven). Main parts of a drill press include an on/off switch, column, table clamp, hand feed lever, chuck, table, and base. See Figure 2.9. The hand feed lever lowers and raises the chuck, which holds the drill bit.

Figure 2.9 – Drill Press



Drill presses are available in bench and floor models. The size of a drill press is determined by doubling the distance between the front edge of the column and the center of the drill bit.

Safety considerations for a drill press include the following:

- Secure the piece before beginning to drill. Clamp the piece on the left side of the table to keep it from rotating.

Unit I – Common Power Tools

- Use a center punch to mark and start the hole.
- Choose the right bit for the material and for the drill. Straight-shank bits should be used with geared chucks and taper-shank bits with taper chucks.
- Make sure the table is properly aligned before turning on the drill press to avoid drilling into the table.
- Reduce the pressure as the drill breaks through the work.

Maintenance considerations for a drill press include the following:

- Inspect bits regularly. Sharp bits cut better and are less likely to break.
- Follow the manufacturer's recommendations for regular care. Light grease on the spindle spline provides lubrication and reduces noise.

Summary

Power tools can help make metalworking tasks quick and efficient, but they can be dangerous to use if an operator does not know how they work and what safety procedures to follow. Electricity, batteries, and compressed air are common sources of power for metalworking tools. It is important to follow the general safety precautions for electric and pneumatic tools. Portable power tools commonly used in metalworking include drills, nibblers, and grinders. Stationary machines include cold circular cutoff saws, bench grinders, sheet metal brakes, and drill presses.

Credits

Agricultural Construction: Volume II. University of Missouri-Columbia: Instructional Materials Laboratory, July 1989.

Becker, W.J. *Safety with Hand and Power Tools.* University of Florida. Accessed January 18, 2002, from <http://www.cdc.gov/niosh/nasd/docs/as02400.html>.

Brodhead Garrett Tools for Teaching. 2002 Catalog.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Cyr, D.L., Johnson, S.B. *Power Tool Safety.* University of Maine Cooperative Extension. Accessed January 30, 2002, from <http://www.cdc.gov/niosh/nasd/docs3/me97023.html>.

Electric Tools – Basic Safety. Canadian Centre for Occupational Health and Safety, 1998. Accessed May 2, 2002, from http://www.ccohs.ca/oshanswers/safety_haz/Power_tools/saf_elec.html.

Exploring Agriculture in America. University of Missouri-Columbia: Instructional Materials Laboratory, June 2000.

Feirer, J.L. *General Metals* (6th ed). New York, NY: Webster Division, McGraw-Hill Company, 1986.

Krar, S.F., Check, A.F. *Technology of Machine Tools* (5th ed). Westerville, OH: Glencoe McGraw Hill, 1997.

Krar, S.F., Rapisarda, M., Check, A.F. *Machine Tool and Manufacturing Technology.* Albany, NY: Delmar Publishers, 1998.

Margentino, M.R., Malinowski, K. *Farm Machinery and Equipment Safety Part I: Recognizing and Understanding the Hazards.* Rutgers Cooperative Extension. Accessed January 29, 2002, from <http://www.cdc.gov/niosh/nasd/docs2/as16700.html>.

Olivo, C.T. *Machine Tool Technology and Manufacturing Processes.* Albany, NY: C. Thomas Olivo Associates, 1987.

Safety in Mechanical Workshops. The University of Sheffield. Safety Services. Accessed January 30, 2002, from <http://www.shef.ac.uk/safety/mech/mech20.html>.

Umstattd, W.D., Davis, C.W. *Modern Cabinetmaking.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Wagner, W.H., Smith, H.B. *Modern Carpentry.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Walker, J.R. *Modern Metalworking.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Zimmerman, F.W., McWard, L.J. *Exploring Woodworking: Fundamentals of Technology.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1999.

Lesson I: Safety and Maintenance Procedures for Arc Welding

Arc welding, a process that uses the heat from an electric arc to join pieces of metal together, is commonly used in agricultural mechanics for construction and repair. Welding can pose hazards such as burns and electric shock, but it is a safe process when the welding equipment is installed correctly and the operator is well trained and follows the safety precautions. This lesson discusses the hazards of arc welding and the ways to avoid such hazards so that accidents can be prevented. It does not cover every possible risk. Your instructor can provide other safety rules for the particular work setting or welding process. Learning how to weld safely is as important as learning the skill itself.

Safety and Health Risks

Four major risks associated with arc welding are electric shock, burns from fire, burns from arc rays, and breathing hazards.

Electric Shock

Arc welders produce relatively low voltage, but electric shock is possible if proper safety precautions are not followed. Electric shock can happen if the welder is not properly installed, the equipment is defective or damaged, or adjustments are made when the welder is connected to the power. Electric shock can also occur if the operator does not wear the proper protective clothing. All electrical conductors on the welder and in the work area can be dangerous if they are not insulated. A conductor is any material that allows electric current to flow easily.

Burns and Fire

The arc produced by an arc welder can reach temperatures in excess of 9,000° F, which poses a great risk for burns and fire. Skin burns can occur from hot metal or spattering molten metal. Burns can also occur from the steam given off by hot metal after it is immersed in water. Fires can start when welding is performed in a booth that is not fireproof or that is near combustible or flammable materials, such as trash, feed, oil, or gasoline.

Burns from Arc Rays

The arc welder produces light rays that can cause first- and second-degree burns within minutes of exposure to the skin or flash burns of the eyes within seconds. These rays cannot be seen and their effects are not felt until after exposure. The light that is reflected off surfaces during the welding process is as dangerous as the direct light. There is a great risk of burns from arc light if proper protective clothing and eyewear are not worn. Workers in the area are also at risk of burns.

Breathing Hazards

All welding processes produce fumes and gases that are given off from the electrode flux and melting metal. Breathing hazards can be from oxygen displacement and from toxic fumes and gases. Oxygen displacement occurs when the arc, flame, fumes or gases replace the oxygen in the air. Oxygen displacement can cause asphyxiation. Exposure to toxic fumes and gases given off in the welding process can cause symptoms such as coughing, a tightness in the chest, nausea, and a metallic taste in the mouth. Toxic fumes and gases are a particular problem with some of the metals, such as those that are painted or coated with grease or other chemical agents. Plated metals also pose a risk of exposure to toxic substances. For example, brass, galvanized, or cadmium-plated metals give off highly toxic fumes. Gases are especially hazardous when welding is done in a confined space. One type of gas is ozone, which is caused by ultraviolet radiation during the welding process. Ozone is extremely irritating to the nose, eyes, mouth, and lungs.

Avoiding Electric Shock

The following safety precautions should be followed to help prevent shock or electrocution.

- **Make sure the welder is properly installed and hooked up.** Welders should be installed by or under the supervision of a qualified electrician. The welder itself should be properly grounded, which helps prevent injury from stray current. When inspection is done to make sure the welder is grounded, it is important to not confuse the grounding device with

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the ground clamp that attaches to the work. The welder should have a power disconnect switch within close reach of the operator for quick, emergency shutoff. The welder should be on its own circuit with a fuse or breaker of the appropriate size.

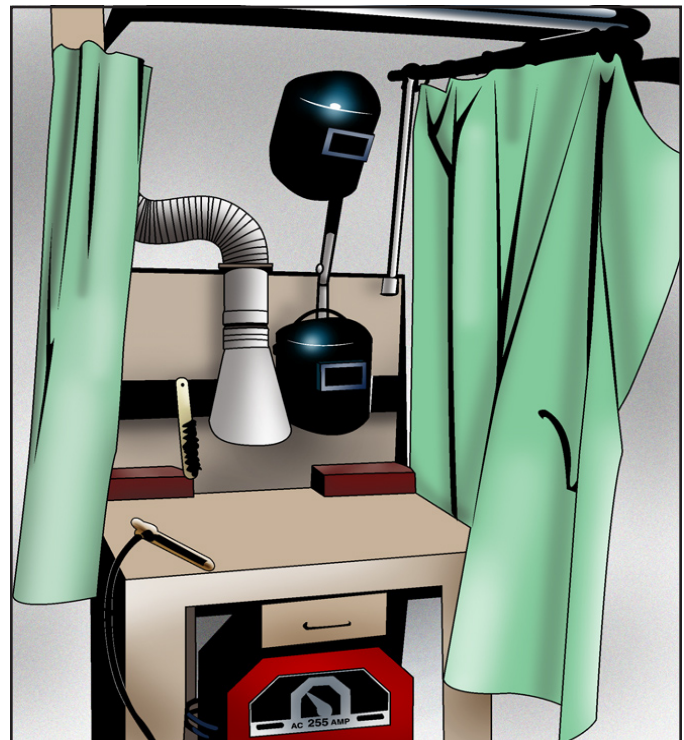
- **Inspect equipment for damage or defects.** The wire and cable connections should be kept tight and clean, because bad connections can heat up and cause dangerous arcs or melting. Do not use electrode holders or cables that are damaged or display poor insulation.
- **Disconnect the welder from the power source before making any repairs.** This includes the power switch on the welder and the main power disconnect switch.
- **Do not change the current setting while the machine is under a load.** The term “under a load” refers to the time in which there is an arc between the electrode and the work. Making adjustments while welding may cause damage to the switch and in turn injury to the person throwing the switch.
- **Keep clothing, gloves, floors, and equipment dry.** Even a small amount of moisture can conduct electricity and cause electric shock. If work must be done in a wet area, the operator should stand on a dry board or rubber mat and wear rubber gloves under the welding gloves to prevent electric shock. Similarly, if it is necessary to stand on a conductive material such as steel, the operator should stand on a dry board or a rubber mat. If the operator is perspiring, rubber gloves should be worn under the welding gloves. The electrode should never be changed when gloves are wet or when standing on a wet surface.
- **Do not put the electrode holder in water to cool it.**
- **Do not use water to put out electrical fires or any fire near the welder.** Water can damage the equipment or cause a shock hazard. Use an appropriately rated fire extinguisher to put out a fire.
- **Remove the electrode from the holder when the work is finished and disconnect the welder from the power source.**

Avoiding Burns and Fires

The following safety precautions should be followed to help prevent burns and fire.

- **Make the work area as fire resistant as possible.** In a shop environment, welding should only be done in a designated area and in a booth constructed of fireproof or fire-resistant materials such as metal sheeting or concrete blocks. The booth should have fire-resistant curtains across its opening to protect people in the area from harmful arc rays. See Figure I.1. Like the walls of the booth, the floor should be made of a fire-resistant material such as concrete. Cracks in the floor should be repaired to prevent sparks or molten metal from collecting in them. The work area should be clean and free of trash, grease, oil, and other flammable materials. In case a person's clothes catch on fire, a fire blanket should be available to wrap around the person to smother the fire. An appropriately rated fire extinguisher, first-aid kit, and safety equipment should be kept within easy reach. Aisles and stairs should be kept free of obstacles to allow a quick exit in case of fire.

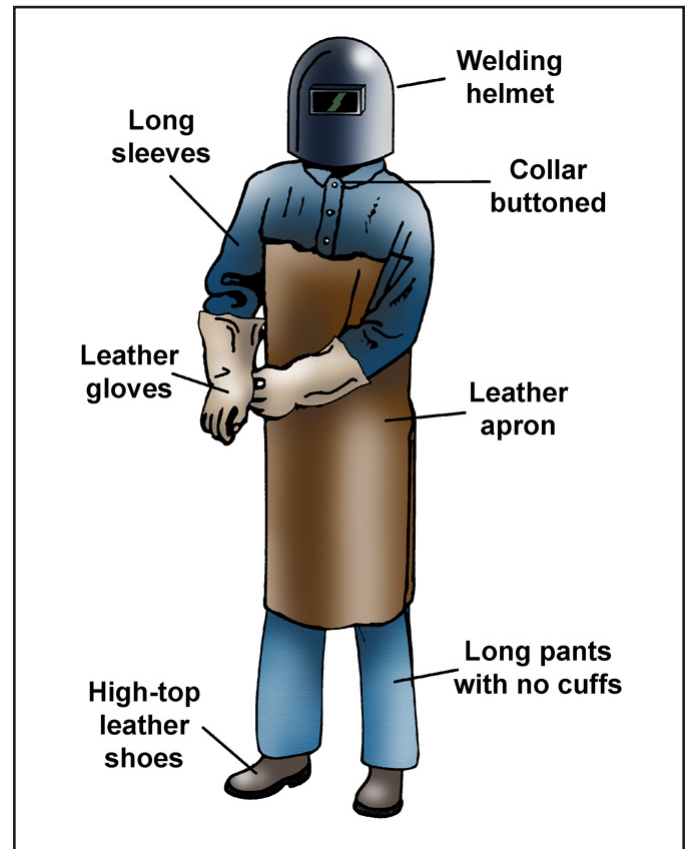
Figure I.1 – Welding Booth



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- **Be careful with hot work pieces.** Handle hot metal with tongs or pliers, not gloved or bare hands. If metal pieces are cooled in water, do so carefully to avoid steam burns. Do not walk around the shop carrying hot metal. If hot metal must be left where others could be in contact with it, carefully mark it “Hot” with soapstone or chalk.
- **Wear appropriate clothing and safety gear.** Various types of safety gear are required to prevent injury from sparks, hot metal, rays from the arc, and flying debris. See Figure 1.2.
 - Hands and feet: Leather gauntlet-style gloves and high-top leather shoes should be worn to protect the hands and feet.
 - Body: Clothing should be made of wool or cotton, not a synthetic material. It should be dark and tightly woven, which also helps block arc rays. Shirts should be long sleeved and the sleeves and front of the shirt should be buttoned, including the top collar button. Pants should come down over the tops of the boots and not have cuffs. Sparks could fall in cuffs. Long-sleeved fire-resistant coveralls provide excellent protection. Other protective gear, such as leather aprons and leather sleeves, are also available and should be worn as needed. Clothing with tears or frayed areas should not be worn because the skin might not be protected and the shreds of material could easily catch fire from sparks. Clothing made of synthetic materials should not be worn because such fabrics can burn readily and give off poisonous gases when they are burning. Pockets should not contain flammable materials, such as matches or butane lighters, which could potentially catch fire or explode.
 - Head and eyes: A cap and safety goggles should always be worn. Safety glasses or goggles and additional head and eye protection such as a flameproof skullcap or face shield should be worn as needed to avoid burns when chipping hot slag from welds. When welding, an arc welding helmet should be worn for protection against harmful arc rays. (See the section on arc rays for more details.)
- **Do not attempt to heat, cut, or weld containers such as tanks, drums, and barrels.** These types of

Figure 1.2 – Protective Clothing and Gear for Welding



containers may have been used to store flammable substances such as gasoline. If so, the welding process could cause a big explosion and fire. Even though a container looks clean, it may still have fumes that could catch fire.

Avoiding Arc Rays

The following safety precautions should be followed to help prevent burns from arc rays during the welding process.

- **Wear a welding helmet with a filter lens classified as no. 10 or higher, depending on the work being done.** Manufacturers of welding equipment provide recommendations for appropriate lenses. Welding helmets are available in different types, including some that have a flip-up or fixed shaded lens. A flip-up lens allows work, such as chipping, to be done without removing the helmet. See Figure 1.3 and Figure 1.4. If a helmet with a flip-up lens is not

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used, safety glasses must be worn under the helmet. Inspect the helmet and lens assembly to make sure they are undamaged and the gaskets are fitting properly to avoid light leaks. Do not use a helmet or lens that is damaged. In addition to the helmet, dark, tightly woven clothing protects the body from exposure to arc rays. All persons in the welding area should wear eye protection, such as flash glasses, to avoid eye injury from the reflected light. Before starting a weld, the operator should always say “cover up” as a warning for others to protect themselves.

Figure I.3 – Helmet with a Flip-up Filter Lens

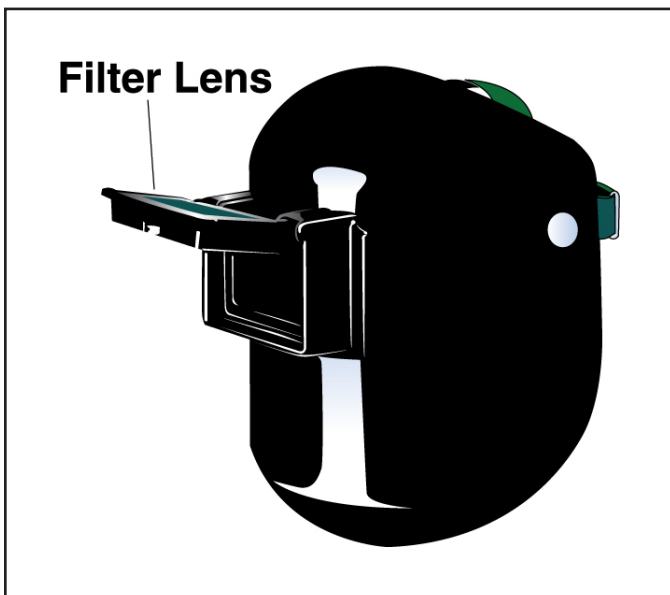
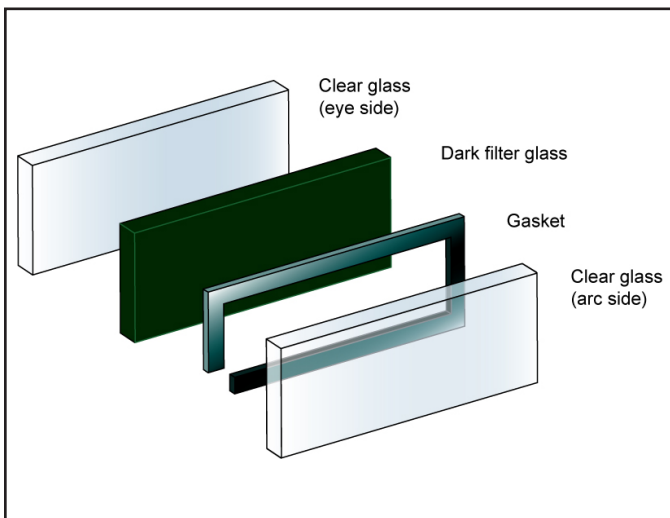


Figure I.4 – Parts of a Filter Lens on a Welding Helmet



Avoiding Breathing Hazards

The following safety precautions should be followed to help prevent respiratory problems.

- **Work in an area with adequate ventilation.** Working outdoors or in a large shop with high ceilings and natural ventilation is best.
- **Use forced ventilation if natural ventilation is not sufficient.** Forced ventilation, such as hoods and exhaust fans, is probably needed in small shops and in shops with many welders operating at the same time. Forced ventilation may also be required if welding is being performed on metals that contain extremely toxic substances. The ventilation system should be as close to the work as possible.
- **Supplement ventilation as needed with an appropriate respirator.** Respirators may be required depending on the size of the work area, ventilation available, and the type of metal being welded. Different types of respirators are available. Some models supply fresh air and other models are designed to filter specific contaminants. See Figure I.5.

Figure I.5 – Respirator With a Powered Air Purifier



Unit II – Arc Welding

- **Clean metal before welding.** It is important to remove chemicals from the metal so they do not mix with the other fumes produced by welding and create a worse breathing hazard. It is also safer and easier to establish an arc on a clean surface than a dirty surface.
- **Operate engine-powered welders in well-ventilated areas or with the exhaust vented directly outdoors.** This is to prevent carbon monoxide, a poisonous gas produced by gas and diesel engines, from building up in the shop.

Care and Maintenance of Arc Welding Equipment

Regular maintenance of welding equipment and inspection of the equipment before each use are critical for safe operation.

- **Inspect the electrode holder frequently to be sure it is not damaged or in need of repair.** Defective jaws, loose connections, and poor insulation are electric shock hazards.
- **Keep cables free of oil and grease.** These substances on the cables may cause them to catch fire.
- **Run cables so that they will not be damaged or cause a tripping hazard.** Be sure that cables will not be exposed to sparks and molten metal and are not located where the operator or others must walk or stand. In temporary work sites, keep cables covered to protect them from traffic.
- **Do not shut off or start the welder while the electrode or electrode holder is in contact with the work or the welding table.** This prevents the possibility of damage to the welder. The electrode holder should be hung from an insulated hanger when it is not in use.
- **Keep the welder and electrodes dry.**
- **Do not allow dust to accumulate on the transformer coils.** Dirty coils can start a fire, short out electrical components, and cause other equipment failures.

Summary

The arc welding process has potential safety risks like electric shock, burns and fire, burns from arc rays, and breathing hazards. Following safety precautions, maintaining the welding equipment, and inspecting it before each use will help prevent injuries to the welder and others in the work area.

Credits

Agricultural Construction: Volume I. Arc Welding Project Construction. University of Missouri-Columbia: Instructional Materials Laboratory, July 1989.

Agricultural Mechanics Unit for Agricultural Science I. University of Missouri-Columbia: Instructional Materials Laboratory, July 1982.

Althouse, A.D., Turnquist, C.H., Bowditch, W.A., Bowditch, K.E. *Modern Welding.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Bowditch, W.A., Bowditch, K.E. *Welding Technology Fundamentals.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1997.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Cyr, D.L., Johnson, S.B. *Welding Safety on the Farm.* University of Maine Cooperative Extension. Accessed February 11, 2002, from <http://www.cdc.gov/niosh/nasd/docs3/me97067.html>.

Fluegel, L., Rein, B. *Arc Welding Safety.* University of Arizona Cooperative Extension, 1988. Accessed February 11, 2002, from <http://www.cdc.gov/niosh/nasd/docs2/as23000.html>.

Fortney, C., Gregory, M. *Shielded Metal Arc Welding* (2nd ed). Stillwater, OK: Mid-America Vocational Curriculum Consortium (MAVCC), 1992.

Jeffus, L. *Welding Principles and Applications* (4th ed). Albany, NY: Delmar Publishers, 1999.

Agricultural Mechanics

Phipps, L.J., Reynolds, C.L. *Mechanics in Agriculture* (4th ed).
Danville, IL: Interstate Publishers, Inc., 1992.

Wagner, W.H., Kicklighter, C.E. *Modern Woodworking*. Tinley
Park, IL: The Goodheart-Willcox Company, Inc., 1996.

Wagner, W.H., Smith, H.B. *Modern Carpentry*. Tinley Park,
IL: The Goodheart-Willcox Company, Inc., 2000.

Welding. University of Missouri-Columbia: Instructional
Materials Laboratory, July 1988.

Zimmerman, F.W., McWard, L.J. *Exploring Woodworking:
Fundamentals of Technology*. Tinley Park, IL: The Goodheart-
Willcox Company, Inc., 1999.

Lesson 2: Controlling Distortion in Arc Welding

To improve the quality of welds, a welder must be able to recognize common welding defects and implement methods for preventing them. Distortion of metal is a common problem in arc welding, but it can be prevented with the use of certain techniques. This lesson describes the causes of distortion and the techniques that can be used before, during, and after the weld to minimize or prevent distortion.

Effects of Temperature Change on Welds

Shielded metal arc welding exposes metals to very high temperatures so they will melt and fuse together. Like many other materials, metal expands when it is exposed to heat and contracts when it is exposed to cooler temperatures. If the entire piece of metal is heated to the same temperature during the process of welding and is then evenly cooled, the whole piece can return to its original shape. However, if only part of the metal is heated and then cooled, the uneven expansion and contraction of the piece can lead to changes in its shape. Such changes are called distortion.

Common Causes of Distortion

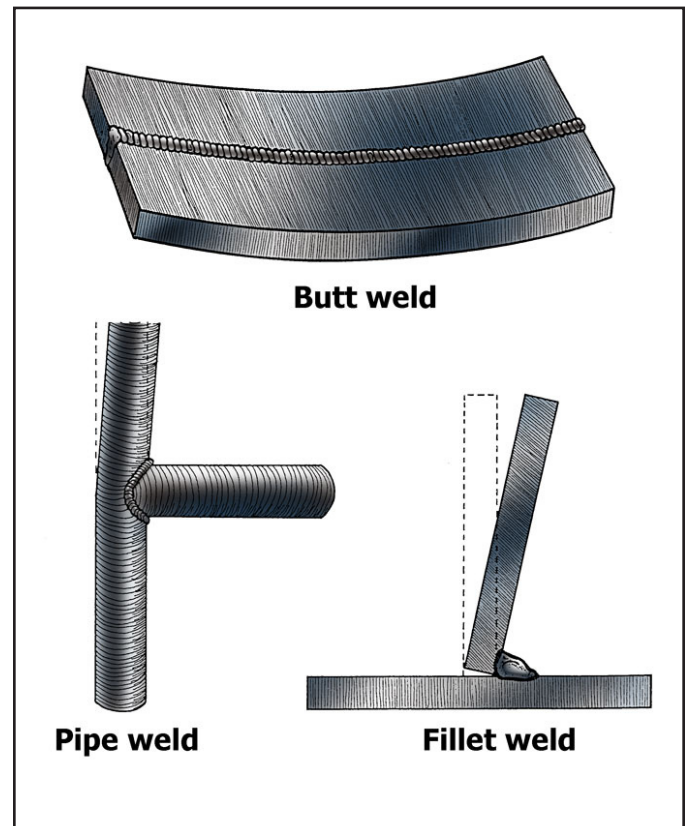
Heating the metal unevenly, running a bead, and then cooling the metal unevenly are steps in the arc welding process that can cause distortion. For example, the part of the metal being welded is much hotter than the metal farther from the weld. As the weld cools, the weld bead itself restricts movement, which may cause distortion.

Distortion in welding may be seen as the development of warping, or a curve upward, in a flat piece of metal. Other examples of distortion include a bend in a previously straight piece, such as a pipe, and a vertical piece pulling away from the weld. See Figure 2.1.

Techniques for Distortion Control

Welders must consider many factors and plan their work carefully to control distortion. Techniques for distortion control have been developed for use before, during, and

Figure 2.1 – Three Examples of Distortion



after the weld. The techniques below are listed separately, but several techniques can be used together or in sequence to control distortion.

Before Welding

Heat treating: The whole piece of metal can be heated before welding (preheating), during welding (interpass heating), and after welding (postheating). Interpass heating is usually used for thicker metals. The process of raising and maintaining the temperature of the whole piece and allowing it to cool slowly promotes uniform expansion and contraction of the piece. See Figure 2.2.

Positioning: By setting the pieces slightly out of alignment opposite the pull of contraction, the contraction force can be used to pull the pieces into position and prevent distortion. See Figure 2.3. For example, with cooling of a weld, the gap between two pieces in a butt joint can become uneven from contraction. To maintain a parallel weld, the two pieces of flat metal can be positioned at an

Agricultural Mechanics

Figure 2.2 – Preheating Base Metal to Control Distortion

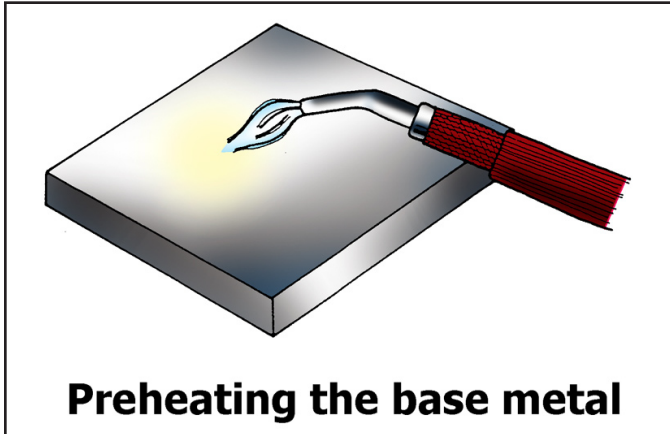
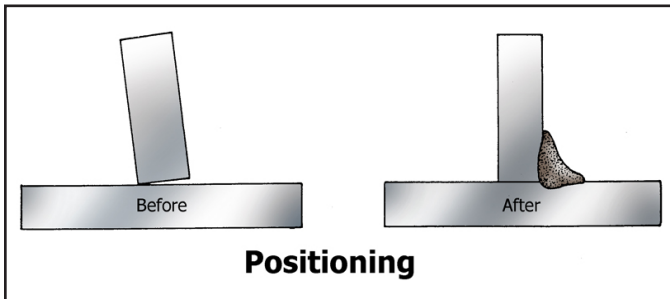


Figure 2.3 – Using Contraction to Control Distortion



angle to each other, with a narrower gap at the start of the weld. This adjustment in positioning before beginning the weld can correct for any contraction that will occur.

Tack welding: Small welds can be made along the seam to hold the pieces in place. See Figure 2.4. The number of tack welds needed depends on the length of the weld. For example, to control distortion in a tee joint, the vertical piece can be tack welded in a position that is slightly off 90 degrees and then welded along the joint. The weld should produce a 90-degree angle after the bead cools.

Prebending: Pieces can be bent before welding so that the contraction force pulls them into position. See Figure 2.5. With the use of this technique, warping in a butt joint can be controlled by prebending the pieces to be welded in the opposite direction of the weld, clamping the pieces in position, welding the pieces, and then allowing the work to cool while the pieces remain in the fixture. After the welded piece is taken out of the fixture, it changes to correct alignment.

Figure 2.4 – Tack Welding to Control Distortion

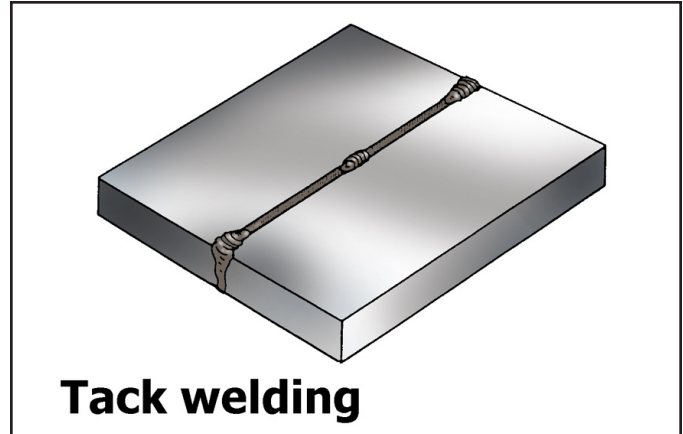
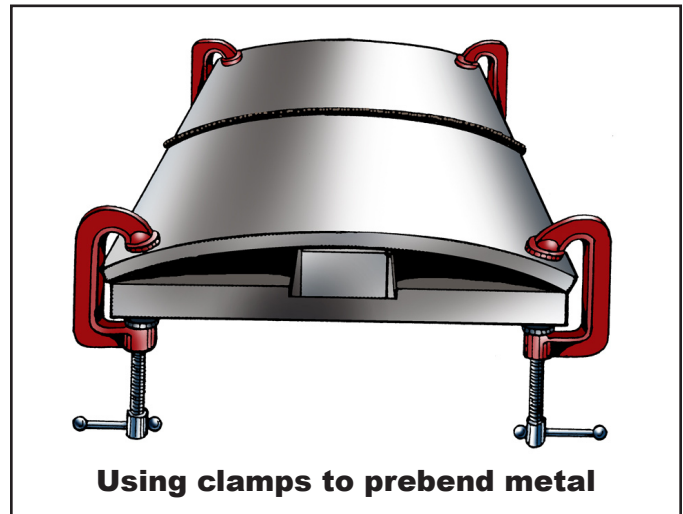


Figure 2.5 – Bending the Metal to Control Warping



Using welding jigs and fixtures: Jigs and fixtures can be used to hold pieces in place for welding, thus minimizing distortion due to movement. See Figure 2.6. However, after the jig or fixture is removed, the development of distortion is still possible if stress remains in the piece.

During Welding

Minimizing passes: Welding should be accomplished with as few passes as possible to avoid adding excessive material during the welding process. See Figure 2.7. Additional passes and filler add more heat to the weld, increasing the likelihood of distortion. The amount of filler in a weld can be minimized with the use of the smallest bevel, electrode size, and joint gap necessary to complete a good quality

Unit II – Arc Welding

Figure 2.6 – Using Clamps and Jigs to Control Distortion

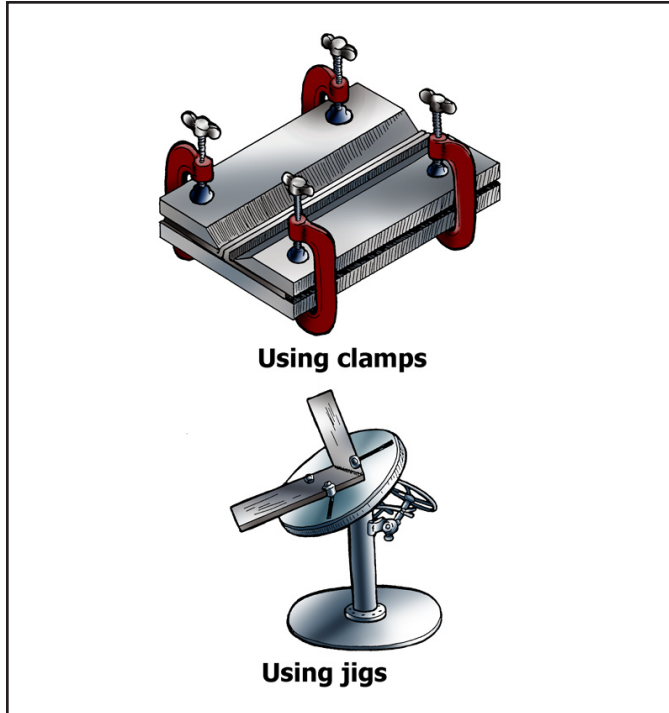
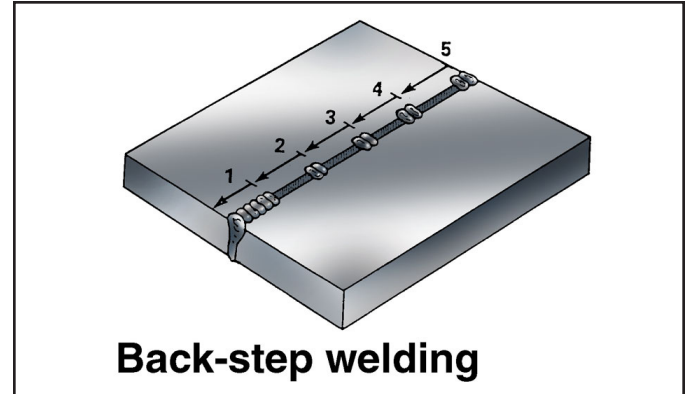


Figure 2.8 – Back-Step Welding to Control Distortion



Alternating sides: Welding on alternating sides is accomplished by running a bead on one side of a joint, then running a bead on the other side, and continuing to alternate sides until the weld is complete. By welding on both sides of the material, the contraction forces on one side offset those on the other side. See Figure 2.9.

Figure 2.7 – Limiting the Number of Passes to Control Distortion

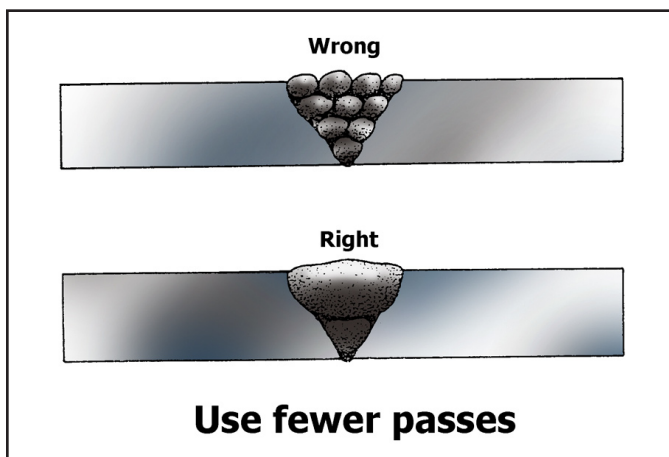
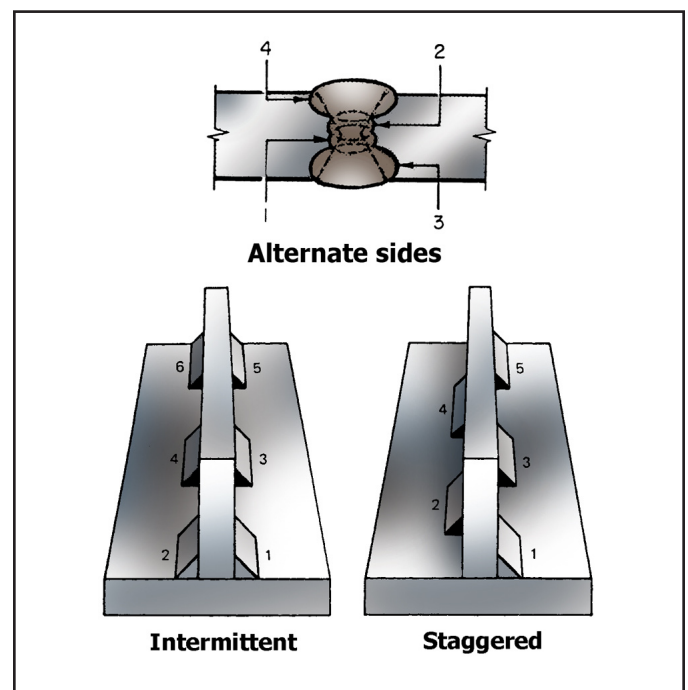


Figure 2.9 – Alternating Sides of Welding to Control Distortion



weld. Use of a larger electrode may help to minimize the number of passes.

Back-step welding: With back-step welding, the joint is completed from left to right, but it is made up of smaller beads put down from right to left. This technique redistributes the stress and minimizes distortion. See Figure 2.8.

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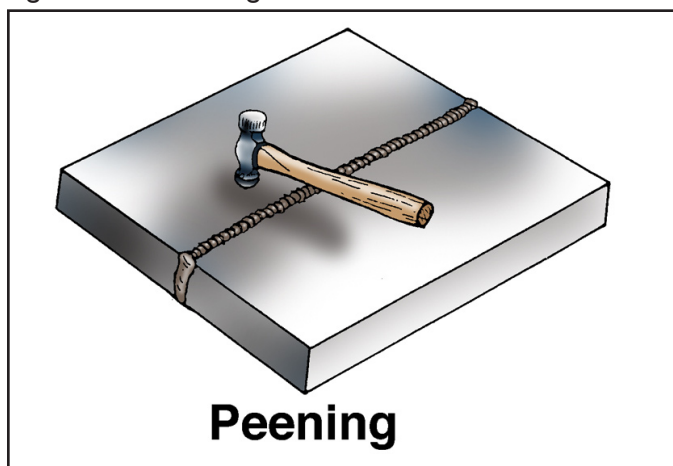
After Welding

Shrinkage: In this technique, distorted pieces are alternately heated and cooled to counteract the distortion.

Shrink welding: Beads are added to the opposite side of the distorted weld. This added weld and the contraction force it produces as it cools helps to pull the original weld into alignment. The additional beads can then be ground off, if desired.

Peening: Hammering the weld bead can alleviate stress and offset distortion. See Figure 2.10. Peening can be done by hand with a ball-peen hammer, but a pneumatic hammer that is fitted with a suitable tool is preferred. Peening can be completed faster with a pneumatic hammer and the hammering is consistent and more easily controlled. Whatever method is used, care should be taken to not overpeen the work, which can cause the weld to become brittle or hard and develop cracks or new stresses.

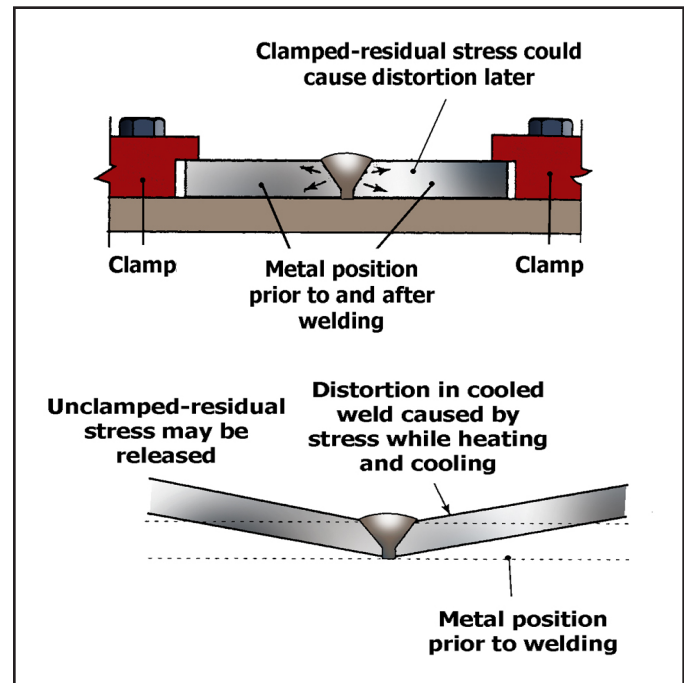
Figure 2.10 – Peening the Weld to Control Distortion



Techniques for Control of Residual Stress

Residual stress is the force that remains in the piece after welding is completed. It can cause cracks or distortion at the weld or elsewhere on the piece. For example, a piece that was secured in a clamping device to control distortion during welding may seem sound after it is unclamped, but it still might contain stresses that could cause defects later. See Figure 2.11. On the other hand,

Figure 2.11 – Distortion After Removal of Clamps as a Result of Residual Stress



a welded joint may be distorted but contain no residual stress. Residual stress contributes to buckling, curling, cracking, fatigue, or distortion of the weld or the work and these defects can happen at any time. Residual stress can be relieved by techniques used to prevent or correct distortion, including preheating, postheating, and peening. With postheating, the entire piece is placed in a furnace and gradually heated to a uniform temperature. The cooling process must be gradual and uniform as well.

Summary

The high temperatures used in the arc welding process cause metal to expand in the welded area and then shrink as the weld cools. Uneven heating and cooling of the piece can lead to distortion. The first step in controlling distortion is understanding its causes and effects. The second step is knowing how to use different techniques before, during, and after the weld to prevent or minimize the development of distortion. These techniques can also help reduce the amount of residual stress in the welded piece. The longevity of the weld and overall quality of the welded piece depend on it.

Credits

Agricultural Mechanics Unit for Agricultural Science II. University of Missouri-Columbia: Instructional Materials Laboratory, June 1983.

Althouse, A.D., Turnquist, C.H., Bowditch, W.A., Bowditch, K.E. *Modern Welding*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Bowditch, W.A., Bowditch, K.E. *Welding Technology Fundamentals*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1997.

Griffin, I.H., Roden, E.M., Jeffus, L., Briggs, C.W. *Welding Processes* (3rd ed). Albany, NY: Delmar Publishers, Inc., 1984.

Phipps, L.J., Reynolds, C.L. *Mechanics in Agriculture* (4th ed). Danville, IL: Interstate Publishers, Inc., 1992.

Sacks, R.J. *Essentials of Welding*. Peoria, IL: Bennett Publishing Company, 1984.

Walker, J.R. *Arc Welding*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1999.

Welding Theory and Application. Training Circular No. 9-237. Department of the Army, 1993. Accessed March 5, 2002, from <http://www.adtdl.army.mil/cgi-bin/atdl.dll/tc/9-237/toc.htm>.

Lesson 3: Selecting and Maintaining Electrodes and Safety Lenses

Arc welding electrodes are available in a variety of sizes and flux coatings. They are designed for use in certain welding positions and with certain electrical currents. Selecting the right electrode for the job depends on the properties of the electrode and the workpiece. In turn, the diameter of the electrode is a useful guide for choosing the correct filter lenses to protect the eyes from the harmful light of the welding arc. Proper eye protection is essential during welding. This lesson discusses the factors to consider when selecting electrodes and safety lenses for welding.

Electrode Parts and Functions

To review, an electrode is a metal rod that a welder uses to establish an arc between the electrode and the metal. The two parts of an electrode are (1) a solid metal core and (2) a flux coating. The solid metal core provides filler metal to the weld as it melts.

Depending on the type of electrode, the flux coating does any or all of the following:

- Adds filler metal to the weld
- Stabilizes the arc
- Produces a gas shield that protects the weld
- Adds flux to the weld, which removes impurities that rise to the surface of the weld and promotes the formation of slag, the protective layer over the weld
- Adds alloying elements to improve the weld
- Determines the polarity (positive or negative) of the electrode

Factors to Consider When Choosing an Electrode

To produce a good-quality weld, it is important to use the right electrode for the job. With some welding tasks, there may be specifications for the electrode to be used. With others, there may not be any specifications for the type of electrode. In such situations, many factors must be taken into consideration when choosing the electrode or combination of electrodes. Some, but not all, of these factors are described below.

- Type of metal being welded and its tensile strength: Tensile strength is the amount of stress the metal can withstand. Electrodes are designed to fuse specific types of metal. The tensile strength of the electrode filler metal should be at least as strong as that of the metal being welded.
- Thickness of the metal: The thickness of the metal affects the number of passes required, the width of the bead, and, thus, the diameter of the electrode chosen. In addition, thicker metals may require deeper penetration, which can be another factor in choosing an electrode.
- Condition of the base metal: Some electrodes work better than others on surfaces that are dirty, rusty, greasy, etc.
- Weld position (flat, vertical, horizontal, and overhead): Weld position mainly becomes important when welding is performed in the overhead position. A smaller diameter electrode is preferred when the weld position is overhead. Because gravity causes the molten metal to fall from an overhead weld, a smaller diameter electrode is preferred to reduce the droplets of molten metal. This factor is not an issue when welding is performed in the flat position.
- Experience of the welder: An experienced welder is capable of using a larger diameter electrode at a higher current setting without overwelding or overheating the base metal.
- Rate at which the filler should be added: Some electrodes are designed to deposit more filler metal in a shorter length of time.
- Design or alignment of the joint: Depending on the design of the joint, a combination of electrode sizes may be required to make a good weld. Some electrodes are designed to fill large gaps in joints with poor alignment.
- Properties of the alloying elements in the flux coating: The alloys in some electrode coatings can affect the quality of the weld, such as its strength and rust resistance.
- Type of electric current being used: Electrodes are designed for use with specific currents, such as alternating current, direct current electrode negative, and direct current electrode positive. The type of electric current produced by the welding machine must be known in order to choose the correct electrode.

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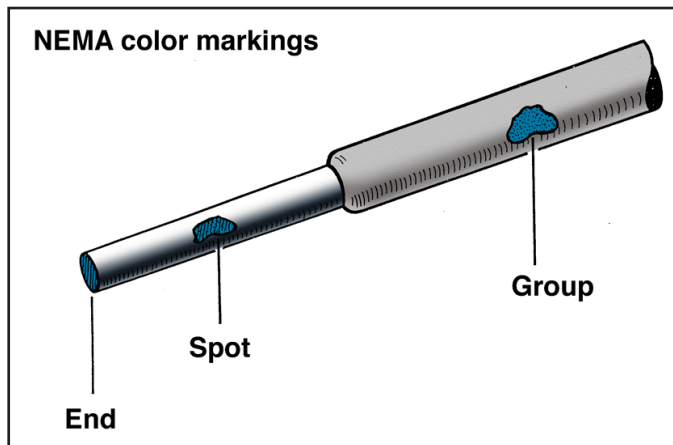
Identifying Electrodes

Electrode manufacturers classify electrodes by using one of two systems. One method is the color-coding system developed by the National Electrical Manufacturers Association (NEMA) and the other is the letter-and-number system developed by the American Welding Society (AWS).

NEMA System

The NEMA color-coding system classifies electrodes by using color markings on the end (end marking), the bare metal core (spot marking), and the flux coating (group marking) of the electrode. See Figure 3.1. Some manufacturers may use their own trademark or coating colors, which should not be confused for NEMA markings.

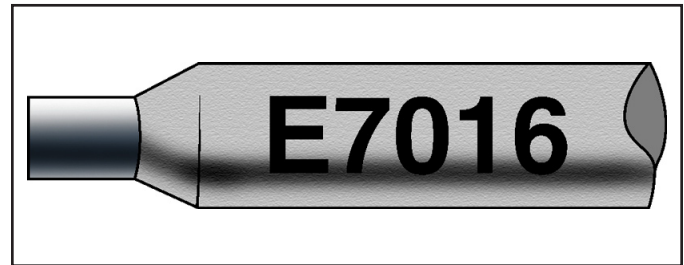
Figure 3.1 – Placement of NEMA Color Codes on an Electrode



AWS System

The AWS classification for electrodes is the most frequently used system. It uses a series of letters and numbers that provide important information about the properties of an electrode. The AWS code is stamped on the side of the electrode, near the bare end. See Figure 3.2. Some of the information in the AWS classification is explained below.

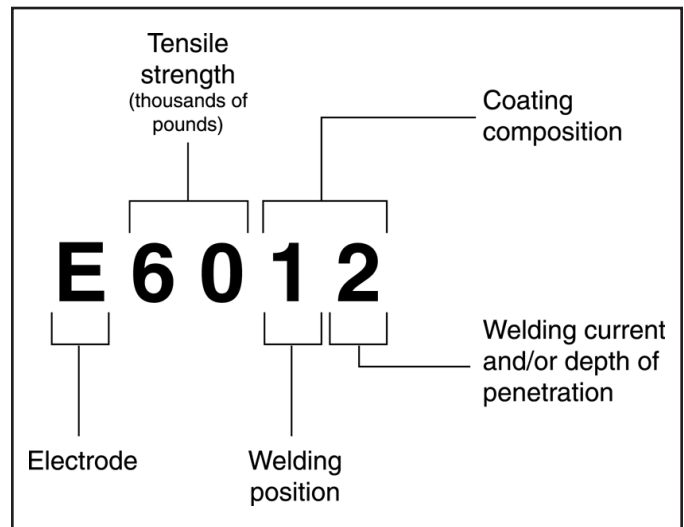
Figure 3.2 – Placement of AWS Code on Electrode



Characters in the AWS Classification System

To understand the meaning of the AWS electrode classification, the letters and numbers in the code must be broken down and examined separately. The classification code begins with a letter prefix followed by four or five numbers. With some electrodes, a letter-and-number suffix is placed at the end of the series of numbers. See Figure 3.3 for the breakdown of a typical AWS classification number.

Figure 3.3 – Breakdown of AWS Code



Letter prefix: The prefix letter or letters provide information about which welding process can be used. An “E” indicates that the electrode is used in arc welding. Another prefix example is “RG,” which indicates it is a rod used in oxyfuel welding.

First two digits or the first three digits: The first two digits of a four-digit number or the first three digits of a five-digit number indicate the minimum tensile strength of the filler metal. Minimum tensile strength is expressed in pounds per square inch (psi) or kilopounds per square inch (ksi). For example, a 60-series electrode has a minimum tensile strength of 60,000 psi and a 100-series electrode indicates a minimum tensile strength of 100,000 psi. Minimum tensile strength can be defined as that following postheating treatment (the stress-relieved state) or that without postheating (the as-welded state). The electrode manufacturer's specifications explain under which condition minimum tensile strength has been determined for an electrode.

Second digit from the right: The second digit from the right indicates the recommended welding position for the electrode. The number "1" indicates the electrode can be used in all positions: flat (F), vertical (V), overhead (OH), and horizontal (H). The number "2" indicates the electrode can be used in flat and horizontal positions. A "3" is no longer used as a code number for weld position. It formerly meant that the electrode was used in flat position. It may still appear in some reference books. The number "4" indicates the electrode can be used in flat, horizontal, overhead, and vertical-down positions.

Last digit on the right: This digit provides operating characteristics, such as the proper welding current and/or depth of penetration of the filler metal. The currents include alternating current (ac), direct current electrode negative (dcen), and direct current electrode positive (dcep). Formerly referred to as direct current straight polarity (dcsp), dcen means that the electrode is the negative pole and the work is positive. Formerly referred to as direct current reverse polarity (dcrp), dcep means the electrode is positive and the work is negative.

Last two digits on the right combined: The last two digits on the right together provide information such as the coating composition and proper application. For example, the coating of an electrode with a code number ending in "10" is composed of high-cellulose sodium and one ending in "11" is composed of high-cellulose potassium.

Letter-and-number suffix: Some less common electrodes have additional designators (suffixes) after the four- or five-digit number to indicate other specifications. See Figure 3.4.

See Table I for AWS classifications of 60- and 70-series electrodes.

Care and Storage of Electrodes

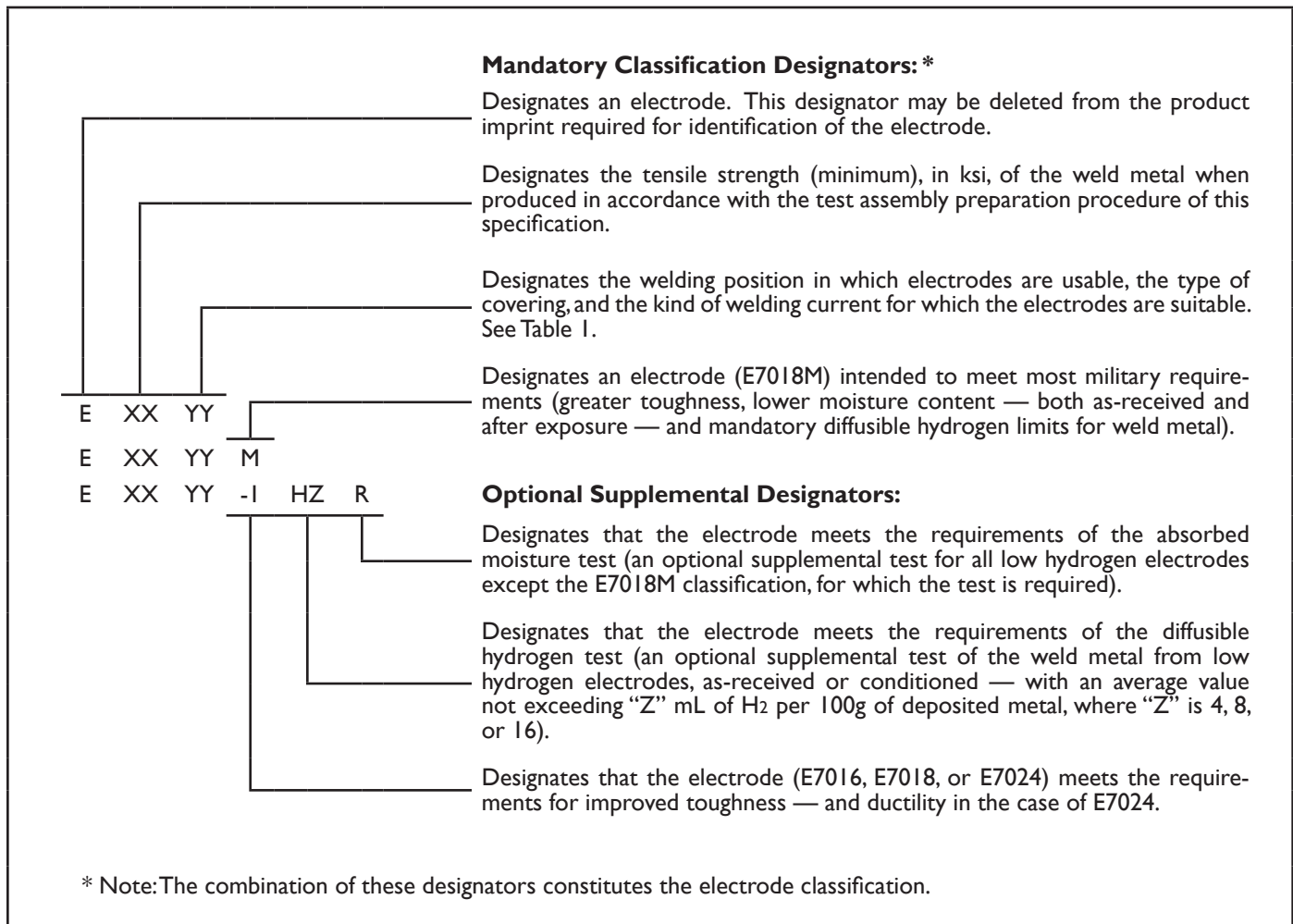
Proper care and storage of electrodes will save time, avoid lost time on the job, and help prevent defective welds. It is essential that electrodes be kept dry in a waterproof container. A moist electrode can produce steam, which can carry away the shielding gases that protect the weld. Damp electrodes can also cause such problems as increased spatter and poor slag removal. Hydrogen from water can be added to welds and weaken them. Welds that are made with damp electrodes may be porous and may crack. Such faulty welds could be a safety threat if they go undetected and subsequently fail under stress.

Knowing the manufacturer's specifications for the moisture-pickup time period for an electrode is key to preventing damage from moisture. The time it takes for an electrode to pick up moisture from the air is called the moisture-pickup time period. To minimize exposure to moisture in the air or from other sources, it is important to take only the number of electrodes needed for a job or only the number that can be used within the moisture pickup period. Electrodes should be kept in their original package before use. Special waterproof dispensers are available for on-the-job storage to help keep electrodes dry. If moisture exposure occurs, electrodes should be dried in an electrode drying oven before they are used.

Electrodes should be handled carefully to avoid damaging the flux coating. Proper storage prevents electrodes from being bent, which causes chips and cracks in the flux coating. Many welding procedures do not allow the use of electrodes with a chipped or cracked coating.

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Figure 3.4 – Explanation of Each Part of the AWS Code



Source: American Welding Society (AWS) Committee on Filler Metal, 1991, Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding, ANSI/AWS A5.1-91, Miami: American Welding Society, Figure 16.

Choosing Safety Lenses

As discussed in the lesson on arc welding safety, light from the welding arc can injure the eyes. Arc rays can damage the retina (back of the eye) and cause loss of vision. Light from the arc can also cause painful burns of the conjunctiva (whites of the eyes). These burns can easily become infected and cause even more problems. Eye burns can be prevented with good-quality filter lenses that shield the eyes from harmful arc rays. Good lenses

filter out about 99.5% of the infrared rays and 99.75% of the ultraviolet rays produced by the welding arc.

The right filter lens must be selected for the welding job. See Figure 3.5. Lenses with shade numbers 10, 12, and 14 are usually worn in arc welding. As a general rule, the larger the diameter of an electrode, the brighter the arc it produces. The brighter the arc is, the greater the

Table I
Electrode Classification

AWS Classification	Type of Covering	Welding Position ^A	Type of Current ^B
E6010	High cellulose sodium	F,V,OH,H	dcep
E6011	High cellulose potassium	F,V,OH,H	ac or dcep
E6012	High titania sodium	F,V,OH,H	ac or dcen
E6013	High titania potassium	F,V,OH,H	ac, dcep, or dcen
E6019	Iron oxide titania potassium	F,V,OH,H	ac, dcep, or dcen
E6020	High iron oxide	{ H-fillets F	ac or dcen ac, dcep, or dcen
E6022 ^C	High iron oxide	F,H	ac or dcen
E6027	High iron oxide, iron powder	{ H-fillets F	ac or dcen ac, dcep, or dcen
E7014	Iron powder, titania	F,V,OH,H	ac, dcep, or dcen
E7015	Low hydrogen sodium	F,V,OH,H	dcep
E7016	Low hydrogen potassium	F,V,OH,H	ac or dcep
E7018	Low hydrogen potassium, iron powder	F,V,OH,H	ac or dcep
E7018M	Low hydrogen iron powder	F,V,OH,H	dcep
E7024	Iron powder, titania	H-fillets, F	ac, dcep, or dcen
E7027	High iron oxide, iron powder	{ H-fillets F	ac or dcen ac, dcep, or dcen
E7028	Low hydrogen potassium, iron powder	H-fillets, F	ac or dcep
E7048	Low hydrogen potassium, iron powder	F,OH,H,V-down	ac or dcep

Notes:

A. The abbreviations indicate the welding positions as follows:

F = Flat

H = Horizontal

H-fillets = Horizontal fillets

V-down = Vertical with downward progression

V = Vertical

OH = Overhead

} { For electrodes 3/16 in. (4.8 mm) and under, except 5/32 in. (4.0 mm) and under for classifications E7014, E7015, E7016, E7018, and E7018M.

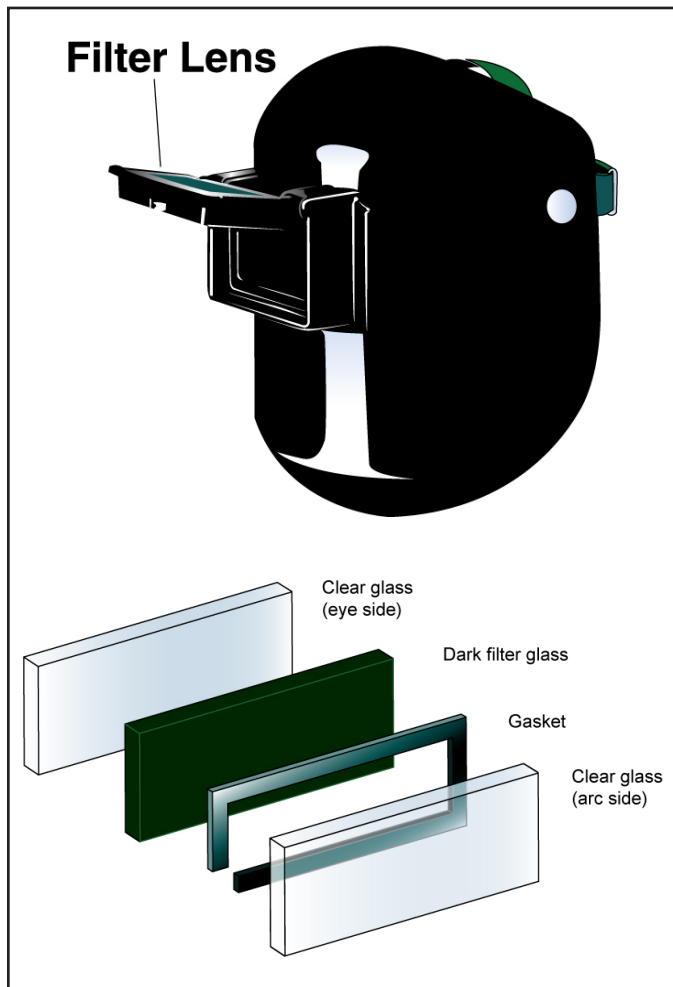
B. The term “dcep” refers to direct current electrode positive (dc, reverse polarity). The term “dcen” refers to direct current electrode negative (dc, straight polarity).

C. Electrodes of the E6022 classification are intended for single-pass welds only.

Source: American Welding Society (AWS) Committee on Filler Metal, 1991, Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding, ANSI/AWS A5.1-91, Miami: American Welding Society, Table I.

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Figure 3.5 – Filter Lens on an Arc Welding Helmet



degree of darkness required in the filter lens. Common electrode sizes and the recommended safety lenses to use with them are as follows:

- Electrodes with a diameter of up to 5/32 in. – no. 10 shade
- Electrodes with a diameter of 3/16 in. to 1/4 in. – no. 12 shade
- Electrodes with a diameter of 5/16 in. to 3/8 in. – no. 14 shade

It is important to check with the instructor or the manufacturer's guidelines to make sure that the shade of filter lens is right for the job. Too dark of a lens can cause eyestrain. If the work cannot be seen comfortably through the lens when the arc is struck, the lens is probably too dark.

In addition to filter lenses, safety glasses must also be worn to protect the eyes. If the welding helmet is not equipped with safety glass under the filter lenses, a pair of safety glasses must be worn under the helmet. Safety glasses should be kept on during the entire welding process, especially when chipping slag. Others in the welding area should also wear eye protection, such as flash glasses, to avoid injury from reflected light.

Care of Filter Lenses and Welding Helmets

Filter lenses and welding helmets need care to keep them in good condition. Unprotected filter lenses can be spattered with molten metal during welding. A clear outer lens of glass or plastic should be used to protect the filter lens from damage and avoid costly replacement. Filter lenses should be inspected for cracks or other damage to make sure no arc rays can leak through to the eyes. Another area of potential leakage is the lens gasket. It should be inspected to make sure all parts of the lens assembly are installed correctly. The shade number should be marked on the filter lens and on its storage container for easy identification.

Before a welding helmet is used, it must be inspected for wear, cracks, and other damage. A damaged helmet must be repaired or replaced. For storage, a welding helmet should be hung or kept in a place where it is protected from impact and other sources of damage.

Summary

The diameter of the electrode, the type of flux coating, and many other factors must be considered when selecting an electrode for arc welding. The two methods of electrode classification are the NEMA color-coding system and the AWS letter-and-number system. Understanding the meaning of the AWS code helps in the selection of the right electrode for the job. Proper care and storage of electrodes protects the coating from moisture, cracking, and chipping. The diameter of the electrode can be used as a guide for selecting filter lenses with the correct shade number. A filter lens should be protected from metal spatter by a clear outer safety glass. Filter lenses and welding helmets should be inspected for damage before use and stored where they are protected from damage.

Credits

Agricultural Mechanics Unit for Agricultural Science II. University of Missouri-Columbia: Instructional Materials Laboratory, June 1983.

Althouse, A.D., Turnquist, C.H., Bowditch, W.A., Bowditch, K.E. *Modern Welding*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Becker, W.J., Stephenson, W.C. *Welding Requirements – General: OSHA Standard 1910.252*. University of Florida. Accessed March 8, 2002, from <http://www.cdc.gov/niosh/nasd/docs/oa05100.html>.

Bowditch, W.A., Bowditch, K.E. *Welding Technology Fundamentals*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1997.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Griffin, I.H., Roden, E.M., Jeffus, L., Briggs, C.W. *Welding Processes* (3rd ed). Albany, NY: Delmar Publishers, Inc., 1984.

Jeffus, L. *Welding Principles and Applications* (4th ed). Albany, NY: Delmar Publishers, 1999.

Sacks, R.J. *Essentials of Welding*. Peoria, IL: Bennett Publishing Company, 1984.

Walker, J.R. *Arc Welding*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1999.

Lesson 4: Identifying Metals

Arc welders should know the properties and characteristics of various common metals so they can adjust welding equipment and procedures to produce a sound weld. This lesson provides information on the basic categories of metals, methods of identification, and characteristics and uses of common metals.

Importance of Metal Identification

With the many different metals used in industrial applications, it is impossible to be familiar with all of their characteristics and the welding techniques recommended for each one. However, welders should be aware that not all welding procedures can be used on all metals with acceptable results. They should find out what kind of metal they are working on in order to determine which electrodes and welding procedures are needed to produce strong, functional joints. For example, when welding cast iron, steps should be taken to prevent cracking as a result of its high carbon content. Mild steel, on the other hand, does not require special welding procedures and can be welded successfully with all processes.

Basic Metal Categories

The two basic categories for metal are ferrous and nonferrous. Ferrous refers to iron and metals with a high-iron content. “Ferrous” comes from the Latin word *ferrum*, which means iron. The world’s iron supply is plentiful, so it is relatively inexpensive and widely used in fabrication, including equipment and tools in agricultural mechanics. Common ferrous metals include wrought iron, all steels, and cast iron. Nonferrous refers to metals that contain little or no iron. Even though nonferrous metals are more expensive and are in more limited supply, it is not uncommon to work with them in agricultural mechanics. Common nonferrous metals include aluminum, copper, brass, and bronze.

Methods of Identifying Metals

Many metals look alike, especially different types of steel. When an individual is working on a welding repair, the metal is typically unmarked and difficult to identify. Various

methods have been developed to help in the identification of different metals. Some of the most common metal identification methods are as follows.

Ferrous and Nonferrous Testing

The most basic tests determine if a metal is ferrous or nonferrous. One way is to use the magnet test. Most ferrous metals are magnetic; nonferrous metals are not. An exception is some types of stainless steel.

Color is another general way in which ferrous metals can be distinguished from nonferrous ones. Ferrous metals (irons and steels) tend to be gray, gray-white, bright silver, or black in appearance. Nonferrous metals tend to be white, yellow, or reddish in color.

Oxyacetylene Torch Testing

Applying an oxyacetylene flame to metal is used to identify the type by how quickly it melts, how the puddle looks, and how the color of the metal changes as it is heated. Torch testing of steels and steel alloys is also used to determine whether or not the metals have good welding properties. In this test, a neutral flame is used to heat the metal to its melting point and make a hole. The metal is observed as it is heated and after it cools. During the heating process, a metal with good welding characteristics does not produce excessive sparks or does not boil. Once it has solidified, a metal with good welding characteristics is smooth and shiny, not rough, dull, or porous.

Spark Testing of Ferrous Metals

Spark testing is used to identify different types of ferrous metals. By comparing sparks made by an unknown metal to those from a known type of metal, the beginning welder can learn to identify metals. To perform the spark test, the metal is held lightly against a grinding wheel and observed as small heated particles of metal oxidize or burn as the wheel throws them off.

Because metals and their alloys produce distinctive spark patterns, these patterns can be used to identify the metals. Sparks are observed for their color, length, explosions along the length of the spark, and shape of the

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explosions. Regarding steel, for example, what the tester will generally find is that as the carbon content increases, the number of explosions increases and the length of the spark decreases. It is recommended to perform the test against a dark background or in low light so the sparks are more distinctive.

Spark testing is not useful on nonferrous metals because they do not produce sparks during grinding. In addition, grinding is not recommended for nonferrous metals because they can frequently clog the grinding wheel. Some types of nonferrous metals produce oxides that are toxic. If a nonferrous or suspected nonferrous metal is to be spark tested, consult the instructor before proceeding. The operator must wear an approved breathing apparatus and the grinding wheel must be equipped with an exhaust system.

Characteristics and Uses of Common Metals

Knowledge about the characteristics and uses of common metals can provide guidance in selecting metals for welding projects in agricultural mechanics and in choosing the proper welding techniques. Characteristics and uses of various ferrous and nonferrous metals are as follows.

Ferrous Metals

- Wrought iron: This metal is almost pure iron and contains very little carbon. Its low-carbon content causes wrought iron to have low strength and hardness, but it has the positive characteristic of being very ductile (easy to shape without fracturing). It rusts slowly and is easily welded. Once an important structural metal, wrought iron is now used mostly in ornamental work.
- Carbon steel: This is the most common type of steel (about 90% of all manufactured steel) and it is cheaper than alloy steel. Generally, as carbon increases, so do hardness, tensile strength, resistance to wear, and cost. As carbon increases, ductility is lost and the melting point is lowered. The three basic types of carbon steel are as follows.
 - Low-carbon steel, including mild steel: This steel cannot be hardened. It is easy to machine, can be used with all welding processes, and produces high-quality welds. Uses include wire, pipe, auto bodies, and storage tanks.
 - Medium-carbon steel: This steel can be strengthened and hardened with heat treatment. Heat treatment before and after welding generally produces the best results with this steel. Uses are similar to low-carbon steel, but medium-carbon steel can withstand greater stress than low-carbon steel. Medium-carbon steel is used in crankshafts, gears, and hammerheads.
 - High-carbon steel: This steel can be heat treated to produce high strength and hardness. It is more difficult to weld than low- and medium-carbon steel because of the hardening effect of the heat treatment. High-carbon steel is used in making tools, dies, and train wheels.
- Alloy steel: These are metals to which other elements besides carbon have been added in large enough amounts to produce qualities not found in carbon steel. Common alloying elements include manganese, nickel, and tungsten. Manganese strengthens steel and increases its resistance to shock. Nickel adds strength and corrosion resistance. Tungsten makes steel self-hardening and able to withstand high temperatures. As the amount of alloying elements increases, the welding difficulty generally increases.
- Stainless steel: Stainless steel basically refers to steels with enough chromium alloy to resist corrosion. This metal is available in over 100 different kinds and has many uses. It is valued for its ability to resist rust and to be sterilized. Stainless steel has good welding characteristics, but it is more difficult to weld than carbon steel.
- Cast iron: This metal contains more carbon than steel, which helps it withstand high-compression loads. The high-carbon content also lowers the melting point, making it good for casting; however, it makes cast iron more brittle than steel. Most cast iron can be welded with oxyacetylene and shielded metal arc welding processes. The exception is white cast iron, which is considered almost impossible to weld. Cast iron is used to make brake drums, engine blocks, and furnace grates.

Unit II – Arc Welding

Nonferrous Metals

- **Aluminum:** In its pure state, aluminum is much weaker than steel, but the addition of alloys, heat treatment, and cold working can make it, pound for pound, stronger than structural steel. Aluminum alloys are valued because they are more lightweight than most metals and resistant to corrosion. Aluminum can be welded, but aluminum oxide must be removed to ensure a good-quality weld. Another consideration when welding aluminum is it does not change color before reaching its melting point. To determine if the metal is softening, the welder can scratch the surface of the metal as it is heated. Its uses include wheels, airplane parts, cans, and castings.
- **Copper:** Pure copper is very soft, but processes such as the addition of alloys and cold working can increase its ductility and malleability (ability to be forged, hammered, or rolled). It is corrosion resistant and is second only to silver as an electrical conductor. Most copper and copper alloys can be joined by common welding methods, brazing, and soldering. Like many nonferrous metals, copper has a tendency toward hot shortness (easily distorting when heated to its melting point). Because of this property, copper must be firmly clamped when heated to this temperature. Copper is used to make wire, pipe, and radiator parts.
- **Brass:** This metal is an alloy of copper and zinc. It has working characteristics similar to those of copper. It is valued for its resistance to acids, ability to be easily formed, attractive appearance, and its ability to be a good brazing alloy. Brass is used in plumbing parts, castings, and ornamental work.
- **Bronze:** This metal is an alloy of copper and tin. It resists corrosion like copper, but is stronger and easier to cast. Like brass, bronze has an attractive appearance. It behaves similarly to brass when welded. Uses include gears, castings, and decorative parts.

Summary

Metals should be identified before welding to aid in selecting the correct electrode and welding procedure. One of the basic categories of metal is ferrous, which describes metals with high-iron content, including wrought

iron, carbon steel, alloy steel, stainless steel, and cast iron. The other category is nonferrous, which refers to metals with little or no iron, including aluminum, copper, brass, and bronze. Common methods of identifying metal are ferrous and nonferrous testing, oxyacetylene torch testing, and spark testing.

Credits

Agricultural Mechanics Unit for Agricultural Science II. University of Missouri-Columbia: Instructional Materials Laboratory, June 1983.

Althouse, A.D., Turnquist, C.H., Bowditch, W.A., Bowditch, K.E. *Modern Welding*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Brandt, D.A., Warner, J.C. *Metallurgy Fundamentals*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1999.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Jeffus, L. *Welding Principles and Applications* (4th ed). Albany, NY: Delmar Publishers, 1999.

Krar, S.F., Rapisarda, M., Check, A.F. *Machine Tool and Manufacturing Technology*. Albany, NY: Delmar Publishers, 1998.

Phipps, L.J., Reynolds, C.L. *Mechanics in Agriculture* (4th ed). Danville, IL: Interstate Publishers, Inc., 1992.

Sacks, R.J. *Essentials of Welding*. Peoria, IL: Bennett Publishing Company, 1984.

Walker, J.R. *Arc Welding*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1999.

Walker, J.R. *Modern Metalworking*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Welding Theory and Application. Training Circular No. 9-237. Department of the Army, 1993. Accessed March 15, 2002, from <http://www.adtdl.army.mil/cgi-bin/atdl.dll/tc/9-237/toc.htm>

Lesson 5: Welding Out of Position

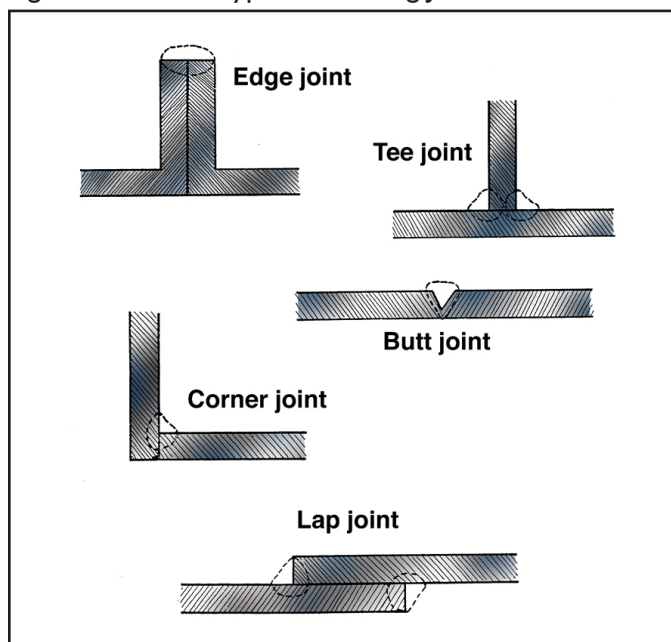
Arc welders in agricultural mechanics should be familiar with the various joint designs they will encounter in their work. They also need to understand the different welding positions and techniques used to improve weld quality in out-of-position welding. This lesson describes the basic types of welding joints and welding positions and discusses the techniques used in each position.

Basic Welding Joints

Welding projects in agricultural mechanics have various types of joints depending on the nature of the project. The five basic joint designs in arc welding are the edge, tee, butt, corner, and lap. See Figure 5.1. There are additional types of joints that are variations of these five basic designs. These variations are not discussed in this lesson. The basic designs are described below.

- **Edge joint:** This joint is formed by positioning pieces parallel or nearly parallel to each other and joining them edge to edge. It is welded on one or more edges.
- **Tee joint:** In this joint, pieces are joined at an angle to form a “T” shape. It is welded on one side or both sides.

Figure 5.1 – Basic Types of Welding Joints



- **Butt joint:** In this joint, the pieces are joined edge to edge in the same plane.
- **Corner joint:** This joint is formed by joining pieces at the edges at an angle (usually a right angle). The welding is done outside or inside the corner joint or on both sides.
- **Lap joint:** This joint is created by overlapping one piece of metal on another. It is welded on one side only or on both sides of the joint, depending on job requirements.

The edges of the joints may be prepared by using various techniques (beveling, squaring, flaring, etc.) to improve penetration and produce a better weld. To keep joints in correct alignment for welding, the pieces are secured in a clamp and/or tack welded.

Arc Welding Positions

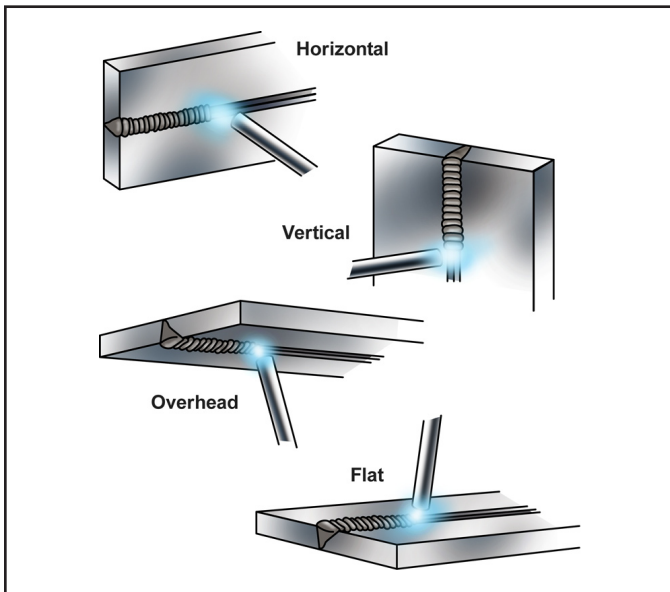
The position of the joints in a welding project may require the welder to weld in various positions. The four basic positions are flat, horizontal, vertical, and overhead. See Figure 5.2. A flat weld is done with the weld axis (imaginary line through the center of the weld) and weld face (surface of the weld on the welding side) in a flat position in front of the welder. Whenever possible, welds should be made in the flat position, because in other positions the welder is working against the force of gravity, which will draw the molten metal out of place. However, welds cannot always be moved. For example, it may be impractical to reposition the joints in a large piece of farm equipment.

Welding in positions other than flat (that is, horizontal, vertical, and overhead) is called welding out of position. Welders must practice making out-of-position welds to ensure that these welds are as strong as and have the same appearance as those made in the flat position. Out-of-position welds are described below.

- A horizontal weld is made with the weld axis in a horizontal position and the weld face and base metal in a vertical (up and down) or nearly vertical position.
- With the vertical position, the weld axis and weld face are both approximately vertical. Welds in the vertical position can be done in an uphill (also called vertical-up) direction or a downhill (also called vertical-down)

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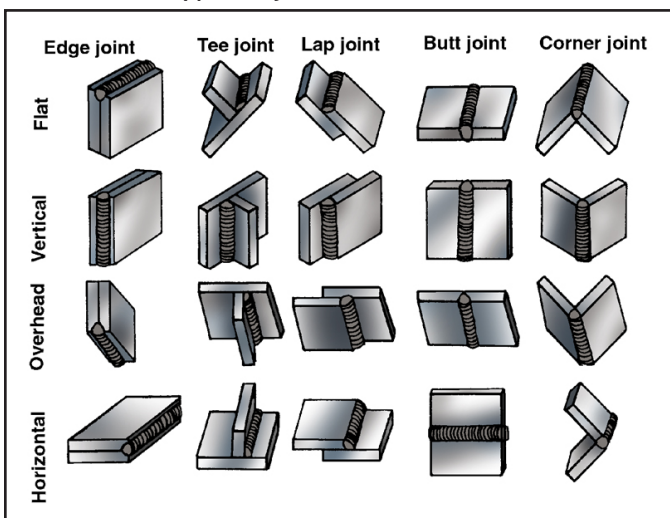
Figure 5.2 – Positions for Welding



direction. In the uphill direction, welding is done from the bottom of the joint to the top. In the downhill direction, welding is done from the top of the joint to the bottom.

- The overhead position is performed from the underside of the joint, with the weld axis and face approximately horizontal. This is the position in which gravity causes the greatest safety hazard and difficulty for the welder.
- With practice, high-quality welds can be produced on all joint designs and in all positions. See Figure 5.3.

Figure 5.3 – Welding Positions for the Five Basic Types of Joints



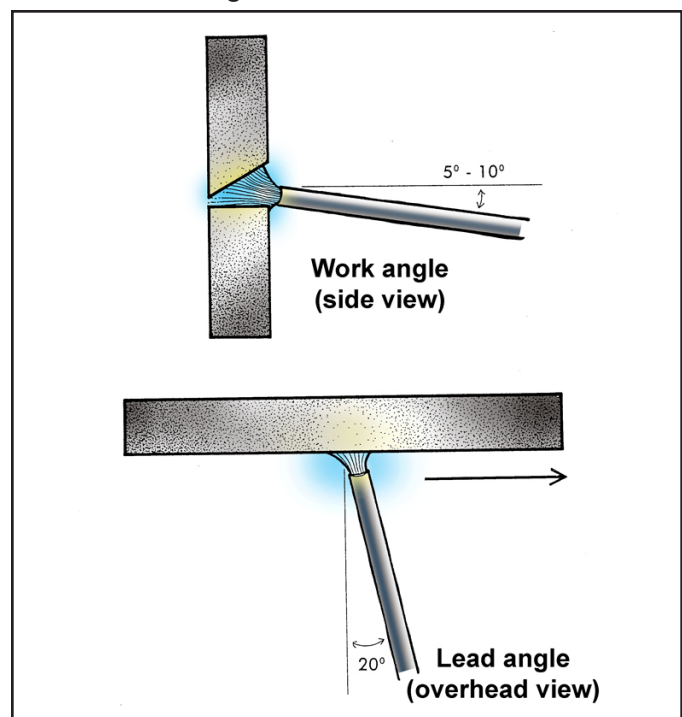
Techniques to Improve Out-of-Position Welds

When welding out of position, changes in welding technique are required to counteract the force of gravity. General guidelines for making out-of-position welds include using a smaller diameter electrode, which allows lower amperage to be used and makes a weld pool that is easier to manage because it is smaller. In addition, use of an electrode that deposits fast-setting filler (e.g., E6010, E6011, and E7018) provides the benefit of keeping the filler metal from sagging. The welder should adjust the electrode in the jaws of the holder to a convenient angle. The electrode itself should not be bent into position, because bending it could cause the flux to break off, resulting in a loss of shielding gas and substandard welds.

Horizontal Welds

Guidelines for butt welds include holding the electrode at a work angle of roughly 5 to 10 degrees below perpendicular, so that the electrode is pointed up at the weld. For the lead angle, the electrode should be leaned approximately 20 degrees in the direction of travel. See Figure 5.4.

Figure 5.4 – Angle of the Electrode for Horizontal Welding



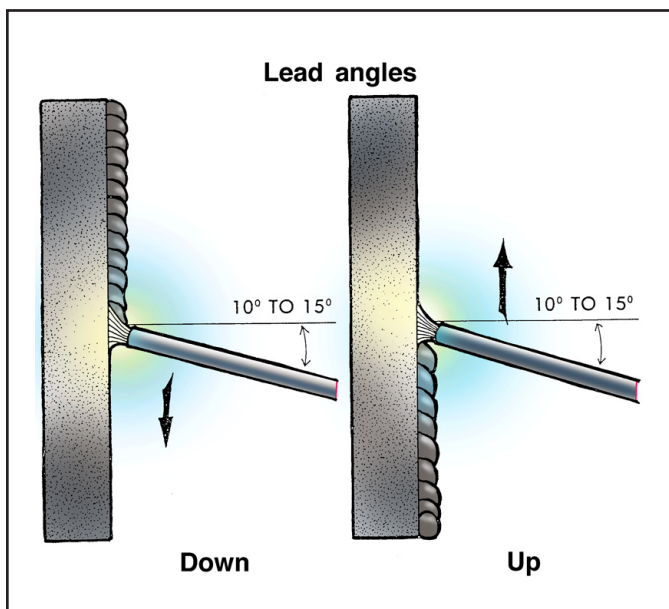
Unit II – Arc Welding

It may be necessary to reposition the electrode for other types of joints. Another recommendation is to maintain a shorter arc length, which creates a shorter distance for the filler metal to travel and in turn less chance for gravity to make it fall.

Vertical Welds

For welding a butt joint in the vertical position, the electrode should be held at a right angle to the base metal and inclined down approximately 10 to 15 degrees, so that the electrode is pointed up in relation to the base metal. It may be necessary to reposition the electrode for other types of joints. The vertical-up direction provides greater penetration and is best for thicker metal, whereas the vertical-down direction can be used for thinner metal. See Figure 5.5.

Figure 5.5 – Angle of the Electrode for Vertical-Down and Vertical-Up Welding



To keep the weld pool from getting too hot, the welder can use a flipping or whipping motion with the electrode. This motion involves moving the electrode forward, lifting it slightly, and bringing it back to the weld pool without breaking the arc. Like horizontal welding, vertical welding benefits from a shorter arc length to ensure better transfer of filler.

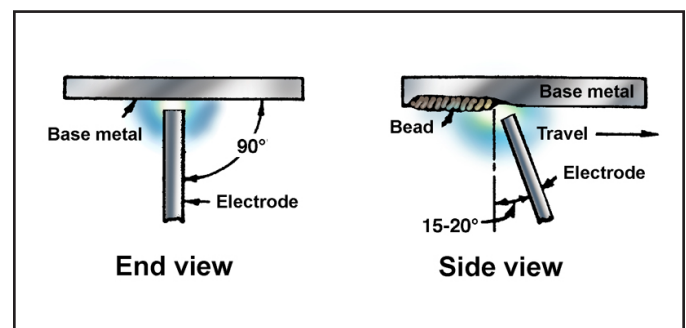
Overhead Welds

Welding in the overhead position is generally the most difficult of all the positions and causes the most safety concerns for the welder. In addition to the usual welding safety procedures, the welder must be sure to take extra steps to protect against falling molten metal. The welder should wear a fireproof cap, be sure that pant legs are cuffless and cover the tops of the shoes, and follow any other guidelines from the instructor.

For overhead butt welds, the electrode is held approximately perpendicular to the base metal and tilted 15 to 20 degrees in the direction of travel. See Figure 5.6.

It may be necessary to reposition the electrode for other types of joints. A flipping motion, the same as that used for the vertical position, can be used to control the weld pool and keep the filler from dropping out.

Figure 5.6 – Angle of the Electrode for Overhead Welding



Summary

The five basic joint designs that arc welders encounter are the edge, tee, butt, corner, and lap. Depending on the nature of the work, a welder will have to weld in various positions. The four positions are flat, horizontal, vertical, and overhead. The flat welding position is the best because the force of gravity is not a factor. Welding in the latter three positions is called out-of-position welding and requires the use of special techniques to keep gravity from causing the molten metal to fall.

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Credits

Agricultural Mechanics Unit for Agricultural Science II. University of Missouri-Columbia: Instructional Materials Laboratory, June 1983.

Althouse, A.D., Turnquist, C.H., Bowditch, W.A., Bowditch, K.E. *Modern Welding*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Bowditch, W.A., Bowditch, K.E. *Welding Technology Fundamentals*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1997.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Jeffus, L. *Welding Principles and Applications* (4th ed). Albany, NY: Delmar Publishers, 1999.

Phipps, L.J., Reynolds, C.L. *Mechanics in Agriculture* (4th ed). Danville, IL: Interstate Publishers, Inc., 1992.

Walker, J.R. *Arc Welding*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1999.

Welding. University of Missouri-Columbia: Instructional Materials Laboratory, July 1988.

Unit III – Oxyacetylene Welding

Lesson I: Safety and Maintenance Procedures for Oxyacetylene Welding

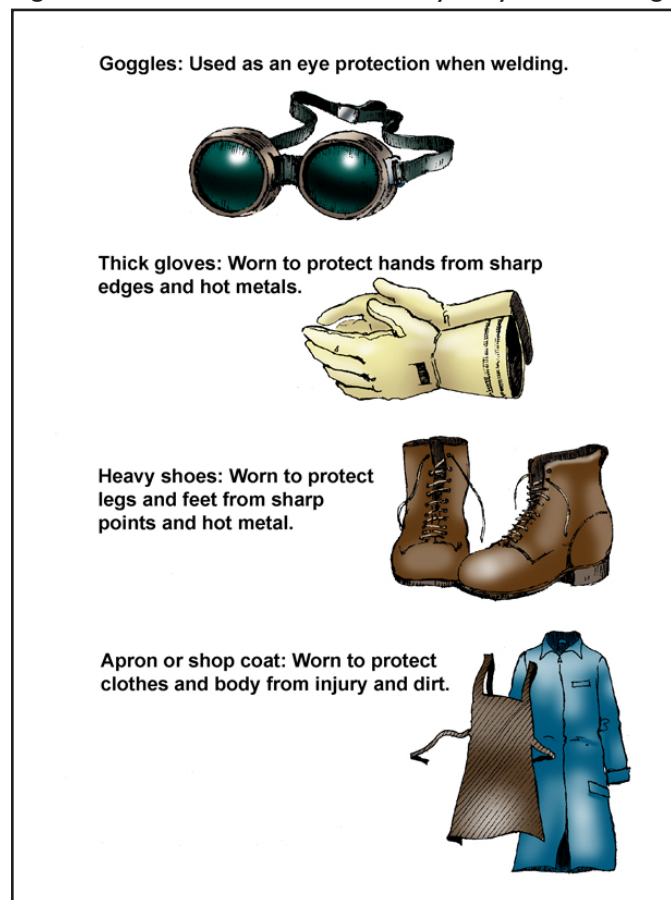
In oxyfuel processes, oxygen and a fuel gas (commonly acetylene) are combined to produce a high-temperature flame to heat, cut, or weld metal. These processes are commonly used in agricultural mechanics. Like arc welding, oxyacetylene welding can pose hazards but is safe when the operator is well trained and follows the safety precautions. This lesson discusses the hazards of oxyacetylene welding and the ways to avoid the hazards so that accidents can be prevented. It does not cover every possible risk; your instructor can provide other safety rules for the particular work setting or process.

Safety hazards of oxyacetylene welding include the volatility of the highly pressurized oxygen and acetylene cylinders, harmful fumes from gases and melting metal, burns from fire and sparks, and burns from light rays.

Protecting the Welder

- **Wear appropriate clothing and safety gear.** When using oxyacetylene, various clothing and gear are necessary to protect the body from sparks, burns, and harmful fumes. The eyes and other body parts must also be protected from harmful light rays. See Figure I.1.
 - Hands and feet: Leather gauntlet-style gloves and high-top leather shoes should be worn to protect the hands and feet.
 - Body: Clothing should be wool or cotton. It should be dark and tightly woven, which helps block light rays. Shirts should be long sleeved and worn with the sleeves and top button at the collar buttoned. Pants should come down over the tops of the boots and be cuffless to avoid getting sparks caught in the cuffs. Other protective clothing, such as leather aprons and leather sleeves, are also available and should be worn as needed. Do not wear clothing with tears or frayed areas that can leave skin exposed or easily catch fire from the sparks. Do not wear synthetic materials, which can burn readily and give off poisonous gases. Do not carry items in pockets, such as matches or butane lighters,

Figure I.1 – Protective Gear for Oxyacetylene Welding



which could potentially catch fire or explode. Do not allow clothing to become saturated with fuel gas or oxygen, which would make the clothing highly flammable. If this happens, clothing must be aired out before it is safe to wear.

- Head and eyes: Welders should never look at the oxyacetylene flame with unprotected eyes; they should wear welding goggles with filter lenses appropriate for the work being done. Lenses with a 4 to 8 shade number are common for oxyacetylene welding. Consult the manufacturer's recommendations. Inspect the filter lenses for cracks and do not use them if they are damaged. Filter lenses are expensive and should be protected with clear cover plates. Wear safety glasses underneath the welding goggles to protect eyes from flying debris. Wear additional head and eye protection, such as a flameproof skullcap or face shield, as needed to avoid burns from sparks or hot metal spatter.

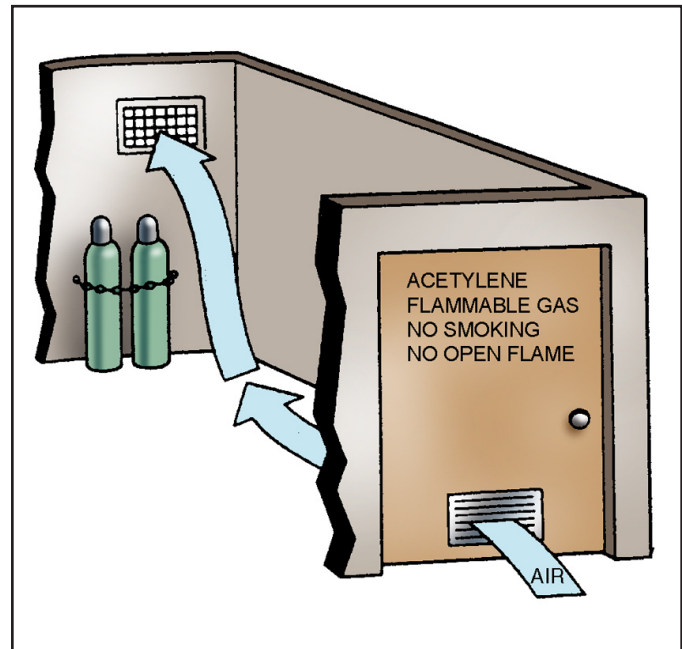
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- o Respiratory system: Some types of metals give off toxic fumes during the welding process. Metals that are covered with paint, grease, or other chemicals can also create a breathing hazard. In addition, acetylene fuel can displace oxygen in the air and cause respiratory problems. Working outdoors or in a large shop with high ceilings and natural ventilation is best. If this is not possible, use forced ventilation, such as hoods and exhaust fans. The ventilation system should be as close to the work as possible. Respirators also may be required depending on the size of the work area, ventilation available, and the metals being welded.

Protecting the Work Area

- **Make the work area as fire resistant as possible.** Oxyacetylene welding should only be done in fireproof surroundings, such as concrete floors and walls. Wooden floors or walls are combustible. The work area should be clean and free of trash, grease, oil, and other flammable materials. In case a person's clothes catch on fire, a fire blanket should be available to wrap around the person to smother the fire. An appropriately rated fire extinguisher, first-aid kit, and safety equipment should be kept within easy reach. Aisles and stairs should be kept free of obstacles for quick exit in case a fire occurs.
- **Work with adequate ventilation.** Besides eliminating breathing hazards, ventilation is required to protect the welder's clothing from becoming highly combustible due to saturation with oxygen or fuel gases. If possible, leave shop doors and windows open.
- **If natural ventilation is not sufficient, use forced ventilation.** A forced ventilation system can be hoods and exhaust fans and should be as close to the work as possible.
- **Store cylinders correctly.** The acetylene and oxygen cylinders used in oxyacetylene welding are highly pressurized and may explode if not handled properly. Acetylene is highly flammable and care must be taken to prevent fires. See Figure 1.2.

Figure 1.2 – Proper Storage of Acetylene Cylinders



- o Acetylene and oxygen cylinders must be stored separately. If the cylinders are stored together and a fire starts, the fuel and oxygen might be released from the cylinders and cause a large explosion and/or blaze.
- o Acetylene and oxygen cylinders should be chained upright or otherwise prevented from being knocked over. The valve may be damaged and cause a leak if the cylinder is knocked over. Use of a fuel cylinder that has been in a horizontal position can release acetone from the valve. This can adversely affect the cutting or welding process and damage equipment.
- o The storage area should be locked and labeled with appropriate warning signs. These areas should only be accessible to authorized personnel and have signs posted warning people not to smoke or use fire near the area. Storage areas should be made of fire-resistant materials and located away from sources of heat and fire, such as furnaces and welding processes.
- o Fuel storage should be adequately ventilated to eliminate buildup of fuel fumes if a leak occurs.

Unit III – Oxyacetylene Welding

- Valve protection caps should be in place when the cylinder is not in use. Cylinder valves are fragile and can be damaged easily. Without the cap, the valve may break off a cylinder if it is knocked over or handled roughly. If the valve is broken off an oxygen cylinder, the cylinder may be propelled with great force. If the valve is broken off a fuel cylinder, a large flame may shoot out.
- A cylinder should be moved using a hand truck or by tilting it slightly and rolling it on its bottom edge with one hand on the valve protection cap. See Figure 1.3.

Figure 1.3 – Method of Moving a Cylinder



- If a cylinder is not properly labeled, do not use it. Return it to the supplier. If the cylinder does not have a label or if the label is illegible, it is impossible to be sure what type of gas is in the cylinder.

- **Do not attempt to heat, cut, or weld containers such as tanks, drums, and barrels.** These types of containers may have been used to store flammable substances, such as gasoline. The oxyacetylene process may cause an explosion and fire that can harm everyone in the area. Even though a container may look clean, it may still have fumes that can catch fire. Do not use oxygen to eliminate fumes in a container; this may cause an explosion and fire.

Safe Handling of the Oxyacetylene Outfit

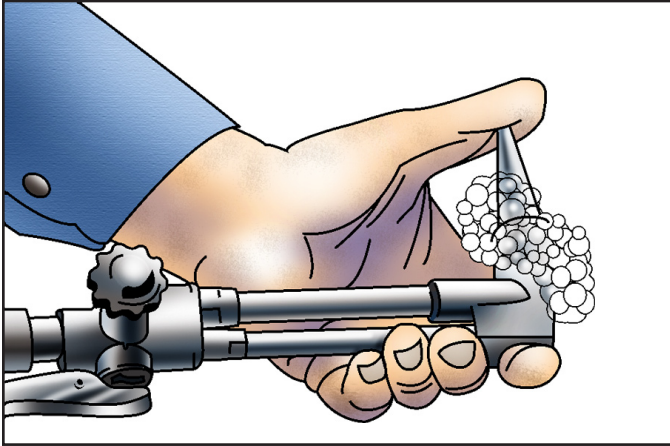
Major parts of an oxyacetylene outfit include the following: acetylene and oxygen cylinders; a truck or other device to keep the cylinders upright; acetylene valve, regulator, gauges, hose, and fittings; oxygen valve, regulator, gauges, hose, and fittings; and a torch. Extreme care must be taken in handling the equipment.

- **Cylinders must be fastened to a wall, post, or approved cylinder truck so that they stay upright at all times.** The valve may be damaged and cause a leak if the cylinder is knocked over. Valve protection caps should be in place when the cylinders are not in use to prevent damage to the valves.
- **Follow the specific procedure for setting up the outfit that will be used and use only parts designed for that setup.** Parts, such as acetylene torch tips and cylinder regulators, can appear similar to those used with other fuel gases, but they cannot be used interchangeably without risk of explosion. For example, when a tip designed for acetylene is used with other fuels, the tip may explode or cause a backfire. When a backfire occurs, there is a loud snapping sound and the flame goes out.
- **Run hoses so that they will not be damaged or cause a tripping hazard.** Be sure that hoses are not exposed to sparks and molten metal and are not located where the welder or others must walk or stand. In temporary work sites, keep hoses covered to protect them from traffic.
- **Check all connections with a leak-detecting solution.** An important step in setting up oxyacetylene equipment is applying a leak-detection solution, such as soap and water, to all connections. Fittings

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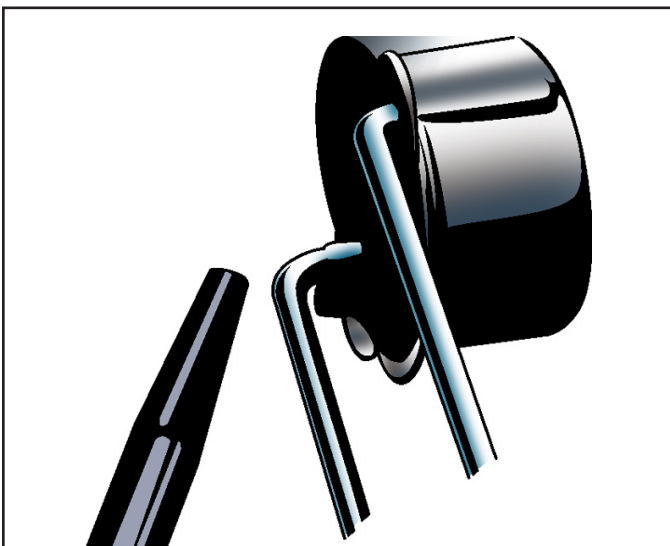
in areas that bubble should be tightened. See Figure I.4. Note that leaking valve stems in cylinders should not be repaired or used. Turn off the valve, label the cylinder as “bad,” and inform the supplier.

Figure I.4 – Checking Connections for Leaks



- **Do not use petroleum-based solutions to check for leaks and do not use grease to lubricate parts.** These substances can cause a fire hazard in the presence of oxygen.
- **Use a spark lighter held at an angle to light the torch.** See Figure I.5. Ensure the spark lighter is long enough to keep the operator from being burned by the flame. Do not use a match or butane lighter as this may cause a flare up that may harm the operator.

Figure I.5 – Using a Spark Lighter to Light a Torch



Position the torch so that the tip is pointing away from the operator, other people in the area, and combustible objects.

- **Always be sure the flame is off before setting the torch down.** If work is suspended for some time, the outfit must be shut down.
- **Follow the correct shutdown procedure when finished.** Close all points where oxygen or fuel gas can escape and bleed lines of any remaining gas. This prevents any undetected leaks in the system from causing a fire or explosion.
- **If equipment catches fire, turn off the gas at the tanks immediately.** If the fire does not go out, leave the area and call for help.

Maintaining the Oxyacetylene Outfit

Maintaining the equipment in an oxyacetylene outfit also promotes safety. This section discusses additional maintenance recommendations for specific pieces of oxyacetylene equipment. Consult the manufacturer or your instructor for other maintenance concerns.

Hoses

Hoses should be inspected regularly and repaired or replaced if they show signs of damage. Using tape to fix a leaky or damaged hose is an unsafe and inadequate way to repair it. When not using the hoses, coil them and store them where they cannot be damaged or cause damage to other equipment. For example, hanging the hoses over cylinder regulators can break the regulators or cause a leak.

Regulators

When the oxyacetylene outfit is not in use, regulators should not be left under pressure. Leaving regulators under pressure can stretch their internal parts, which will make them less accurate and reduce their life expectancy. It is important to use the proper tool to attach and remove regulators so that the fittings are not damaged. Regulators are designed so that they do not require oiling. Oiling a regulator can cause a fire or explosion. Only a properly trained technician should perform repairs on regulators.

Unit III – Oxyacetylene Welding

Torch Tips

Many torch tips are made of a soft metal and should be handled with care. Dropping them or subjecting them to other types of impact can damage the tips. Tips become dirty and clogged from use and should be inspected and cleaned frequently. Tip cleaners in various sizes are available to insert in the tip openings to remove dirt and spatter. It is important to use the correct size of tip cleaner. For example, if the tip cleaner fits too tightly, it may enlarge the tip openings. Damaged tips should be reconditioned or replaced as needed to ensure proper function.

Summary

Oxyacetylene welding is useful and safe when the welder follows the rules and is well trained. However, it has potential safety risks, such as explosions, burns, light ray burns, and breathing hazards. Welders must understand how to protect themselves by wearing protective clothing, ensuring the work area does not pose a fire hazard, and properly handling and maintaining oxyacetylene equipment.

Credits

Agricultural Construction: Volume II. University of Missouri-Columbia: Instructional Materials Laboratory, July 1989.

Althouse, A.D., Turnquist, C.H., Bowditch, W.A., Bowditch, K.E. *Modern Welding*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Bowditch, W.A., Bowditch, K.E. *Welding Technology Fundamentals*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1997.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Cyr, D.L., Johnson, S.B. *Welding Safety on the Farm*. University of Maine Cooperative Extension. Accessed February 11, 2002, from <http://www.cdc.gov/niosh/nasd/docs3/me97067.html>.

Jeffus, L. *Welding Principles and Applications* (4th ed). Albany, NY: Delmar Publishers, 1999.

Phipps, L.J., Reynolds, C.L. *Mechanics in Agriculture* (4th ed). Danville, IL: Interstate Publishers, Inc., 1992.

Sacks, R.J. *Essentials of Welding*. Peoria, IL: Bennett Publishing Company, 1984.

Unit III – Oxyacetylene Welding

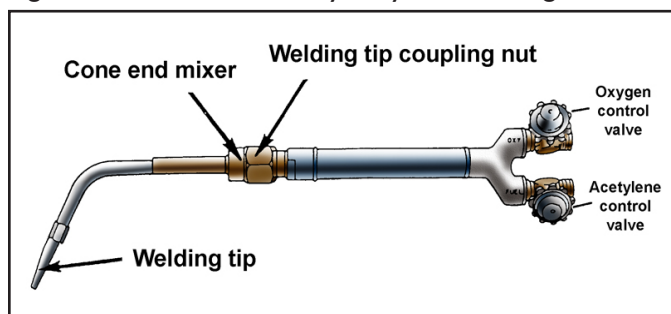
Lesson 2: Welding With Oxyacetylene

Oxyacetylene welding is another method commonly used in agricultural mechanics to melt and fuse two metals together. To be skilled at this process, welders must be familiar with the equipment and welding rods used. In addition, they should understand the methods used to improve weld quality and ways to avoid common problems that can occur. Because oxyacetylene welding can be hazardous, strict observation of the safety rules is critical. Your instructor must be present to demonstrate the step-by-step procedures for welding metal with oxyacetylene and guide you through them.

Differences Between the Welding Outfit and Cutting Outfit

In Agricultural Mechanics Unit for Agricultural Science I, you were introduced to the major parts and functions of the oxyacetylene cutting outfit. The components of an oxyacetylene welding outfit are the same as those in a cutting outfit except for differences in the torch and oxygen regulator. Unlike a cutting torch, a welding torch does not have an additional oxygen line to produce a cutting jet of oxygen. See Figure 2.1. The oxygen regulator used with the cutting outfit may be designed to work under higher pressure because of the volume of oxygen that can be used when cutting thicker pieces of metal. If different types of oxygen regulators are used in the shop for different applications, check with the instructor to be sure the regulator is designed for the work that is being done. With the acetylene regulator, the same one that is used for cutting can also be used for welding because the working pressure of acetylene should always be kept below 15 psi to avoid risk of fire and explosion.

Figure 2.1 – Parts of an Oxyacetylene Welding Torch



Use of a Welding Rod

Oxyacetylene welding can be done with or without the use of a welding (filler) rod. When the process is done without a welding rod, the base metal is used as filler and one piece is welded directly to another. An example of a joint that can be welded with this method is an edge joint made of thin metal. Many other types of joints will require the use of a welding rod to add metal and strengthen the weld.

Characteristics of Welding Rods

Like the electrodes used in arc welding, oxyacetylene welding rods are metal rods made of materials similar to various base metals. The rods can also contain other materials that strengthen the weld or provide other positive characteristics. They come in different diameters, from 1/16 in. to 3/8 in., and are generally 36 in. long. Welding rods are also identified by the American Welding Association (AWS) classification system. For example, in the classification number RG-45, the "R" indicates it is a welding rod, the "G" indicates it is used for gas welding, and "45" indicates it has a tensile strength of approximately 45,000 psi.

Only welding rods that have a classification number and are specifically designed for the procedure and conditions should be used. Substituting other types of metal or wire for welding rod is not acceptable because (1) the composition of the wire can vary greatly, (2) it can produce porous, substandard welds, and (3) it can include finishes or coatings that produce toxic fumes.

Factors in Weld Quality

Factors that can affect the quality of the weld include torch tip size, torch position, torch movement, and welding rod size. Knowing the correct adjustments and techniques for the job is important to making strong welds.

Torch Tip Size

The size of a torch tip affects the width of the weld bead, the penetration of the weld, and the speed of movement. Follow the instructor's or manufacturer's

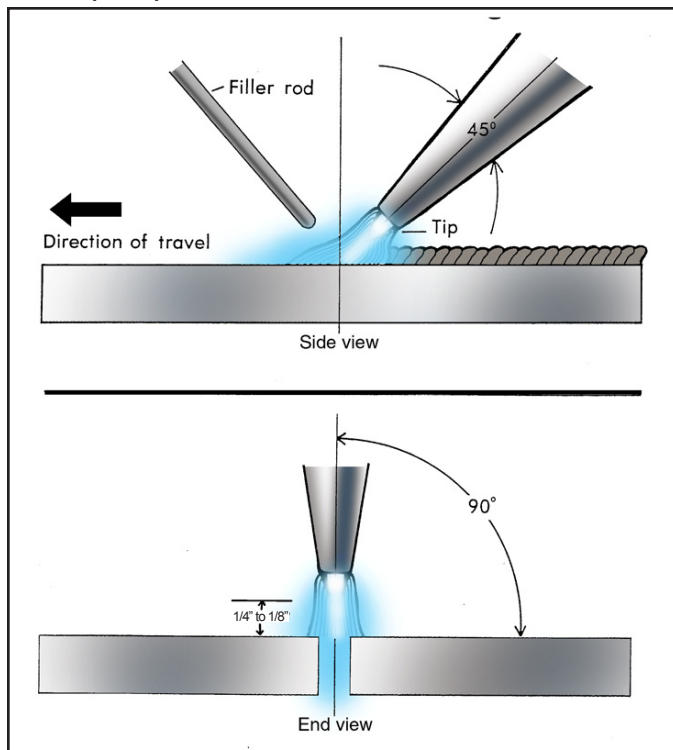
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recommendations on the proper torch tip size to use for the work. Torch tips are also designed to work within a specific operating range that must be appropriate for the thickness of the metal. Some beginning welders may make the mistake of trying to adjust the torch flame to compensate for the wrong tip size. Welding with the wrong kind of flame can adversely affect weld quality. Avoid this pitfall by using the correct size tip.

Torch Position

Torch positioning has a great effect on the speed of melting and the size of the weld pool. Two key aspects of torch position are its angle and its distance from the work. The appropriate torch angle depends on the tip size, thickness of the metal, and welding conditions. The closer the torch is held at a right angle to the work, the more heat is transferred to the base metal. A 45-degree angle is often used. The usual distance for holding the inner cone of the flame from the work is 1/8 to 1/4 in. As the torch is moved closer to the work, the heating rate increases. It is also important to maintain the torch angle and distance consistently throughout the weld. See Figure 2.2.

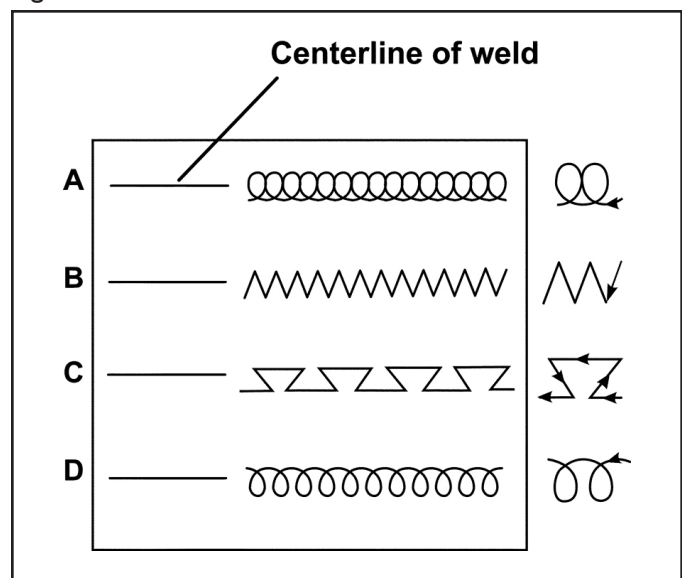
Figure 2.2 – Angle and Distance for Holding the Oxyacetylene Torch



Torch Movement

Another factor that affects weld quality is torch movement, which should be adjusted to suit the type and thickness of metal being welded. The basic torch movement in oxyacetylene welding is to move the torch forward along the centerline of the weld and also move in a pattern, such as circular or back and forth. See Figure 2.3. The cone of the flame should be kept in the weld pool during this motion and should be advanced about 1/16 in. each time.

Figure 2.3 – Torch Movement Patterns



In addition, two general methods for directing the flame can be used. These methods are called forehand welding and backhand welding. In forehand welding, the flame is pointed in the direction of travel and preheats the metal ahead of the weld pool. In backhand welding, the flame is pointed in the opposite direction of travel and postheats the metal behind the pool. The backhand technique helps relieve welding stress. Backhand welding is generally used for welding cast iron and thicker metal.

Welding Rod Size

Using a welding rod of the correct diameter is essential to produce a good-quality bead. A welding rod that is too small will not add enough filler material. A welding rod that is too large can remove too much heat from the weld pool too quickly, causing the pool to freeze and

Unit III – Oxyacetylene Welding

trap the rod. As a general principle, as the welding rod decreases in diameter, it absorbs less heat, the weld pool becomes wider with deeper penetration, and buildup of filler is reduced. On thicker metal, for example, it may be necessary to use a smaller diameter rod to enhance penetration.

Common Welding Problems

Common welding problems include backfire, flashback, and improper flame adjustment. A welder should be able to recognize these problems as well as know the ways to avoid them.

Backfire

A backfire happens when the flame goes out and there is a loud pop or snapping sound. Possible causes of backfire include the following:

- The tip may be overheated due to overuse, getting too close to the work, or working in a hot corner.
- The torch may be operating at pressures that are too low for the tip being used.
- The tip may have touched the work.
- The tip may be loose or damaged.
- The tip may be dirty.

After a backfire, the torch should be shut down immediately and all possible causes checked and eliminated before relighting the torch. A backfire may cause a flashback, which is a dangerous problem.

Flashback

A flashback occurs when the flame burns back inside the tip, torch, hose, or regulator. When flashback occurs, a squealing or hissing sound is usually heard. It is a hazardous situation that can cause equipment damage and personal injury. Possible causes of flashback are the failure to purge the system (clear the lines) before use and overheating the torch tip.

If a flashback occurs, immediately turn off the oxygen torch valve and then the acetylene torch valve. If the fire might extend to the hoses, quickly shut off the acetylene cylinder valve, followed by the oxygen cylinder valve.

Flashback indicates a serious problem with the equipment or its operation. An experienced operator or technician should inspect the equipment to determine whether it is safe to use or which parts must be repaired or replaced. The torch must be allowed to cool before investigating the problem.

Improper Flame Adjustment

Another common problem that can adversely affect weld quality is improper adjustment of the oxyacetylene flame for the application or type of metal.

- The carburizing (carbonizing) flame is low temperature and may add carbon to the cut or weld. With this flame, too much acetylene is present and three distinct parts of the flame are visible. In the case of steel, it will cause the weld pool to boil, appear cloudy, and produce brittle welds. It may, however, be used for some brazing or welding procedures.
- An oxidizing flame is high temperature and may add oxygen to the cut or weld. Too much oxygen is present in this flame, the flame is noisy, and the inner cone is shortened. It is not recommended for most operations because it will form oxides with many metals, which will produce brittle, low-strength welds. An oxidizing flame used on steel causes foaming and sparking of the weld pool, producing welds with low strength and ductility (pliancy).
- A neutral flame is an approximately even balance of acetylene and oxygen. It does not add carbon to the weld or burn it with oxygen. A neutral flame is the best choice for most welding and cutting tasks.

Summary

The oxyacetylene cutting outfit and the welding outfit are similar except for the design of the torch and oxygen cylinder regulator. Oxyacetylene welding can be performed with or without a welding rod, depending on the type of joint or thickness of the metal. Welding rods are classified by AWS and are similar in design to electrodes used in arc welding. Factors such as torch tip size, torch position, torch movement, and welding rod size have a big effect on weld quality. Common problems that occur in oxyacetylene welding are backfire, flashback, and improper flame adjustment for the application.

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Credits

Agricultural Mechanics Unit for Agricultural Science II. University of Missouri-Columbia: Instructional Materials Laboratory, June 1983.

Althouse, A.D., Turnquist, C.H., Bowditch, W.A., Bowditch, K.E. *Modern Welding*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Bowditch, W.A., Bowditch, K.E. *Welding Technology Fundamentals*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1997.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Jeffus, L. *Welding Principles and Applications* (4th ed). Albany, NY: Delmar Publishers, 1999.

Phipps, L.J., Reynolds, C.L. *Mechanics in Agriculture* (4th ed). Danville, IL: Interstate Publishers, Inc., 1992.

Sacks, R.J. *Essentials of Welding*. Peoria, IL: Bennett Publishing Company, 1984.

Unit III – Oxyacetylene Welding

Lesson 3: Brazing on Mild Steel

Fabrication and repair needs vary widely in agricultural mechanics. Brazing and braze welding processes provide valuable options for joining materials together. Before using these processes, it is important to understand how they work, the materials required, and the techniques used for producing a good joint. Your instructor must be present to demonstrate the step-by-step procedures for using these processes and guide you through them.

Safety Precautions for Brazing and Braze Welding

Before beginning to braze a joint, one should understand the various safety precautions associated with the process. The safety precautions that apply to cutting or welding with oxyacetylene also apply to brazing or braze welding with oxyacetylene. See Lesson 1 in this unit to review safety measures for welding. Below are safety precautions that are pertinent to brazing and braze welding.

- **Make sure the work area has excellent ventilation.** Fumes from the fluxes, filler metals, and base metal coatings may be toxic. They can harm the lungs, skin, or eyes. They can even cause death. Some fumes do not have an odor and the effects are not experienced until hours after exposure. Two examples of dangerous substances are zinc oxide (type of filler alloy) and cadmium (additive in some filler metals). A respirator may be required when these or other harmful substances are used. Consult the instructor and manufacturer's recommendations.
- **Avoid letting fluxes come into contact with skin.** Many fluxes are harmful to skin. Wearing protective clothing, gloves, and eye goggles will help

eliminate the chances of contact. If fluxes do touch the skin, wash the area thoroughly with soap and water. If flux material gets in the eyes, rinse them thoroughly with water and seek medical attention.

- **Do not store or eat food in the work area.** Fumes from fluxes, filler metals, base metal coatings, and other chemicals may contaminate food, making it harmful to consume. Operators and others in the work area should wash their hands and face before eating or when finished with work.
- **Wear the same type of clothing and protective clothing when brazing as when welding or cutting.** This includes a long-sleeved shirt with collar and cuffs buttoned, long pants without cuffs, leather gloves and shoes, and other protective clothing as needed for brazing.
- **Wear goggles with filter lenses appropriate for the work being done.** To prevent eye burns from light rays, operators commonly wear lenses with shade no. 3 or 4 for torch brazing. Consult the instructor and manufacturer for specific recommendations.
- **Make sure that persons using acids or other cleaning solutions wear the appropriate protective gear.** Persons using acids or other chemicals to prepare the base metal for brazing and braze welding should wear rubber gloves, long sleeves, and goggles approved for use around chemicals.

Comparing Brazing to Other Processes

Many aspects of brazing, soldering, and braze welding are the same and sometimes these processes are referred to interchangeably. See Table 1 for the definitions and differences among the processes. The capillary action used in brazing and soldering is a physical process in which liquid filler metal is drawn into the space between

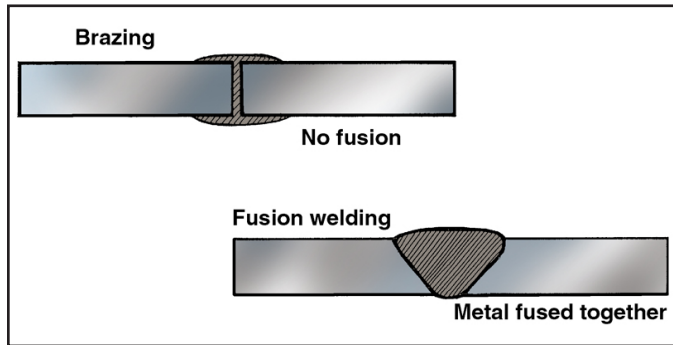
Table 1 – Differences Between Brazing and Other Processes

Process	Definition	Capillary Action	Melts Base Metal
Brazing	Joining materials by adding filler metal that becomes liquid at a temperature above 840° F but below the temperature at which the base materials start to melt.	Yes	No
Soldering	Same definition as above, but the filler metal that is used becomes liquid at a temperature below 840° F.	Yes	No
Braze welding	Joining materials by running a braze pool to fill a groove or make a fillet.	No	No
Fusion welding	Joining materials by melting them together to form one piece.	No	Yes

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two closely fitted surfaces. In braze welding, the filler metal does not fill the space in the joint by means of capillary action. Fusion welding, such as shielded metal arc welding and oxyacetylene welding, also are described in the table for comparison purposes. See Figure 3.1 for a comparison of brazing and fusion welding.

Figure 3.1 – Comparison of Brazing and Fusion Welding



Advantages and Disadvantages of Brazing

Common uses for brazing include producing joints that are leakproof, joining thin sheets of steel, and repairing broken or cracked castings. Knowing the advantages and disadvantages of brazing will help in deciding if it is the best process for the job.

Some of the advantages of brazing over fusion welding are the following.

- With brazing, a lower temperature can be used because the base metal does not have to melt. The lower temperature allows very thin parts to be joined together or thin parts to be joined to thick parts without damaging them. In addition, the heating time is reduced, there is less chance of warping the base materials, and stress in the joint is reduced.
- Dissimilar metals can easily be joined because the base metal does not have to melt. Two examples are joining copper to steel or cast iron to stainless steel. Nonmetals can also be joined to metals, such as a ceramic piece to steel.
- The joined pieces can easily be disassembled without damaging them. Reheating the filler metal allows the pieces to be pulled apart. Then the filler metal is wiped off and the parts can be reused. This capability is useful for realigning joints as well.

Some of the disadvantages of brazing as compared with fusion welding are the following.

- Brazed joints may not be as strong as similar joints made by fusion welding. The filler metals used for brazing are not as strong as the base metals they join; therefore, joints should not be designed to depend on the filler for strength.
- The lower service temperature of filler metal in brazing precludes its use on assemblies that will be exposed to higher temperatures. The service temperature refers to the highest temperature at which the material can be used.
- Filler metal used for brazing may not be as resistant to chemical solutions as the base metal. This would be a consideration when the assembly will be exposed to chemicals that might corrode the filler.

Functions of Flux

Using flux directly on the base metal or as a coating on filler metal is an essential step in brazing. Flux is used to remove the oxides from the filler and base metals and protect the joint from oxidizing during brazing. Another function of flux is to help the filler flow, spread evenly, and adhere on the base metal, which aids the capillary action. This is known as “wetting.” Without a flux, the melted filler metal will bead up and roll off the base materials.

Factors in Choosing Flux and Filler

There are many factors to consider when choosing flux and filler. All the variables should be weighed in order to achieve the best overall result. The various types of flux are designed to function with specific base metals, filler metals, and in certain temperature ranges. Filler metals are made of various alloys that have varying brazing and service temperatures and are compatible with certain base metals. The compatibility of the flux and filler with the base metal is an important consideration because using incompatible materials can result in joints that corrode, are brittle, and lack strength. For example, the combination of brass filler used on stainless steel can result in a weak joint if heated too long. Check the manufacturer’s information about the flux because some types can be harmful to skin or produce toxic fumes.

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Fluxes are available in various forms, including powders, pastes, liquids, and as coatings on some filler metals. Filler metals are available as preformed shapes, powders, and as bare rods, or rods with flux already applied.

Materials Used for Brazing Mild Steel

A flux with a base of borax or borax and water (boric acid) is commonly used for brazing on steel. Brass, an alloy made of copper and zinc, is a filler metal commonly used on steel and other ferrous metals. Brazing filler metals are designated with a “B” followed by the chemical symbols of the elements of the alloy. For example, brass filler metal is designated as BCuZn. Bronze is an alloy made of copper and tin. Some brazing rods are called “bronze,” but are actually made mostly of brass, with only small amounts of tin.

Techniques for Brazing and Braze Welding

Before beginning to braze or braze weld, it is important to know the general techniques used for the processes.

- Check the fit and alignment of pieces before they are brazed or welded. For brazing, a close fit of the pieces is essential so that capillary action can occur. The recommended clearance between pieces is from .001 in. to .010 in. A joint with a clearance that is too small or too large will be weak and may break under force. For braze welding, rules for the fit are the same as those for fusion welding. Whereas joints to be braze welded do not require as close a fit as brazed joints do, a good fit will produce a stronger joint.
- Clean base materials before brazing or braze welding. This step is essential for successful results in either process. Clean surfaces allow capillary action to take place during brazing. The flux must be applied immediately after the surfaces have been cleaned to eliminate further contamination. Mechanical or chemical methods or both are used to clean surfaces.
 - o Mechanical cleaning: Surface dirt is removed by grinding, sanding, and wire brushing. After mechanical cleaning, the base material should be washed and dried to remove particles knocked loose while cleaning.

- o Chemical cleaning: Oil and grease are removed so that they are not ground into the surface by mechanical cleaning. Acids or other solutions can be used to remove rust and scale. This process is called “pickling.” Chemical cleaning should be followed by washing and drying of the parts.
- Adjust the flame properly when brazing with a torch. A carburizing flame produces a joint with a neat appearance, but its strength may be weakened. An oxidizing flame produces a joint that is strong, but it may be rough looking. The torch adjustment depends on the job; however, in general, a neutral flame gives the best results for brazing and welding under normal conditions.
- Prevent overheating of the base material, filler, or flux when brazing with a torch. Brazing is performed by heating a large area, whereas fusion welding and braze welding are performed by heating a localized area. Acetylene produces a flame with a very hot inner cone but a relatively cool outer flame. If acetylene is used, care must be taken to avoid overheating a small area instead of heating a larger area uniformly. It is recommended to keep the torch moving over the surfaces rather than have it in one spot for too long. Overheated flux can stop working and contaminate the joint. If this occurs, the flux must be removed before continuing.

Summary

The safety precautions that apply in oxyacetylene welding also are used in brazing and braze welding. Brazing joins materials by means of capillary action and not melting the base materials. Braze welding is similar to oxyacetylene welding, but the base materials are not melted. A major advantage of brazing over fusion welding is that the materials that are joined are not damaged because a lower temperature is used. A disadvantage of brazing is that the joints are not as strong as those created in fusion welding and this limits its application. Fluxes and filler metals used for brazing are available in various types and forms, which are designed for specific metals and temperature ranges. Techniques for brazing with a torch include aligning and fitting the pieces closely, cleaning the base materials before brazing, properly adjusting the flame, and preventing overheating of the base materials.

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Credits

Agricultural Mechanics Unit for Agricultural Science II. University of Missouri-Columbia: Instructional Materials Laboratory, June 1983.

Althouse, A.D., Turnquist, C.H., Bowditch, W.A., Bowditch, K.E. *Modern Welding*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Becker, W.J., Stephenson, W.C. *Welding Requirements – General: OSHA Standard 1910.252*. Accessed April 1, 2002, from University of Florida at <http://www.cdc.gov/niosh/nasd/docs/oa05100.html>.

Bowditch, K.E., Bowditch, M.A. *Oxyfuel Gas Welding*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1997.

Bowditch, W.A., Bowditch, K.E. *Welding Technology Fundamentals*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1999.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Jeffus, L. *Welding Principles and Applications* (4th ed). Albany, NY: Delmar Publishers, 1999.

Sacks, R.J. *Essentials of Welding*. Peoria, IL: Bennett Publishing Company, 1984.

Unit IV – Tool Sharpening and Reconditioning

Lesson I: Sharpening and Reconditioning a Twist Drill, Lawn Mower Blade, and Chain Saw Chain

Sharpening and reconditioning tools to their original condition has many benefits. Tools that are sharp and in proper condition are safer to use, perform more easily, and produce better quality work. In addition, tools are a major investment and maintaining them is less expensive than replacing them with new ones. This lesson discusses how to sharpen and recondition twist drills, lawn mower blades, and chain saw chains, all common tools used in agriculture. It also describes how to maintain a grinding wheel, which is used to sharpen tools. Your instructor must be present to demonstrate the step-by-step procedures for sharpening and reconditioning and to guide you through them.

Safety Procedures for Using a Bench Grinder

A bench grinder is a common tool used for rough sharpening and for producing the correct bevel on tool blades. Follow the safety procedures listed below when using a bench grinder.

- Wear a face shield and leather apron. Wear other protective clothing or gear, such as a filter mask or respirator, as required by the instructor.
- Unplug the grinder before making any inspections or adjustments, such as changing a wheel.
- Make sure that the guards are in the proper position before starting the grinder.
- Stand to the side of the wheel when starting the grinder and let the wheel run for a short period before using it. Wheels that are going to break usually do so within the first minute of use.
- Move the work slowly back and forth across the face of the wheel to avoid overheating the work or damaging the wheel.
- Do not force work into the grinding wheel. Allow the speed and grit of the wheel to do the work.
- Inspect wheels frequently and do not use a wheel that is damaged or out of round. If the wheel is damaged, consult the instructor about dressing or replacing the wheel. Dressing the wheel means to use a tool to recondition the wheel, making the diameter perfectly

round and the face square. Dressing also removes debris from the abrasive material.

Factors for Selecting Grinding Wheels

To operate a grinder safely and successfully, it is important to select the correct wheel for the job. Manufacturers provide specifications about wheels that will help in the selection process. Some of the specifications are described below.

- **Abrasive material:** Wheels are made of different types of abrasive materials for various grinding purposes. Some are made of natural materials, such as Arkansas stones, and others are made of synthetic materials, such as silicon carbide or aluminum oxide.
- **Grit:** Grit refers to the small abrasive cutting particles in the material. The grit size of a wheel is indicated by a number generally ranging from 10 (most coarse) to 600 (most fine).
- **Grade:** The grade of a wheel indicates its hardness. Grades range from the letter “A” (the softest) to the letter “Z” (the hardest). Tool sharpening is commonly done with a medium-hard wheel.
- **Bond:** The bond refers to the way the abrasive materials are held together to form a wheel. The manufacturing process for grinding wheels includes mixing abrasive materials with a bonding agent and pouring the mixture into a mold. The mold is heated and then cooled to form a solid abrasive. Vitrified bonding, using a silica agent, is one of the most common bonding processes.
- **Dimensions:** This measurement is the outside diameter and width of the wheel. Consult the grinder manufacturer’s specifications for the correct size.

Dressing a Grinding Wheel

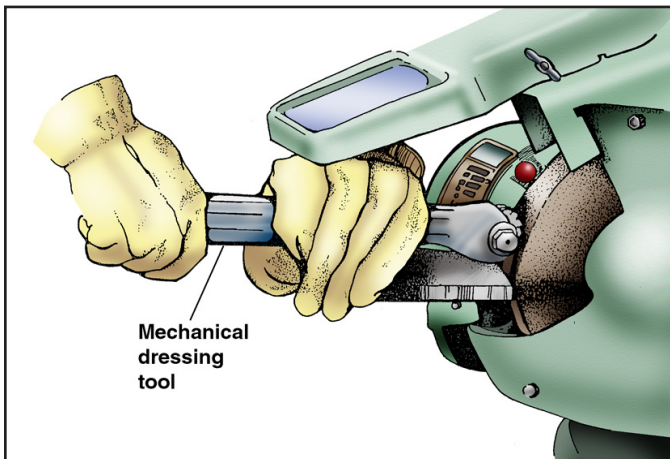
The cutting ability of a grinding wheel is impaired when it becomes out of round or the abrasive material becomes loaded (clogged with debris) or glazed (dulled). A procedure called dressing is performed on a wheel to restore its effectiveness. This procedure requires the operation of the grinder. The safety guidelines used for other grinding procedures should be followed when dressing the wheel. Various types of tools are available,

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including a mechanical dressing tool, to dress the wheel. The tool rest on the grinder may need to be adjusted for the dressing tool. If so, it should be moved back to 1/16 in. from the wheel after the procedure is complete.

To dress a grinding wheel, the grinder is turned on and a dressing tool is held with even pressure on the wheel and moved from side to side. See Figure 1.1. If heavy sparking is produced, the dressing tool should be held with more pressure against the wheel. Excessive sparking indicates that the dressing tool is being ground away. When dressing is complete, the grinder is turned off and disconnected from the power. The shape and surface of the wheel are inspected. A successfully dressed wheel should be perfectly round and the face should be flat and square. The abrasive material should be sharp and free of debris.

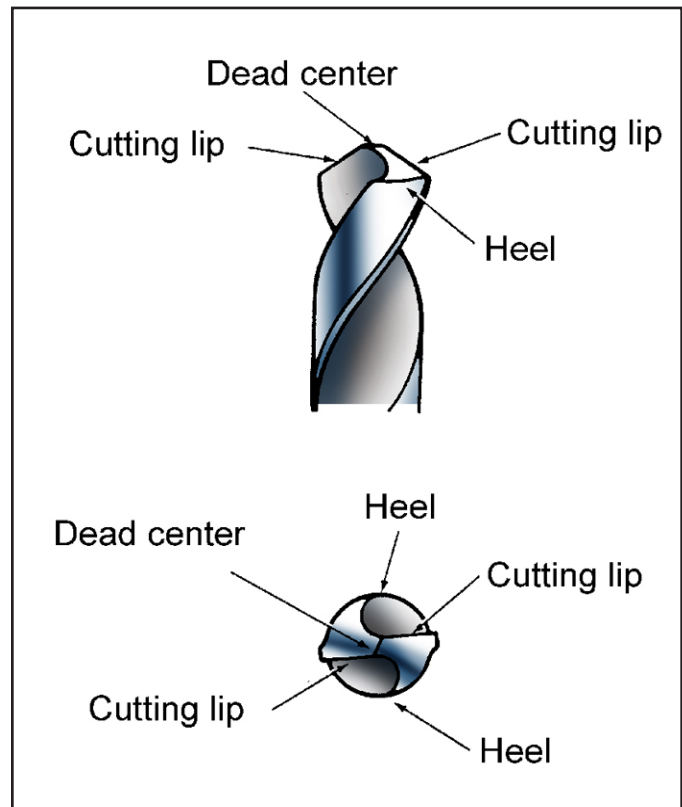
Figure 1.1 – Dressing a Grinding Wheel



Sharpening a Twist Drill

Twist drills should be kept sharp to operate safely and produce good-quality work. The frequency of use and type of material that is drilled affect how quickly the drill becomes dull. For example, a drill used on wood remains sharp for much longer than one used on metal. Twist drills can be sharpened by hand using a grinder. Knowing the parts of the cutting tip on a twist drill is helpful for understanding how to sharpen it. The tip parts are the dead center, two cutting lips, and two heels. See Figure 1.2.

Figure 1.2 – Parts of a Twist Drill

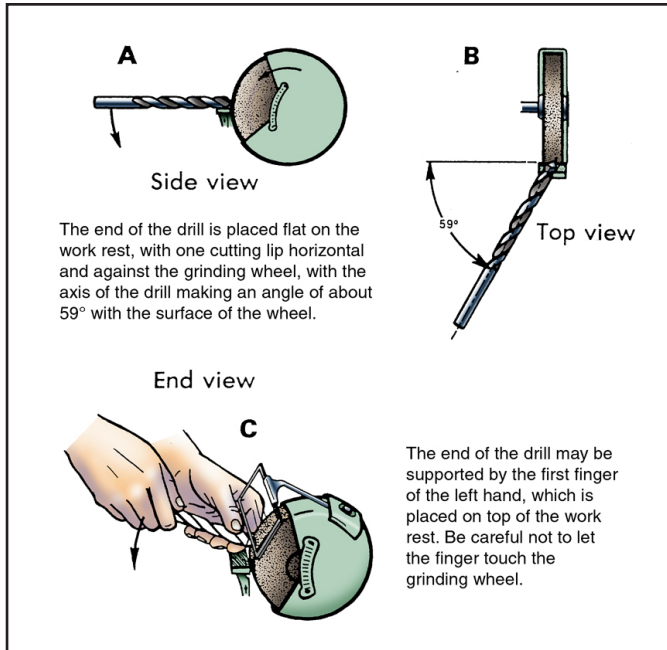


Examining a new or properly sharpened twist drill before beginning the procedure can also be helpful. The dead center of a properly sharpened drill is at the exact center of the drill and the cutting lips are at a 59-degree angle to the centerline of the drill. The angle between dead center and the heel should be 12 degrees for each cutting lip. This angle provides clearance for the bit and support so the cutting lips do not break. A drill should also be inspected to make sure it is not bent. If the drill is bent and cannot be straightened, it should be discarded. A bent drill will produce an oversized hole.

The same safety guidelines used for other grinding procedures should be followed when sharpening a drill. The proper position for sharpening is to hold the drill perpendicular to the face of the wheel with a cutting lip at a 59-degree angle. See Figure 1.3. For grinding the tip on the wheel, the back end of the drill should be lowered as the drill is rotated slightly clockwise. When one lip is sharpened, the procedure is repeated on the other lip.

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Figure 1.3 – Proper Position of the Twist Drill for Sharpening



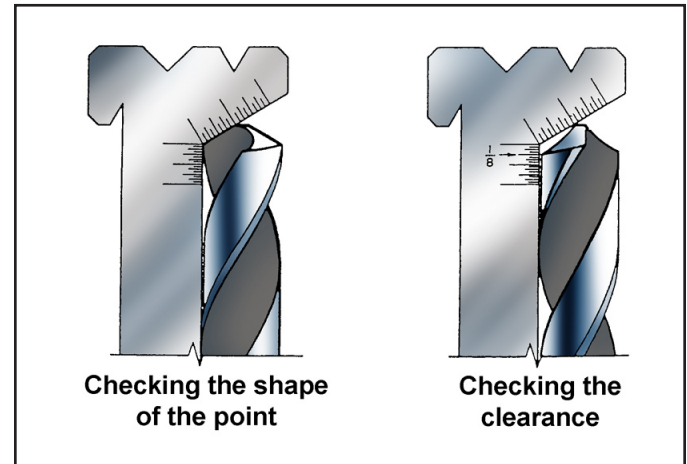
To determine if a twist drill has been properly resharpened, a tool gauge should be used to measure the following criteria.

- Angle formed by the cutting lip and outer edge of the drill: This should be 118 degrees.
- Clearance of the cutting lip: The gap made by the drop of the cutting lip to the heel is measured. For example, a 1-in. drill should have approximately a 1/8-in. gap between the drill and the corner of the tool gauge. See Figures 1.4 and 1.5.

Figure 1.4 – Drill Size and Proper Clearance of Cutting Lip

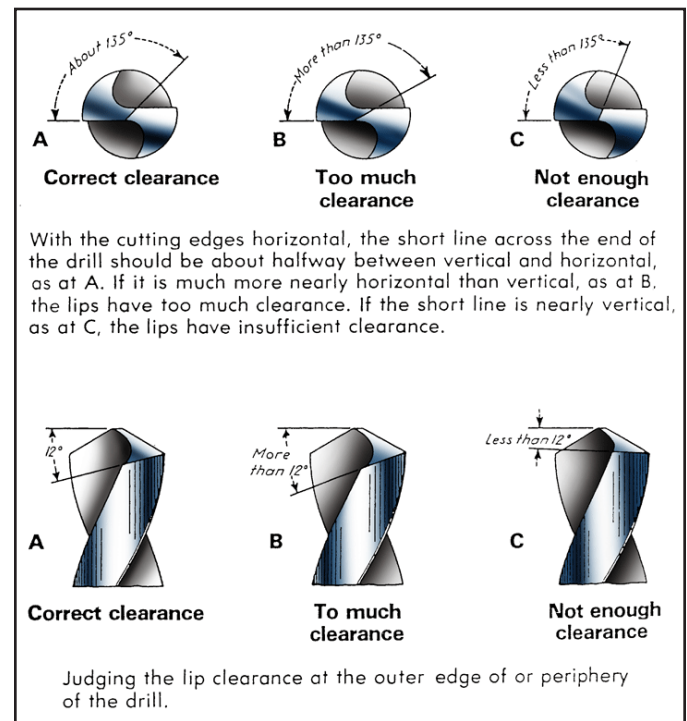
For 12° Clearance	
Drill size	Amount of drop
1/4"	1/32"
1/2"	1/16"
3/4"	3/32"
1"	1/8"
other sizes	prorated amount

Figure 1.5 – Checking the Shape and Clearance of a Twist Drill With a Tool Gauge



The clearance of the cutting lip can also be checked visually. When the cutting lips are placed in horizontal position, the angle between the dead center line and the cutting lip should be approximately 135 degrees. An angle greater than 135 degrees indicates too much clearance, whereas an angle less than 135 degrees indicates not enough clearance. See Figure 1.6.

Figure 1.6 – Judging Lip Clearance



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Sharpening a Lawn Mower Blade

A lawn mower blade should be sharpened frequently because a sharp blade requires less power, produces a cleaner and more even cut, and does less damage to plants. A mower blade can be sharpened with a file or a portable grinder.

Safety rules for sharpening mower blades include the following.

- Before removing the blade, disconnect the spark plug wire and secure it so it cannot come in contact with the spark plug and accidentally start the mower. Disconnect an electric mower from its power source.
- Wear gloves when removing or installing the blade to protect the hands from scrapes and cuts.
- If using a grinding wheel to sharpen the blade, wear safety goggles or a face shield and any other protective gear recommended by the instructor. Follow all of the assigned safety and use procedures for a portable grinder.
- If using a file to sharpen the blade, wear safety goggles and leather gloves.
- Follow instructions in the owner's manual for the lawn mower and guidelines from the instructor for correct sharpening procedures.

When a lawn mower blade is sharpened, the cutting side of the blade is restored to its original angle. A typical angle for a lawn mower blade is 45 degrees. The noncutting side is kept flat. A grinding wheel or file can be used to sharpen the cutting edge of the blade to its original angle. See Figure 1.7. Any nicks and burrs should be ground off the noncutting side of the blade to keep it flat.

An equal amount of metal should be taken off both ends of the blade during the sharpening procedure to keep the blade in balance. A blade is out of balance when one end is heavier than the other end. An improperly balanced blade causes the mower to vibrate, which could damage the shaft, bearing, and body of the mower. The balance of a blade can be checked with a blade balancer or by inserting a rod in the center hole of the blade. The blade sits level when it is properly balanced. See Figure 1.8.

Figure 1.7 – Using a File to Sharpen a Lawn Mower Blade

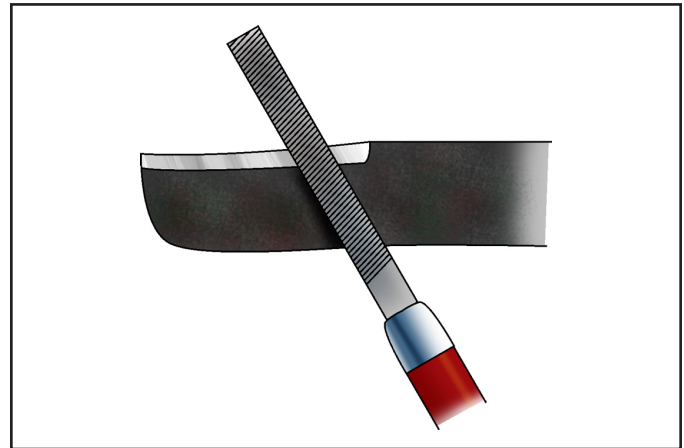
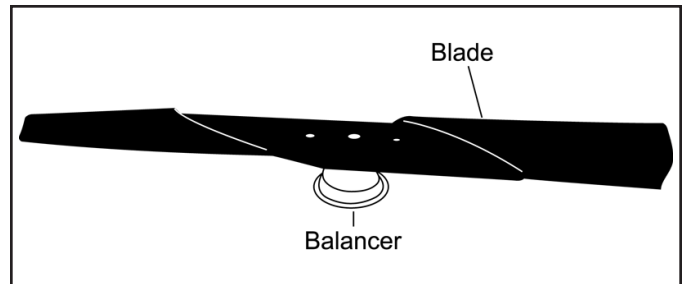


Figure 1.8 – Checking the Balance of a Lawn Mower Blade With a Balancer



Sharpening and Maintaining a Chain Saw Chain

A chain saw chain also becomes dull through use and needs to be sharpened frequently. The benefits of a sharp chain saw include the ability to cut more wood faster, reduced operator fatigue, increased work site safety, and reduced wear and tear on the chain saw.

Factors affecting how often the chain needs to be sharpened include the frequency of use and the type of wood being cut. For example, hardwoods dull a chain quicker than softwoods. The following are signs that a chain needs sharpening.

- The chain tends to “walk” sideways while cutting.
- The cut produces fine powdery shavings instead of chips.
- The cut takes longer to make.
- More pressure is required to make the cut.
- The cut produces the smell of burned wood.

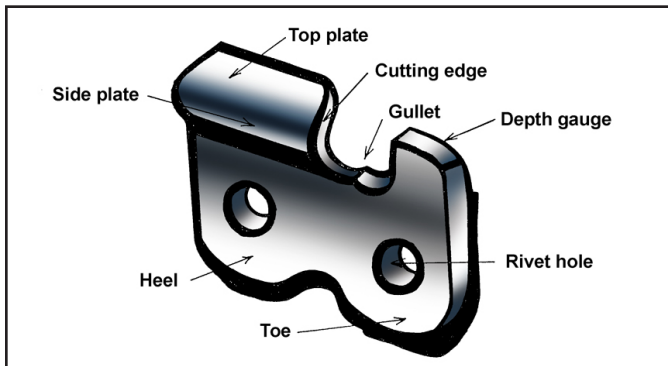
Unit IV – Tool Sharpening and Reconditioning

Safety rules for making repairs or adjustments to a chain saw are as follows.

- Before making any adjustments or repairs to the saw, disconnect the spark plug wire and secure it so it cannot come in contact with the spark plug and accidentally start the saw. Disconnect an electric chain saw from its power source.
- Wear leather gloves when working with the blade to protect hands from the cutters.
- Wear safety goggles and leather gloves when using a file to sharpen the chain.
- Follow instructions in the owner's manual for the chain saw and guidelines from the instructor for correct work procedures.

It is important to be familiar with the design of a chain saw chain before beginning the sharpening procedure. Chains vary in the design of their cutting links (cutters). The differences are seen in the cutting teeth and depth gauges. The parts of a cutter are the rivet hole, depth gauge, gullet, cutting edge, top plate, side plate, heel, and toe. See Figure I.9.

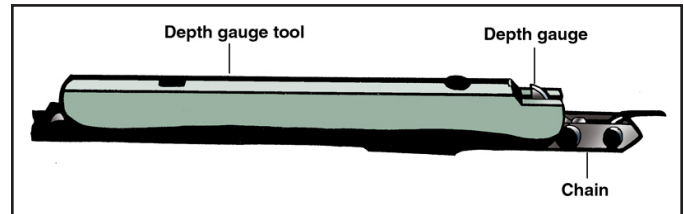
Figure I.9 – Parts of a Cutter on a Chain Saw Chain



A chain saw chain can be sharpened with a round file and a file guide. The file guide is used to maintain the round file at the proper depth and angle while the cutting edges of the cutter are filed. The design of these tools can vary depending on the chain saw. Operators should consult the manufacturer's recommendations for the correct chain-sharpening tools in order to maintain correct angles, shape, and proportions of the cutters. The depth gauges on the cutters should also be checked and adjusted as needed. As a general rule, depth gauges should be checked every third or fourth sharpening. Depth gauges control

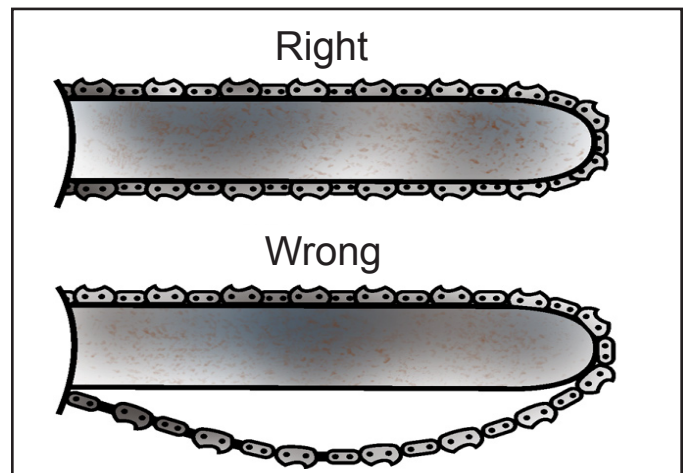
the thickness of the chips that the cutters will cut. Tools for this procedure are a depth gauge tool and a flat file. The depth gauge tool is a specific tool recommended by the manufacturer. It is used to determine if the depth gauges are the proper height. If the top of a depth gauge on a cutter extends above the depth gauge tool, it should be filed off with the flat file. In filing a depth gauge, it is important to maintain its original shape. See Figure I.10.

Figure I.10 – Depth Gauge Tool



Checking the tension of the chain and adjusting it as needed is another essential procedure for safe operation and good performance of a chain saw. If the chain tension is too loose, the chain has a greater tendency to kickback or jump off the bar, which is dangerous. A loose chain can also increase the wear on parts of the saw. If the chain tension is too tight, the chain may bind, which can lead to accidents and increase the wear on parts. The manufacturer's and instructor's guidelines for the proper procedure should be followed when adjusting the tension of a chain. Chain tension should be adjusted only when the chain is cold. If the chain tension is adjusted properly, the chain moves freely when rotated but does not hang loose from the bar. See Figure I.11.

Figure I.11 – Correct and Loose Tension of the Chain on a Chain Saw



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Summary

Tools that are sharp and in good condition are necessary for high-quality work and safe operation. Many sharpening and reconditioning procedures are done with grinders and hand files. Some of the most common procedures for tool maintenance in agricultural mechanics are dressing a grinding wheel, sharpening a twist drill, sharpening and balancing a lawn mower blade, and sharpening and adjusting the tension of a chain saw chain.

Credits

A Guide to Safety With Chainsaws. Occupational Safety and Health Service of New Zealand, 1993.

Agricultural Mechanics Unit for Agricultural Science I. University of Missouri-Columbia: Instructional Materials Laboratory, July 1982.

Agricultural Mechanics Unit for Agricultural Science II. University of Missouri-Columbia: Instructional Materials Laboratory, June 1983.

Baker, D.E., Day, D. *Chain Saw Safety.* University of Missouri-Columbia Extension. Accessed April 24, 2002, from <http://www.cdc.gov/niosh/nasd/docs2/as24600.html>.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Feirer, J.L. *Furniture and Cabinet Making.* Peoria, IL: Bennett Publishing Company, 1983.

Harvesting and Chainsaw Tips and Hints. Government of Newfoundland & Labrador. Accessed April 24, 2002, from http://www.gov.nf.ca/forest/forest/forest_use/tiphint/chainst.htm.

Hetzel, G.H., Butler, J. *Safety With Chainsaws.* Virginia Cooperative Extension. Accessed April 25, 2002, from <http://www.cdc.gov/niosh/nasd/docs4/va98052.html>.

Krar, S.F., Check, A.F. *Technology of Machine Tools* (5th ed). Westerville, OH: Glencoe McGraw Hill, 1997.

Lilly, S., Michaels, M. *Basic Chainsaw Maintenance.* Society of Commercial Arboriculture. Accessed April 22, 2002, from <http://www2.champaign.isa-arbor.com/sca/newsletter/chainsaw-maintenance.html>.

Maintenance and Service. Canadian Center for Occupational Health and Safety. Accessed April 24, 2002, from http://www.ccohs.ca/oshanswers/safety_haz/chainsaws/maintenance.html.

Olivo, C.T. *Machine Tool Technology and Manufacturing Processes.* Albany, NY: C. Thomas Olivo Associates, 1987.

Oregon Cutting Systems. Accessed April 24, 2002, from <http://www.oregonchain.com/faq.htm>.

Phipps, L.J., Reynolds, C.L. *Mechanics in Agriculture* (4th ed). Danville, IL: Interstate Publishers, Inc., 1992.

Roth, A.C. *Small Gas Engines.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Sharpen a Rotary Mower Blade. DoItYourself.com. Accessed April 25, 2002, from <http://doityourself.com/lawn/sharpenmowerblade.htm>.

Umstattd, W.D., Davis, C.W. *Modern Cabinetmaking.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Use of Bench and Pedestal Grinders. Canadian Center for Occupational Health and Safety. Accessed April 24, 2002, from http://www.ccohs.ca/oshanswers/safety_haz/abrasive_wheels/safeuse2.html?print.

Lesson I: Working With Cold Metal

Working with cold metal in agricultural mechanics has many applications, including fabrication, repair, and assembly of machines, equipment, tractors, tools, and buildings. This lesson covers some of the common tools and processes.

Common Layout and Marking Tools

The marking tools for cold metal either mark or scratch the surface of the metal. Using these tools to make an accurate layout is essential to a successful project. Some common tools for marking cold metal are as follows.

A scratch awl is used with a straight edge to scratch straight lines in metal. It consists of a pointed metal shaft attached to a wood or plastic handle. An awl must be kept sharp to ensure fine, accurate markings.

Dividers are used for scribing arcs and circles on metal. They also are used to transfer dimensions from one scale or object to another item. They consist of two steel legs with sharp points to mark on dark metal.

Soapstone, a soft, gray rock, is cut into thin pieces and used like a pencil to mark metal. The stone marks the surface of metal rather than scratches it. Soapstone marks are harder to rub off than chalk or pencil marks.

A permanent marker that has a hard tip and fine point can also be used to mark an accurate line on metal. A marker is safer to use than an awl and its mark is harder to rub off than a pencil or chalk mark.

A layout dye is commonly applied to metal before marking to make the layout lines sharper and more visible. Before applying the dye, grease and oil should be removed from the surface of the metal to make sure the dye adheres properly to the surface.

A center punch is a pencil-shaped tool that is used to make a small dent in metal for marking the center of a hole and starting a twist drill bit. It is made out of steel with the end ground to a 90-degree angle. To mark a hole, the point of the punch is positioned on the metal and the other end is tapped lightly with a hammer.

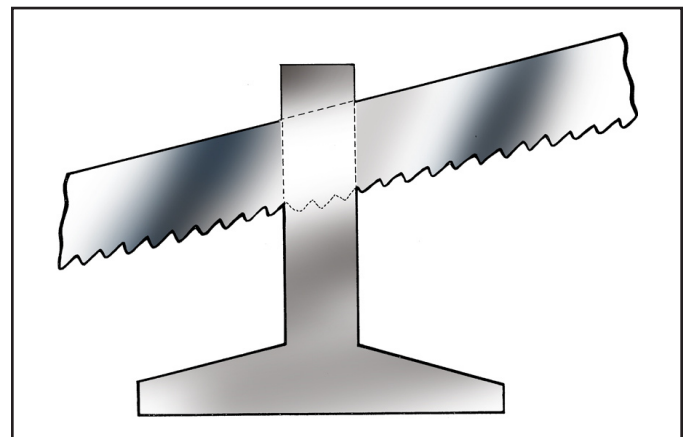
Common Cutting Tools

The following common metalworking tools cut cold metal and remove unwanted material in different ways.

Hacksaw

A hacksaw is one of the most useful cutting tools for metal. Main parts include a handle, frame, and blade. An important factor for selecting the correct blade for the material is the blade's pitch (the number of teeth per inch). Blades are available with 14, 18, 24, and 32 teeth per inch. For example, a blade with 18 teeth per inch is an 18-pitch blade. The correct pitch depends on the shape, hardness, and thickness of the metal. One rule of thumb is the thicker the metal, the lower the pitch should be. The size of the metal to be cut should be compared with the pitch to ensure that three teeth are on the metal at all times. See Figure I.1. This helps eliminate clogging the teeth, which can happen if too many teeth are on the metal. It also prevents breaking the teeth, which can happen when fewer than three teeth are on the metal. Hacksaw blades are also available in different sets (positioning of teeth). The set of the blade allows the teeth to make a slightly wider cut or kerf than the blade so that the blade will not bind.

Figure I.1 – Three Teeth on the Metal When Cutting With a Hacksaw Blade



The blade of a hacksaw is designed to cut on the forward stroke and must be installed so that the teeth face the front of the saw, away from the handle. When cutting with a hacksaw, strokes should be long and even, exerting light

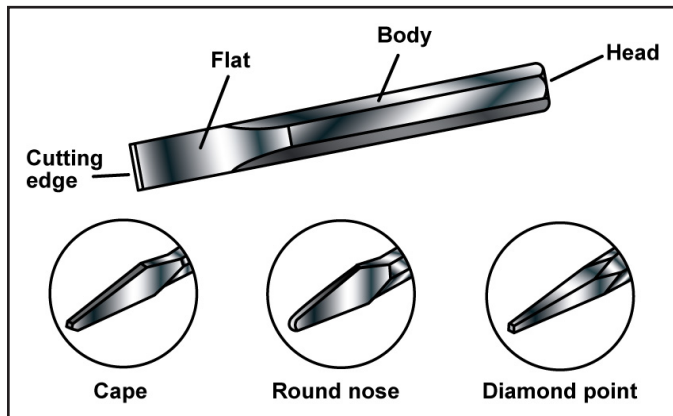
Agricultural Mechanics

pressure on the forward stroke and no pressure on the backward stroke. A new blade will have a wider set than a used one, even if both blades are the same type and pitch. Consequently, if a blade breaks while a cut is being made, a new blade should not be used to complete the cut. The cut should be started in a different place because a new blade will be damaged when forced into the kerf made by a used blade.

Cold Chisel

A cold chisel is used for chipping (removing or cutting pieces of metal) and shearing (cutting metal apart). Parts of a chisel include a cutting edge, body, and head. Common types of chisels, named according to their cutting edge, include flat, cape, round nose, and diamond. See Figure 1.2.

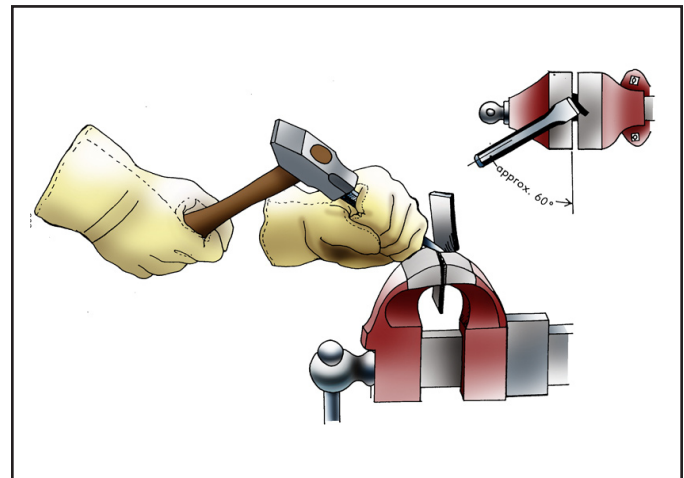
Figure 1.2 – Common Types of Chisels



The flat chisel is the most common and is used for cutting and shearing. Cape, round-nose, and diamond chisels are used for cutting grooves of different shapes.

To cut metal with a chisel, the cutting edge is positioned on the work and the head is hit firmly with a hammer. When shearing metal that is held in a vise, the chisel should be held at a 60-degree angle to the work. See Figure 1.3. The chisel should be positioned after each blow so that the center of the blade makes the cut. A method for cutting thick or round metal is to make a groove with a chisel along the line that is to be cut. The piece is then bent back and forth until it breaks.

Figure 1.3 – Position of the Chisel When Cutting Metal



A chisel's cutting edge and head must be kept ground to the proper angle and shape for safe use. For example, a mushroomed head should be reconditioned because when the head is struck, metal chips can break off and cause injury.

Snips and Shears

Snips and shears are scissorlike tools for cutting metal, such as wire and sheet metal. Regular snips have handles like scissors, which require all the force to be provided by the operator. They are designed for various purposes, such as cutting straight or curved lines or making left-hand or right-hand cuts. Combination snips cut both straight and curved lines. Compound or aviation snips have heavier handles, which increase the leverage and allow cutting of heavier metal.

For best results when cutting with snips, the metal must be lifted up and out of the way as the cut is being made. See Figure 1.4. It also helps to open the blades wide to improve leverage. The metal should be inserted as far back as possible in the blades and the blades should not be closed completely on a cut. Closing them completely can cause a ragged edge on the cut.

Figure I.4 – Lifting Metal Out of the Way When Using Snips to Cut Metal



Power Shears

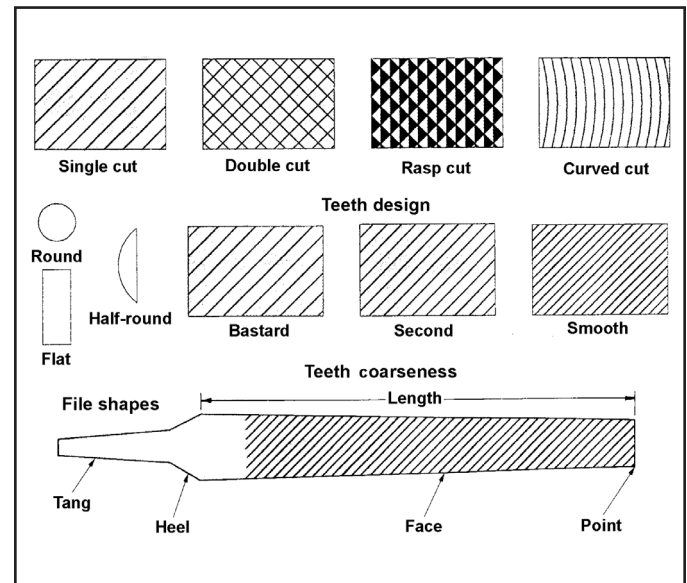
Power shears do the same job as snips and shears but make cuts faster and cleaner. They are especially useful for cutting metal such as structural steel, which would be difficult or slow to cut by hand or with a power saw. Power shears can be operated by hand, treadle, or hydraulics.

To cut with power shears, the handle of the shears is raised and the cut mark on the metal is lined up with the stationary blade. The metal is held level and the handle is lowered to make the cut. It is important to properly shut down the power shears and follow all other safety and use procedures recommended by the manufacturer and instructor. Power shears can cause injury if the handle is operated accidentally.

Files

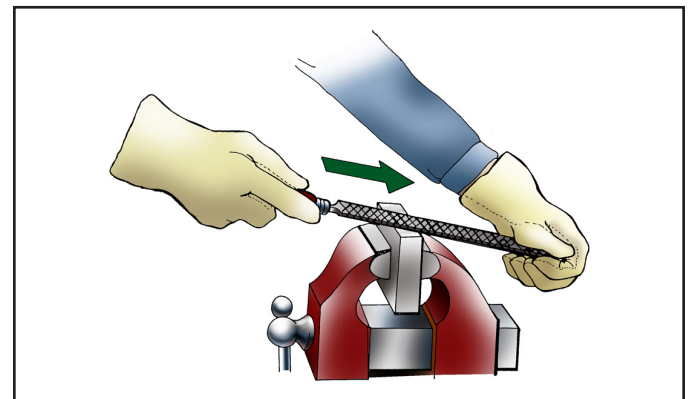
Files are used to change the shape of the work, remove material, and finish the surface. They are available in different cuts, shapes, and coarseness. The cuts of metalworking files include single (parallel rows of teeth all going the same direction), double (teeth that cross one another), rasp (individual teeth that are raised and sharp), and curve (teeth in a curved pattern). The shapes of the file itself are flat, round, half-round, and three cornered. Different coarseness of cuts are bastard, second, and smooth. See Figure I.5.

Figure I.5 – Types of Files



Metal should be put in a vise with the area to be filed just above the jaws of the vise. This will hold the metal firmly and reduce vibrations during filing. A file should always be used with a handle on the tang (smooth, pointed end) to prevent serious injury. The correct way to hold a file is to grasp the point with the thumb and index finger and hold the handle in the other hand. See Figure I.6. Files are designed to cut only on the forward stroke. Filing strokes should be long and even, with light pressure on the forward stroke and no pressure on the backward stroke.

Figure I.6 – Correct Way to Hold a File When Filing Metal



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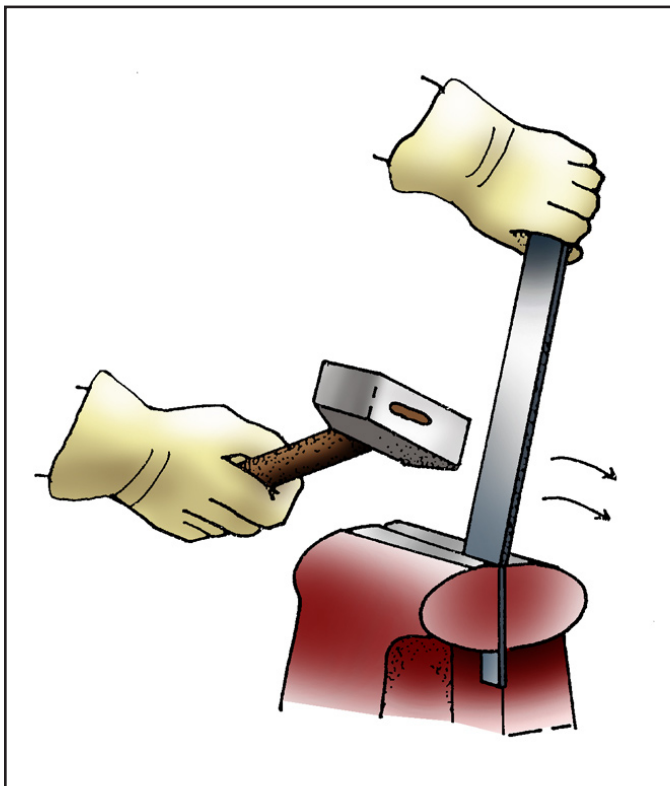
To maintain files, they should be kept dry to prevent rust. A file card or brush is used to clean the teeth to keep them free of material. In addition, to prevent dulling their teeth, they should not be dropped or stored with other files or hardened steel tools.

Techniques for Bending Cold Metal

Some metals can be bent cold if they are not too thick. For example, mild steel can be bent cold in sizes up to the following dimensions: 1/2 in. square, 1/2 in. round, and 3/16 in. x 1 in. flat. Common techniques for bending cold metal are described below.

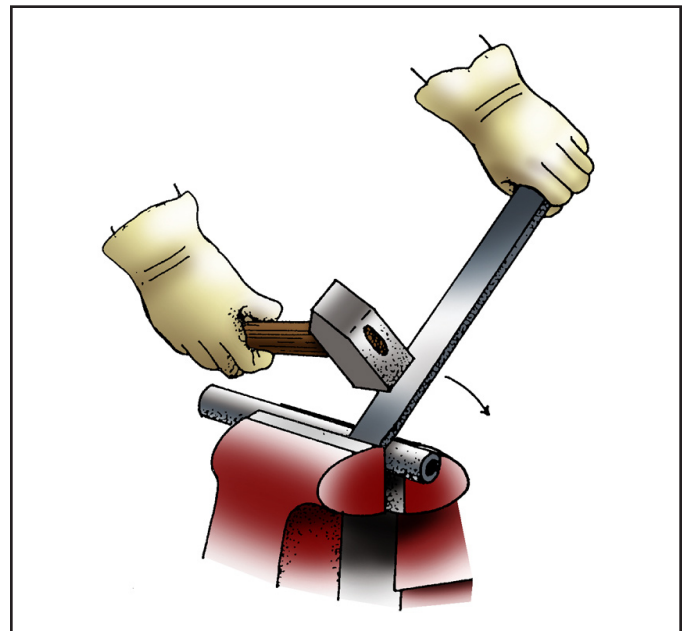
- Cold metal can be bent at an angle with the use of a vise and ball-peen or blacksmith's hammer. The metal should be secured in the vise with the mark for the bend at the top of the jaws and the longest part of the metal extending above the vise. The metal is pushed with one hand while hammering the metal just above the vise with the other hand. It is important to bend the metal sharply at the jaws of the vise and not above them. See Figure 1.7.

Figure 1.7 – Making a Right-Angle Bend



- Metal can be rounded using a piece of pipe or round stock that is the correct diameter for the desired bend. The metal is positioned tightly between the jaw of a vise and the pipe. Like the above method for angling, the metal is pushed with one hand and hammered with the other. After rounding one part of the metal, the jaws of the vise are opened and the metal is adjusted around the pipe. The jaws are tightened and the metal is hammered. These steps are repeated until the desired rounding is obtained. See Figure 1.8.

Figure 1.8 – Using a Pipe to Round Metal



- To increase leverage, the above techniques can be done with a pipe slipped over the metal. The pipe is hammered with the metal inside of it.
- Cold metal can be twisted using a vise and an adjustable wrench. The metal is marked in two places: 1) where the twist is to begin and 2) above the first mark, a distance of one and a half times the width of the metal. The metal is then positioned and tightened in the vise, with the twist mark just above the jaws. The adjustable wrench is positioned so that the bottom of the wrench is even with the second mark and its jaws extend the width of the metal. The metal is held with one hand while the wrench is turned with the other hand until the desired amount of twist is obtained.

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- Sheet metal is another metal that can be bent using hand tools. The position for the bend is marked on the metal and the mark is positioned flat on the edge of a bench top. If the edge of the bench is not sharp enough, an angle iron can be clamped to the edge. The metal is hammered over the edge of the bench until the angle is obtained.
- For bending small pieces of sheet metal, pieces of angle iron can be used in a vise to extend the work surface. With this method, two pieces of angle iron are placed in the jaws of a vise. The metal is positioned between the two irons, the vise is tightened, and the metal is bent over the angle iron using a hammer.
- Machines, such as the cornice brake and the box and pan brake, are also used to bend cold metal. They can be used on different types and shapes of metal and can make various types of bends, depending on the design of the machine. These machines exert a great amount of force and it is important to follow all guidelines from the manufacturer and instructor for safe and correct use.

Methods for Fastening Cold Metal

Metalworking projects can be fastened by various means. Some projects may require a combination of several methods. Choosing the right method for the job is important. Common types of fasteners for cold metal are discussed below.

Screws and Bolts

Screws and bolts have the advantage of allowing easy assembly and disassembly of parts. Many types of screws and bolts are available. Two of the most commonly used screws for fastening metal are sheet metal screws and cap screws. As its name indicates, a sheet metal screw is designed for fastening thin stock, such as sheet metal. Sheet metal screws have wide threads that run the length of the shank and allow the metal to sit between the threads. A cap screw is designed for fastening thick metal that has been threaded to match the screw. Three ways to fasten with screws and bolts are the following:

- Fastening metal with a bolt and nut consists of drilling or punching a hole through pieces of metal the same diameter as the bolt, inserting the bolt through the

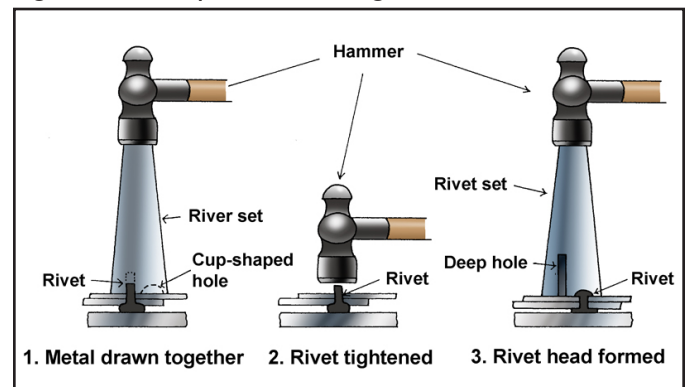
holes, threading a lock washer and nut on the bolt, and tightening the bolt.

- Fastening with only a bolt is a similar procedure, except that the hole that the bolt threads into needs to be slightly smaller to leave enough material to cut internal threads. Internal threads are cut with a tap, which is discussed in more detail later in this lesson.
- Fastening with a sheet metal screw consists of drilling or punching a hole in the first piece of metal to accommodate the shank of the screw, drilling or punching a smaller pilot hole in the second piece of metal, assembling the pieces, and inserting the screw and tightening it. The screw should not be overtightened because overtightening will strip the threads in the pilot hole. The screw will not hold if the threads are stripped.

Rivets

A rivet is a nonthreaded metal pin with a head on one end. Rivets are available in different designs and are typically made of copper, steel, or aluminum. A general rule for determining the correct length of rivet to use is as follows: it should be as long as the thickness of both pieces of metal together plus the diameter of the rivet. For example, a 1/8-in. diameter rivet should extend 1/8 in. above the two pieces of metal. To join metal together, a rivet is placed with the headless end up in the holes of two or more pieces of metal. The end of the rivet is then hammered with a ball-peen hammer to form a rounded head. See Figure I.9. A special tool called a rivet set can be used to draw the pieces of metal together and form a smooth rounded head. The head of the rivet should not be flattened because this weakens the rivet.

Figure I.9 – Steps for Fastening With a Rivet

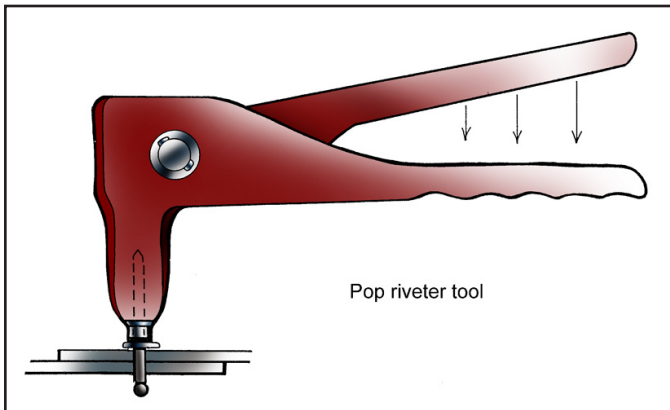


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Pop Rivets

Pop rivets consist of a metal sleeve with a flange on one end and a stem that fits in the sleeve. They are installed on one side of the piece or pieces of metal with a special tool called a pop riveter. See Figure I.10. Pop rivets are useful for situations in which it would be difficult to support the rivet and use a hammer at the same time or when only one side of the metal is accessible. The pop rivet gets its name from the popping sound that is made when the stem breaks off during installation. When choosing pop rivets, be sure to select ones that are compatible with the metal being fastened. For example, aluminum rivets should not be used to fasten steel.

Figure I.10 – Fastening With Pop Rivets



Tap and Die Set

Threads can be cut in metal by hand with the use of a tap and die set. A tap is a cutting tool that is turned with a tap wrench to cut internal threads in a hole. A die is a cutting tool that is turned with a die stock to cut external threads on round metal, such as a rod or bolt.

Tapping is done by turning the tap clockwise in the hole with a tap wrench and backing it off to break chips of metal that form. These steps are performed until the tap is through the metal or the bottom of the hole is reached. Oil should be added during the process to keep the hole and the tap threads lubricated. A tap must be handled carefully because it is brittle and breaks easily. The tap must be started square and kept straight during the threading process, so that the threads will be straight.

To select the right size tap to thread a hole for a bolt, the type of threads (thread system) and the diameter of the bolt must be determined. The different types of thread systems commonly encountered in the United States are as follows:

- National Coarse (NC): This type of thread is frequently chosen for general-purpose work. Coarse threads allow for quicker assembly and are not as prone to cross-threading as fine threads.
- National Fine (NF): This thread is frequently used for precision assemblies and for assemblies that must withstand high stress and high loads. Fine threads are less likely to loosen under such conditions.
- International Standards Organization (ISO) coarse: These are coarse metric threads.
- International Standards Organization (ISO) fine: These are fine metric threads.
- National Pipe Threads (NPT): These threads are tapered to create a tight fit that can hold gas, liquid, or steam under pressure without leaking.

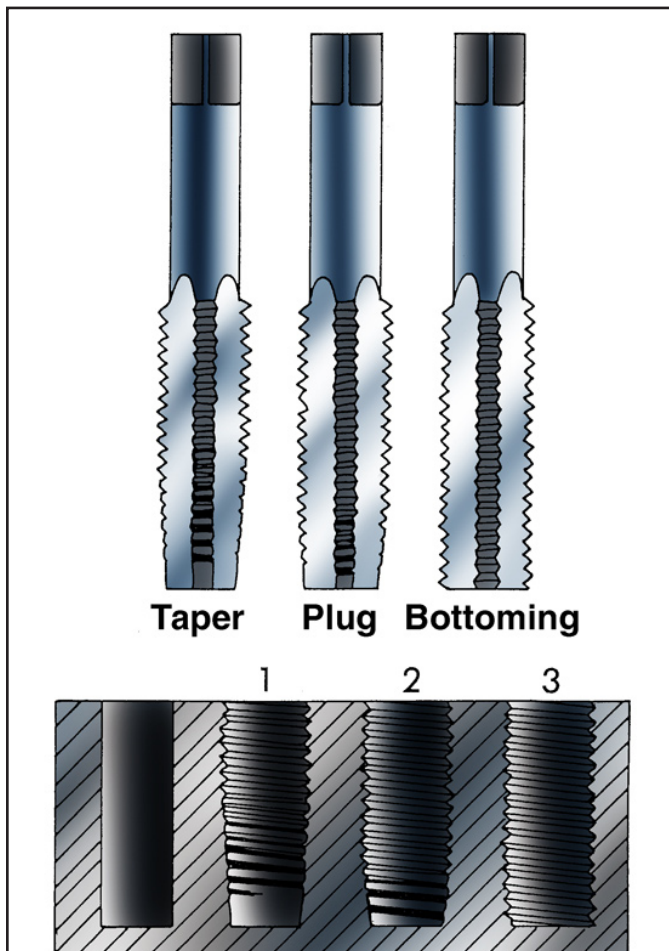
Taps are usually available in a set of three types for a specified diameter. See Figure I.11. The three types are as follows:

- Taper tap: This tap is tapered at the end for the first six or more threads. It is useful for starting a thread in a hole or for threading a hole that goes all the way through the metal.
- Plug tap: This tap is tapered at the end for only approximately the first three threads. A plug tap is used after the taper tap to thread part of the distance required.
- Bottoming tap: This tap is tapered approximately one to one and a half threads. It is used to finish a blind hole (hole that does not go all the way through the metal). The correct sequence for threading a blind hole is to first use the taper tap to start the hole, use the plug tap for a distance, and then the bottoming tap to finish the hole.

The major diameter of a tap, number of threads per inch, and type of thread are stamped in a code on the tap. For example, a stamp of 3/8 - 16NC indicates a 3/8-in. tap with 16 threads per inch of the National Coarse system.

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Figure I.11 – Three Types of Taps



A tap drill is used to drill a hole for the tap. It is important to choose a tap drill that is the correct size for the bolt. The tap drill hole must be slightly smaller than the tap to leave enough material in the stock for the tap to cut the thread. To determine the correct tap drill size, consult tables or use the following formula.

$$\text{TDS} = D - 1/N$$

(Note: TDS means tap drill size, D means the major diameter of tap, and N means number of threads per inch.)

For example, to find the tap drill size for a 3/8 - 16NC tap, the following formula can be used.

$$\text{TDS} = 3/8 - 1/16$$

$$\text{TDS} = 6/16 - 1/16$$

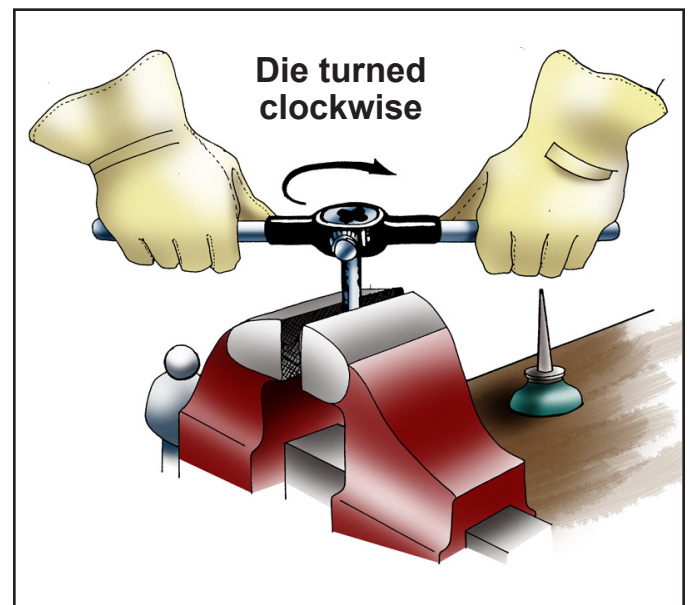
(Converted 3/8 to the common denominator of 16)

$$\text{TDS} = 5/16$$

A 5/16-in. hole must be drilled for this tap.

There are solid dies (not adjustable) and adjustable dies available in the same thread systems as taps. Adjustable dies can be adjusted to different thread sizes. Before threading a rod with a die, the end of the rod is chamfered to a 45-degree angle with a file. This step makes it easier to start the die. The tapered side of the die is placed on the rod end. Similar to the tapping process, threading with a die basically consists of turning the die clockwise with a die stock and backing it off to break chips of metal that form. These steps are performed until the rod is threaded the desired length. See Figure I.12. Oil should be added during the process to keep the die and chamfered end of the rod lubricated. The die must be started squarely on the work and kept straight during the threading process.

Figure I.12 – Using a Die to Thread a Rod



Removing Burrs From Cold Metal

Drilling and cutting procedures cause burrs around holes and on cut edges. Burrs are the sharp, turned-up edges on metal. Burrs should be removed to allow for safe handling, provide for the correct fit of parts, avoid damage to tools and equipment, and improve the appearance of the work. Removal of burrs on the cut edges of metal is usually done with a file or grinder. Burrs on the edges of holes can be removed by drilling a small chamfer around the hole using a drill bit that is two times the size of the hole.

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Summary

Working with cold metal involves numerous procedures, such as marking the layout of cutting lines and drill holes, cutting and filing to remove or shape metal, bending and fastening, and removing burrs from cut edges and holes. Workers should be familiar with metalworking tools and procedures before attempting to work with cold metal.

Credits

Agricultural Mechanics Unit for Agricultural Science II. University of Missouri-Columbia: Instructional Materials Laboratory, June 1983.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Krar, S.F., Check, A.F. *Technology of Machine Tools* (5th ed). Westerville, OH: Glencoe McGraw Hill, 1997.

Krar, S.F., Rapisarda, M., Check, A.F. *Machine Tool and Manufacturing Technology*. Albany, NY: Delmar Publishers, 1998.

Olivo, C.T. *Machine Tool Technology and Manufacturing Processes*. Albany, NY: C. Thomas Olivo Associates, 1987.

Phipps, L.J., Reynolds, C.L. *Mechanics in Agriculture* (4th ed). Danville, IL: Interstate Publishers, Inc., 1992.

Solutions in Tools. 2002 Industrial & MRO Supplies Catalog. Airgas Mid America.

Wagner, W.H., Kicklighter, C.E. *Modern Woodworking*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1996.

Walker, J.R. *Modern Metalworking*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

The World's Most Complete Real Estate Dictionary. Accessed May 7, 2002, from <http://www.homeglossary.com/>.

Unit VI – Material Selection, Plan Reading, and Interpretation

Lesson I: Planning a Project

Carefully planning projects in agricultural mechanics saves time and money in the construction process. This lesson describes the steps in planning a project, from the factors to consider in selecting a project to preparing a thorough bill of materials.

Importance of Planning

The value of planning a project cannot be overemphasized. Workers that do not plan carefully get that sinking feeling when they discover that they have skipped a critical step, cut materials to the wrong size, or ran out of time to complete the project. Correcting mistakes like these can require working additional hours and spending more money on materials.

Carefully thinking through each step of a project before purchasing materials and beginning the work saves time, effort, and money. Understanding the value of thorough planning and how to do it are keys for preventing problems and frustrations when working on a project. It is important to closely review all of the plans, such as the design of the project and bill of materials, so that errors can be detected and corrected before beginning the work. Correcting the planning documents is much easier and less costly than correcting the project itself. Careful review of the planning documents may also uncover ways to improve the design or construction process.

Part of planning a project is deciding if the project is a good choice. Factors to consider when making this decision are discussed in the following section.

Factors for Selecting a Project

When deciding on a project, it is important to ask questions about various aspects of the project. Taking time to examine the factors below will help ensure a successful project.

- **Function:** The function of a project is its usefulness to the builder or person requesting the work. Builders

should ask if there is a particular need for the project and if the project will be functional as designed. For example, if the project is designed for outdoor use, are the materials listed in the plan weather resistant? Some projects may require design modifications to make them functional.

- **Procedure:** The procedure in a project includes all the skills needed to complete the work and their level of difficulty. Builders should evaluate their skills and ask if the project's procedures will require using skills they already have or learning new skills. If the skills required are challenging, they will need to decide if they are willing to put in the extra time and effort.
- **Appearance:** Drawings of the project provide information about its appearance and quality. A good design is eye appealing, balanced, and proportional. In addition, all the parts should work together.
- **Time:** Builders should ask when a project must be completed and if they can complete it within the allotted time. The difficulty of a project is an important factor in making scheduling decisions.
- **Cost:** Cost includes all the tools and materials that must be purchased for the project. Builders will need to estimate the cost and try to determine if there will be any hidden costs, such as tools required for a special procedure. They will need to decide if the cost of the project is within their budget. Some projects may not be a good choice because they require expensive materials or too many materials to be affordable.

Steps in Planning a Project

Basic steps in planning a project appear below. Reviewing these steps will help in getting an overall view of the planning process.

1. Choose a project. Make sure the project is the best choice overall by evaluating the factors listed in the previous section.
2. Make a working drawing, if none is available. Drawing the project on paper provides a picture of the overall design and might uncover potential problems.

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Possible sources for drawing ideas include agricultural mechanics textbooks, equipment and tool manufacturers, and the instructor. If plans from an outside source are chosen, be sure to show them to the instructor for approval before beginning the project.

3. Develop a plan of procedure. A plan of procedure lists the steps and materials required to build the project. Builders should have a thorough understanding of the project drawing before writing the plan of procedure. Writing the steps for building the project helps in thinking through the process and in determining what equipment and materials are required. In this step, it is important to consider all factors that could affect the project, such as purchasing special parts or tools, arranging for financing, and complying with building codes. The starting point of the plan of procedure will depend on the operations involved. For example, in a woodworking project, the most logical first step might be to cut lumber to required lengths. Grouping like operations together is a way to increase efficiency and reduce the number of equipment setups. For example, all crosscutting can be done at one time and then all rip cutting can be done. The information gathered in the plan of procedure is used in preparing a cutting list and bill of materials, which are described below.
4. Prepare a cutting list. A cutting list typically consists of the exact sizes and lengths of all materials that will need to be cut to size for a project. It is helpful to group materials with similar dimensions together. Grouping items together that can be cut from the same piece of stock helps save money and materials.
5. Prepare a bill of materials. A bill of materials is a list of all the materials required to build the project, including fasteners, finish, etc. Two common types of this list are called the construction bill of materials and the purchasing bill of materials. Both types list all the materials for a project; however, they are different in the following ways. The construction bill of materials

lists all materials in their final dimensions and can be used to prepare a cutting list. The purchasing bill of materials is developed based on the material sizes in the cutting list. It lists standard sizes of stock to purchase that will minimize waste and cost. The following is a sample cutting list and purchasing bill of materials for a bluebird house.

Cutting list:

- 1 - 16 1/2" x 1" x 6" pine board – back
- 1 - 9 3/4" x 1" x 6" pine board – front
- 1 - 6 1/2" x 1" x 6" pine board – roof
- 2 - 10 3/4" x 1" x 6" pine boards (ripped to 4") – sides
- 1 - 4" x 1" x 6" pine board (ripped to 4") – bottom
- 1 - 5 1/2" x 3/4" x 3/4" pine board – roof holder

Purchasing bill of materials:

- 1 - 5' x 1" x 6" pine board
- 20 - 6p (six-penny) finish nails
- 1 - 1 1/2" screw

6. Obtain all necessary supplies and have them readily available when needed. When the construction process is under way, looking for supplies and making numerous trips to purchase supplies takes precious time away from the project.

Summary

Thoroughly planning a project before purchasing materials and beginning construction saves time, effort, and money. Selecting a good project is one step in the planning process. Factors to consider when selecting a project include function, procedure, appearance, time, and cost. After the project has been selected, a plan will need to be drawn if a prepared plan is not available. After studying the drawing, a plan of procedure is then developed. This plan lists all steps and materials required in the construction process. From the plan of procedure, a cutting list and bill of materials are carefully prepared to make sure that all materials are purchased and available for the project.

Unit VI – Material Selection, Plan Reading, and Interpretation

Credits

Agricultural Construction: Volume I. Arc Welding Project Construction. University of Missouri-Columbia: Instructional Materials Laboratory, July 1989.

Agricultural Mechanics Unit for Agricultural Science II. University of Missouri-Columbia: Instructional Materials Laboratory, June 1983.

Agricultural Structures. University of Missouri-Columbia: Instructional Materials Laboratory, July 1999.

Umstattd, W.D., Davis, C.W. *Modern Cabinetmaking.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Wagner, W.H., Kicklighter, C.E. *Modern Woodworking.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1996.

Zimmerman, F.W., McWard, L.J. *Exploring Woodworking: Fundamentals of Technology.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1999.

Unit VI – Material Selection, Plan Reading, and Interpretation

Lesson 2: Making and Reading Working Drawings

The ability to read and develop working drawings is an essential skill in agricultural mechanics. This lesson explains why a working drawing is important and describes the basic features and procedure for preparing a working drawing.

Importance of Working Drawings

A working drawing provides a detailed picture of the design of a project. Imagine how difficult it would be to build a project from a plan with only words. The project probably would take longer to build and the end result might not turn out as intended. A working drawing is a visual representation of a project that communicates a great deal of information to the builder. The symbols, lines, and dimensioning techniques in working drawings are standardized, which ensures the consistency and accuracy of the work. A working drawing of an object is also useful when a repair is needed. The drawing helps to orient the worker and ensure the accuracy of the repair. Knowing how to read and interpret working drawings allows a designer or builder to modify existing drawings or make new drawings.

Definition and Scale

A working drawing is a drawing of an object that includes all the dimensions and specifications necessary to build the object. It may or may not be drawn to scale, but the general shape and arrangement of parts in relation to each other are in the drawing. If an object is drawn to scale, all parts should be full size or in proportion to full size. The scale appears on the drawing as a ratio that represents the relationship between the size of the object in the drawing to its actual size. Examples of ratios are $6'' = 1'$ (half size) and $1/2'' = 1'$ (1/24th size). Many times the object to be drawn is too large to represent it at full size (full scale). For example, a building may be drawn at a scale of $1/4'' = 1'$ to fit it on the drawing paper.

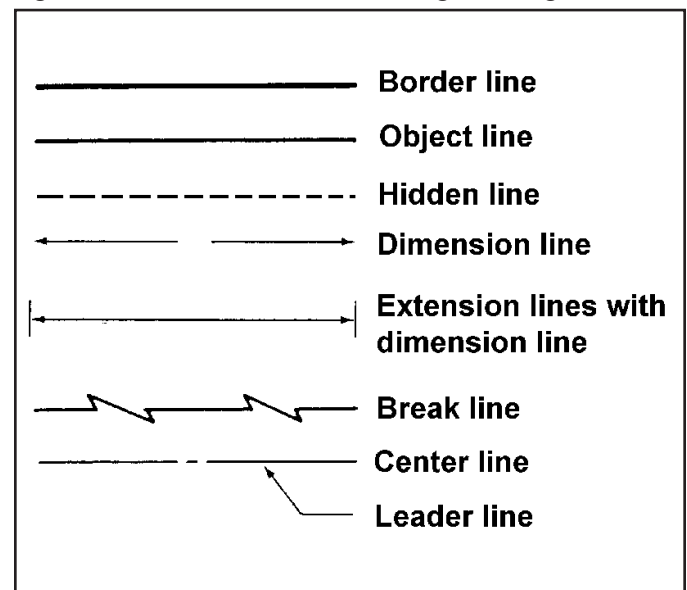
Views

A working drawing includes different views of the object to show all the parts of the object and how they work together. The number of views depends on the nature of the object. For many objects, views of the front, top, and side provide all the necessary information. Some objects, such as a round table leg, may only need an end view and a front view to provide sufficient detail. If needed, other types of views are included, such as a detail view and sectional view. A detail view provides more information about a portion of the object. A sectional view is a cutaway that reveals the interior of part of the object.

Lines and Symbols

A language of lines and symbols is used to communicate information in working drawings. Using lines and symbols makes it easier to indicate features and construction materials that would be difficult to draw. These lines and symbols are standardized so that persons who know the language can interpret a drawing done by another person. The lines differ in weight and form. Some of the commonly used lines are described in Figure 2.1.

Figure 2.1 – Lines Used in a Working Drawing



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Lines

- Border line – a heavy, solid line used to enclose the entire drawing or separate one drawing from another
- Object or visible line – a solid line used to show the visible edges and outline of the object
- Hidden line – a dashed line used to show edges that cannot be seen in the drawing
- Dimension line – a thin, solid line with arrowheads at the ends that is used to indicate the length, width, or height of an object; appear between extension lines; have a break in the center to allow room for the dimension
- Extension line – a thin line that marks the edge or corner of a part to be dimensioned
- Break line – a light, solid line with zigzags that is used to indicate part of the object has been left out of the drawing
- Center line – a thin line that is made of long, short, long segments; used to indicate the center of a round object
- Leader line – a line with an arrowhead on one end that is commonly accompanied by a note; used to point out a feature of the object

Symbols

Symbols in working drawings represent items that would be hard to draw. See Figure 2.2.

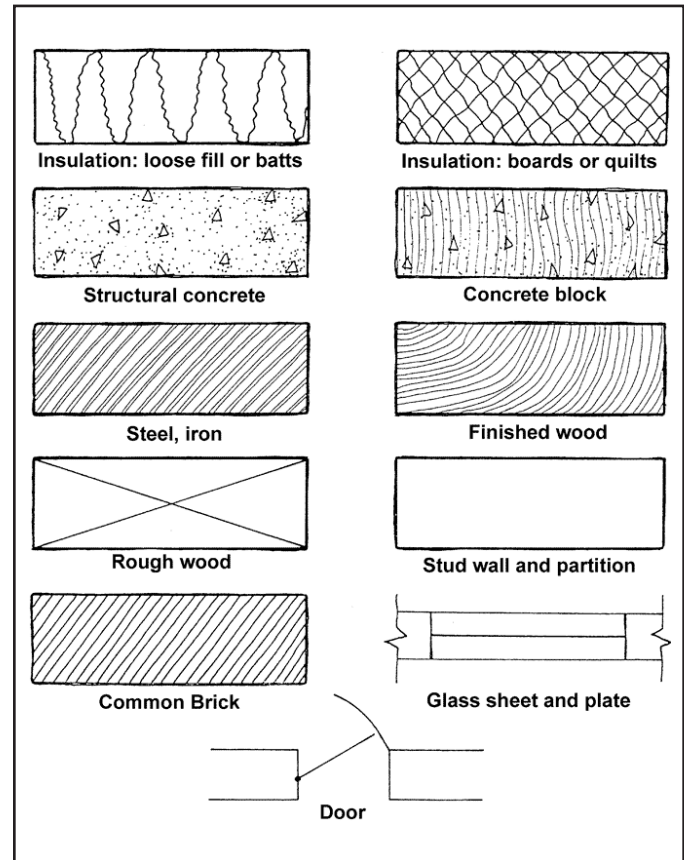
Standardized symbols are used to represent the following:

- Show the proper scale and location of objects, such as doors and windows
- Show the location of fixtures, such as electrical and plumbing
- Indicate the type or grade of the materials that objects are made of, such as wood, steel, brick, or concrete

Preparing Drawings and Adding Dimensions

The basic steps for making a working drawing are as follows:

Figure 2.2 – Commonly Used Symbols in Working Drawings



1. Draw a border line along each side of the paper. A border line is a heavy, solid line that establishes the work area for the drawing and gives the drawing a finished look. This line is commonly drawn 1/2 in. from the edge of the paper.
2. Add a title block to the drawing. The title block contains important information about the whole drawing and is the part of the drawing that should be read first. Information in the title block typically includes:
 - Who made the drawing
 - When the drawing was made
 - Name of the drawing
 - Scale of the drawing
3. Decide on the scale of the drawing, if it is to be drawn to scale. Be sure to leave enough room to add dimensions on each view.

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- Decide on the views that will be drawn and where they will be positioned. The number of views drawn should be the minimum number required to present the essential information. For most objects, three views are adequate. Views are generally placed on the drawing as follows: front view at lower left-hand corner, top view directly above the front view, and end view to the right of the front view. Each view can show dimensions for different edges of the object, which helps to keep the drawing uncluttered and easy to read.
- Complete the working drawing using a sharp lead pencil and measurement tools.
- Add dimensions and any construction notes using dimension, extension, and leader lines. See Figure 2.3. The dimensions indicate the length, height, width, and thickness of all the parts of the object. The dimensions must be accurate and exact. The builder uses the dimensions to prepare a bill of materials and as a guide for measurements made during the construction process. See Figure 2.4 for a sample drawing.

Figure 2.3 – Techniques for Showing Dimensions in a Working Drawing

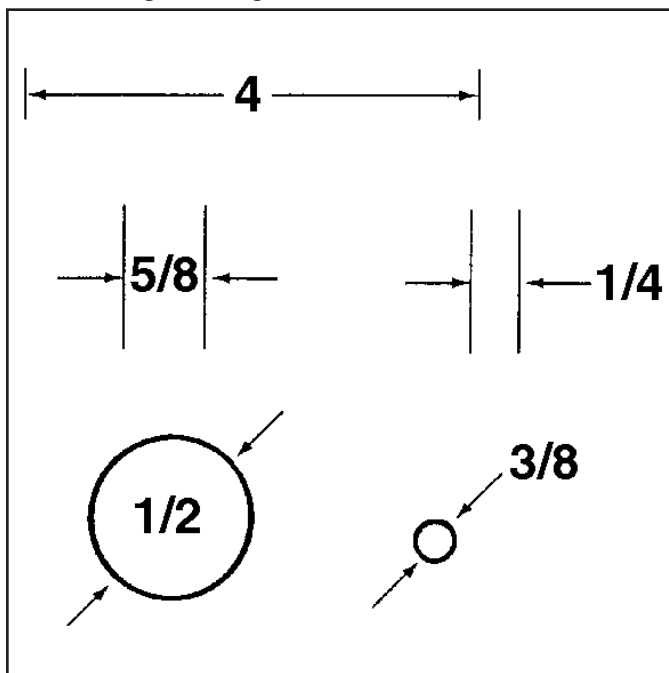
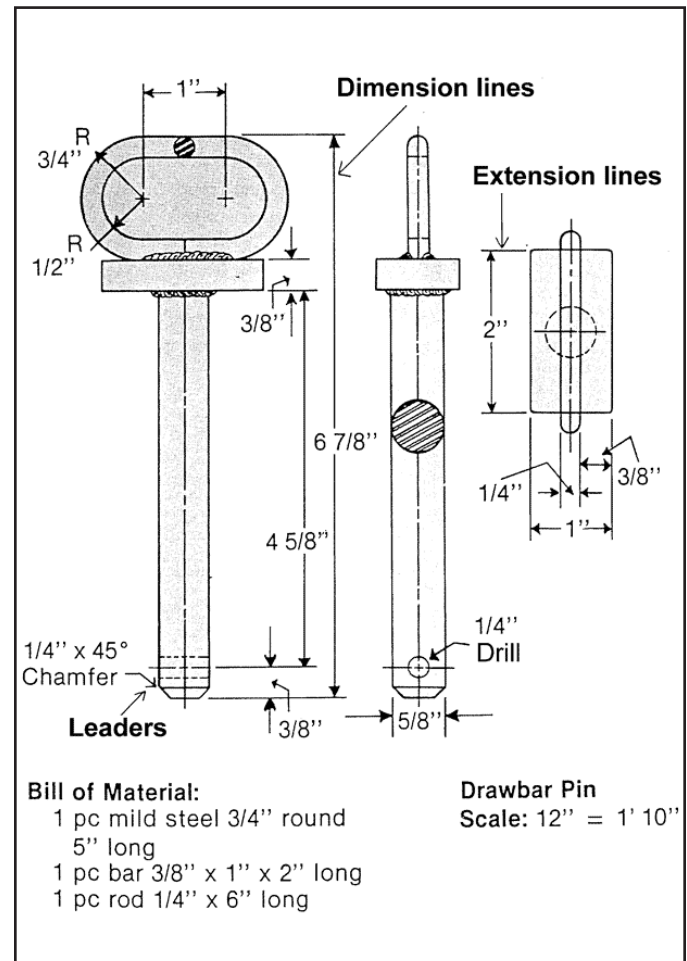


Figure 2.4 – Example of Dimensions in a Working Drawing of a Drawbar Pin



Summary

A working drawing of an object includes all the dimensions and specifications necessary to build the object. A working drawing should be used for every building project because a drawing promotes efficiency, consistency, and accuracy. Some drawings are drawn to scale, which means the object is drawn full size or in proportion to full size. Features of a working drawing include different views to show all parts of the object, a title block that provides information about the whole drawing, and lines and symbols to communicate information that would be difficult to draw. Another important feature is the dimensions. The dimensions indicate length, height, width, and thickness of all parts of the object and must be exact and accurate.

Agricultural Mechanics

Credits

Agricultural Mechanics Unit for Agricultural Science II. University of Missouri-Columbia: Instructional Materials Laboratory, June 1983.

Agricultural Structures. University of Missouri-Columbia: Instructional Materials Laboratory, July 1999.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Feirer, J.L. *Furniture and Cabinet Making.* Peoria, IL: Bennett Publishing Company, 1983.

Phipps, L.J., Reynolds, C.L. *Mechanics in Agriculture* (4th ed). Danville, IL: Interstate Publishers, Inc., 1992.

Umstattd, W.D., Davis, C.W. *Modern Cabinetmaking.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Wagner, W.H., Kicklighter, C.E. *Modern Woodworking.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1996.

Zimmerman, F.W., McWard, L.J. *Exploring Woodworking: Fundamentals of Technology.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1999.

Unit VI – Material Selection, Plan Reading, and Interpretation

Lesson 3: Selecting Building Materials

Knowing how building materials are classified, measured, and sold is important for selecting the right materials for a project. This knowledge is also essential to preparing an accurate and clear bill of materials. This lesson discusses the ways that common building materials are measured and sold.

Classification of Softwood and Hardwood

Projects in agricultural mechanics are commonly constructed of softwood and hardwood. The grouping of woods as softwood or hardwood indicates the type of tree from which they are cut. Softwoods are cut from coniferous trees (trees that do not shed their leaves), such as pine, cedar, or redwood. Hardwoods are cut from deciduous trees (broad-leaved trees that shed their leaves each fall), such as oak, walnut, and ash. The terms “softwood” and “hardwood” do not indicate the actual softness or hardness of the wood. For example, balsa is a soft wood that comes from a hardwood tree.

Some of the common uses for softwood are framing, studs, and construction of structures. Hardwood is often used for furniture, flooring, and cabinets. Understanding the various ways that softwood and hardwood are classified is a key factor in selecting and purchasing the most suitable wood for a project. For example, if a project will be painted or does not require a near-perfect appearance, buying a satisfactory wood of a lower grade saves money while not sacrificing the usefulness of the project.

Softwood

Ways that softwood is classified include the following:

- How the wood will be used
 - Construction or yard lumber: This type is the least expensive and most readily available lumber. It is not reworked before it is sold and it is used for general construction.
 - Factory and shop or remanufacture lumber: This type is made and graded to be reworked for specific applications, such as the manufacture of doors or windows.
- By the size of the wood: See the table on the next page for more detail.
 - Boards: Boards have a nominal thickness of less than 2 in.
 - Dimension lumber: This distinction indicates the nominal thickness ranges from 2 in. to 5 in.
 - Timbers: Timbers have a nominal thickness and width of 5 in. or greater.
- By how much the wood has been dressed (surface trimmed and smoothed) or worked
 - Rough lumber: This type of lumber has been sawed and trimmed to length, but none of the surfaces have been dressed.
 - Dressed or surfaced lumber: This lumber is cut to length and at least one surface has been planed smooth. The number of smooth surfaces and edges are indicated by a letter and number code. For example, a piece of lumber with the designation of S2S1E has been surfaced on two sides and one edge.
 - Worked lumber: This lumber has been surfaced and has had some additional processing. For example, it may be cut for tongue-and-groove joints or shaped to use for molding.
- By the grade of the wood
 - The grade of a piece of wood is an indication of its quality. Softwood grades are based on the American Softwood Lumber Standard (PS 20-70), which is published by the U.S. Department of Commerce. Lumber associations, such as the Western Wood Products Association, have developed additional rules and details about the grades to help the buyer determine the quality of the wood.
 - When softwood is graded, it is evaluated for moisture content, intended use, and the location and size of irregularities, such as knots, splits, decay, and manufacturing defects. Wood used for general construction is typically graded on a number system ranging from 1 to 5, with 1 being the best quality or producing the least waste. There may also be a grade of select or premium that surpasses the no. 1 grade. Wood used for finishing, such as flooring or paneling, is given a letter grade that ranks it for appearance. This grade ranges from A to D, with A being the best quality.

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Common Softwood Classifications and Grades

Classification and Grade	Description or Use
Finish or selects – Up to 1 1/2 in. thick, 2 in. or more wide; graded on basis of appearance	
B & BTR	Nearly clear, with only minor defects; suitable for natural finish
C	More and larger defects than B & BTR but suitable for paint finish
D	A little lower in quality than C but still suitable for paint finish
Boards – Up to 1 1/2 in. thick, 2 in. or more wide; graded for suitability for use in construction	
SEL MER or 1	Use in housing and light construction for exposed paneling, shelving, etc.
CONST 2	Used for subfloors, roof sheathing, etc.
STD 3	Used about the same as CONST 2 grade but a little lower in quality
UTIL 4	Combines usefulness and lower cost for general construction purposes
ECON 5	Used for low-grade sheathing, crating, and bracing
Dimension – 2 to 5 in. thick, 2 in. or more wide	
Structural light framing	2 to 4 in. thick, 2 to 4 in. wide; for engineered used when higher strength is needed
Select structural (SEL STR)	Used where high strength, stiffness, and good appearance are needed
No. 1	Used about the same as SEL STR grade but a little lower in quality
No. 2	Recommended for most general construction uses
No. 3	Used for general construction where appearance is not a factor
Light framing	2 to 4 in. thick, 2 to 4 in. wide; provides good appearance where high strength and high appearance are not needed
Construction	Recommended and widely used for general framing purposes
Standard	About the same uses as construction grade but a little lower in quality
Utility	Used for studding, blocking, plates, etc., where economy and good strength are desired
Economy	Suitable for crating, bracing, and temporary construction
Studs	2 to 4 in. thick, 2 to 4 in. wide; only one grade for studs, which is suitable for all stud uses
Structural joints and planks	2 to 4 in. thick, 6 in. and more wide; for engineering applications
Select Structural	Used where high strength, stiffness, and good appearance are needed
No. 1	Used about the same as SEL STR grade but a little lower quality
No. 2	Recommended for most general construction use
No. 3	For use in general construction where appearance is not a factor
Appearance and framing	2 to 4 in. thick, 2 in. and more wide
A	Used in housing and light construction for high strength and finest appearance
Timbers – 5 in. or more in least dimension	
Select Structural	Used where superior strength and good appearance are needed
No. 1	Similar to SEL STR grade but a little lower in quality
No. 2	Recommended for general construction
No. 3	Used for rough general construction

Adapted from *Structures and Environmental Handbook*, Midwest Plan Service.

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- o Wood that is graded according to the American Softwood Lumber Standard is stamped with the following information: 1) the grading agency that issued the grade stamp, 2) the species of the wood, 3) the grade, 4) the mill identification (appears as a name or number), and 5) the moisture content of the wood when it was stamped.

Hardwood

The majority of hardwood is graded according to its size and the number of pieces without defects that can be cut from it. The best grade, First and Seconds, has the highest percentage of usable area. The lowest grade, Number 3 Common, has the lowest percentage. The minimum cutting widths and lengths also decrease as the grade gets lower. Grades of hardwoods are:

- Firsts and Seconds (FAS)
- Selects
- Number 1 Common
- Number 2 Common
- Number 3 Common

The grades may be sold separately or several grades may be sold together. The standards for grading hardwood are established by the National Hardwood Lumber Association.

Measurements and Specifications for Lumber

Information about lumber that must be specified on a bill of materials includes the board feet (volume); the grade; and the thickness, width, and length. Lumber is commonly measured and priced by the board foot. It is helpful to remember that a board foot is equivalent to a piece of lumber 1 in. thick, 12 in. wide, and 12 in. long, or 144 cu in. The way to determine the number of board feet in a piece of wood is to multiply the thickness in inches by the width in inches by the length in feet and then divide by 12: $(T'' \times W'' \times L') \div 12$. When several boards with the same measurements are being used, include the number of boards as a multiplier in the formula. See the following examples.

$$\begin{aligned} &2'' \times 4'' \times 14' \text{ board} \\ (2'' \times 4'' \times 14') \div 12 &= 9.333 \text{ board feet} \end{aligned}$$

Formula for 3 boards that are the size above and cost \$0.35 per board foot:

$$(3 \times 2'' \times 4'' \times 14') \div 12 = 28 \text{ bd ft} \times \$0.35 = \$9.80$$

Boards that are less than 1 in. thick are figured as 1 in. Boards that are more than 1 in. thick are figured using their nominal size. The nominal size is the measurement of a board when it is green and has not been planed. The actual size is the measurement after the board has dried and been planed. Boards are sold using their nominal measurements, but their actual size is smaller. For example, a 2'' x 4'' actually measures 1 1/2'' x 3 1/2''.

When ordering lumber, the grade should be specified per the standards established by the appropriate lumber association. Nominal sizes should be used and they should be written in standard thickness, width, and length. Common softwood lengths range from 8 ft to 20 ft in 2-ft intervals. Because hardwood is not as readily available as softwood, it is usually cut and sold in random widths and lengths.

Classification and Measurement of Plywood

Plywood is a structural panel used extensively in construction. Common uses include subfloor (first layer of floor) and roof and wall sheathing (first outer layer of roof or wall). Plywood is made of a core material with a thin sheet of wood on each side. The thin sheets of wood are called face veneers. The layers are bonded together by adhesives. Typical plywood cores include additional sheets of veneer, thin boards laid side by side, and composite materials, such as wood chips or pressed paper. Plywood is classified by type of wood and adhesive and by grade.

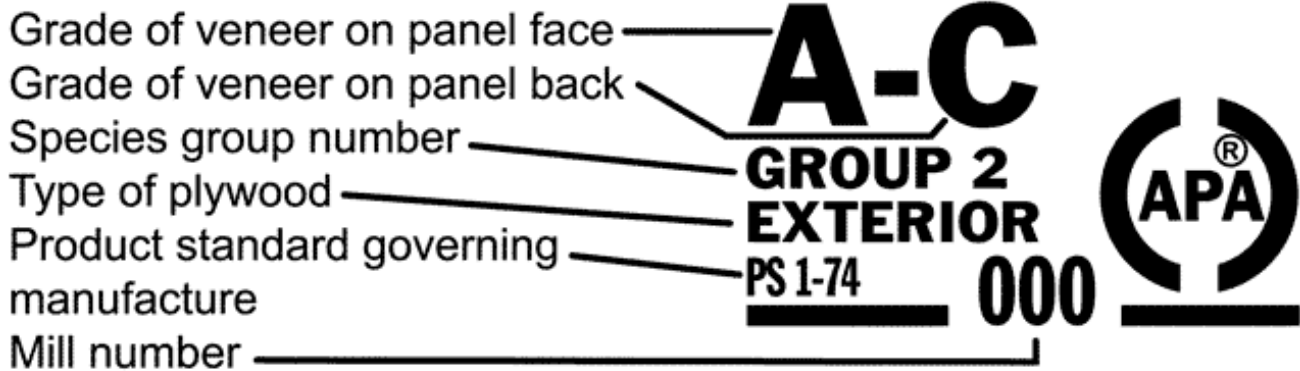
Type of Wood and Adhesive

Plywood is either softwood or hardwood, depending on the type of wood used for the face veneers. Plywood is either exterior grade or interior grade, based on the kind of adhesive used to bond the layers. Exterior grade is manufactured with adhesives that are fully waterproof. This type of plywood is designed for structures that must withstand excessive moisture. The adhesives used for the interior grade are moisture resistant. Interior grade plywood is intended for structures that will not be exposed to the weather.

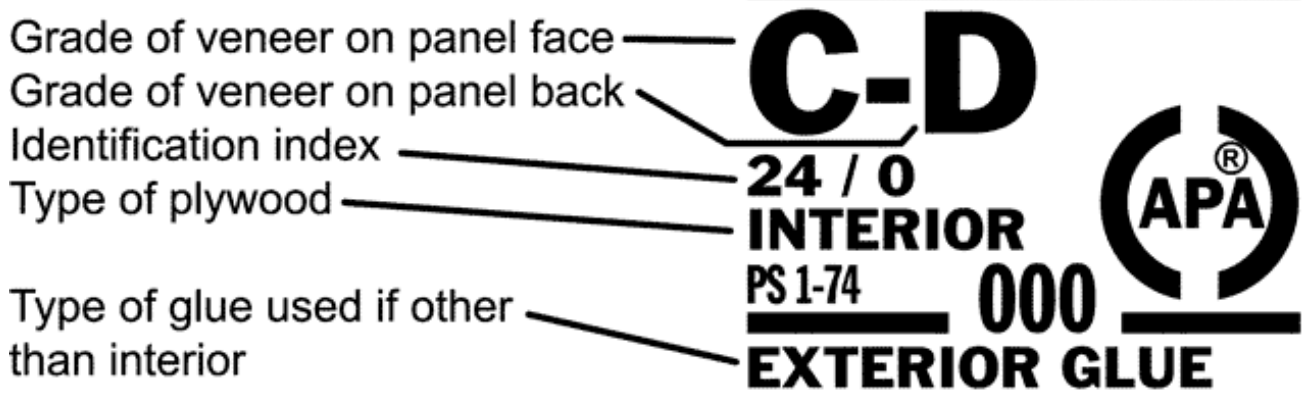
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Figure 3.1 – Examples of Plywood Grade Stamps and Their Meanings

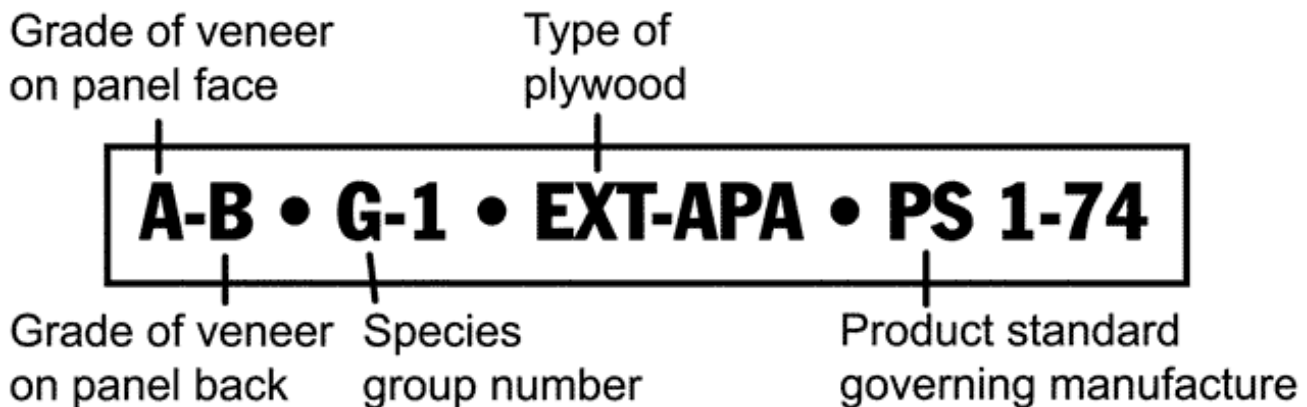
Typical sanded panel back-stamp



Typical unsanded panel back-stamp



Typical edge stamp



Adapted from *Structures and Environmental Handbook*, Midwest Plan Service.

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Grading of Softwood and Hardwood Plywood

Both softwood and hardwood plywood are commonly designated by the general grade G2S or GIS. G2S means “good on two sides” and GIS means “good on one side.” They may also be referred to as S2S or SIS, meaning surfaced or sanded on two sides or one side. Each plywood panel is stamped with a grade stamp by the group that oversees their manufacture. See Figure 3.1. The stamp includes the following information:

- Species of wood on the face veneer
- Quality of the face veneer
- Type of adhesive used
- Standard governing manufacture

Mill Identification Grading Information Specific to Softwood Plywood

Manufacturers associations, such as APA–The Engineered Wood Association, set the standards for grading softwood plywood. The standards are based on specifications written by the National Bureau of Standards. The grade of a piece of softwood plywood depends on the quality of the front and back veneers. Letter grades (N, A, B, C, D) are given to each side of the panel. N is the highest grade; it is given to materials that have a natural finish. D is the lowest grade. See Figure 3.2 for a description of some of the grades. For example, a panel with a grade of A-D has good-quality veneer on one side and bad quality on the other. For softwood plywood, the grade stamp also includes a group number from 1 to 5 that is based on the strength of the type of wood. Group 1 is the strongest species and Group 5 the weakest. The group number given is based on the weakest type of wood used in the face veneer. If the panel is sanded, the stamp will include the wood species also.

Grading Information Specific to Hardwood Plywood

Much of hardwood plywood is manufactured for uses where appearance is important. Standards for grading hardwood plywood are set by the Hardwood Plywood & Veneer Association. A grading system of numbers (1 to 4) is used to rank the quality of both face veneers. A No. 1 ranking is the best, indicating few defects, and a No. 4

ranking is the worst. Like softwood plywood, hardwood plywood can be ordered that is made from various types of wood and grades of veneer faces.

Figure 3.2 – Grades for Plywood Veneers

A	Smooth, paintable. Not more than 18 neatly made repairs, boat, sled, or router type, and parallel to grain, permitted. Wood or synthetic repairs permitted. May be used for natural finish in less demanding applications.
B	Solid surface. Shims, sled or router repairs, and tight knots to 1 inch across grain permitted. Wood or synthetic repairs permitted. Some minor splits permitted.
C Plugged	Improved C veneer with splits limited to 1/8 inch width and knotholes or other open defects limited to 1/4 x 1/2 inch. Wood or synthetic repairs permitted. Admits some broken grain.
C	Tight knots to 1-1/2 inch. Knotholes to 1 inch across grain and some to 1-1/2 inch if total width of knots and knotholes is within specified limits. Synthetic or wood repairs. Discoloration and sanding defects that do not impair strength permitted. Limited splits allowed. Stitching permitted.
D	Knots and knotholes to 2-1/2 inch width across grain and 1/2 inch larger within specified limits. Limited splits are permitted. Stitching permitted. Limited to Exposure 1 or Interior panels.

Source: *Agricultural Structures*. Instructional Materials Laboratory, University of Missouri Columbia, 1999.

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Measurements for Plywood

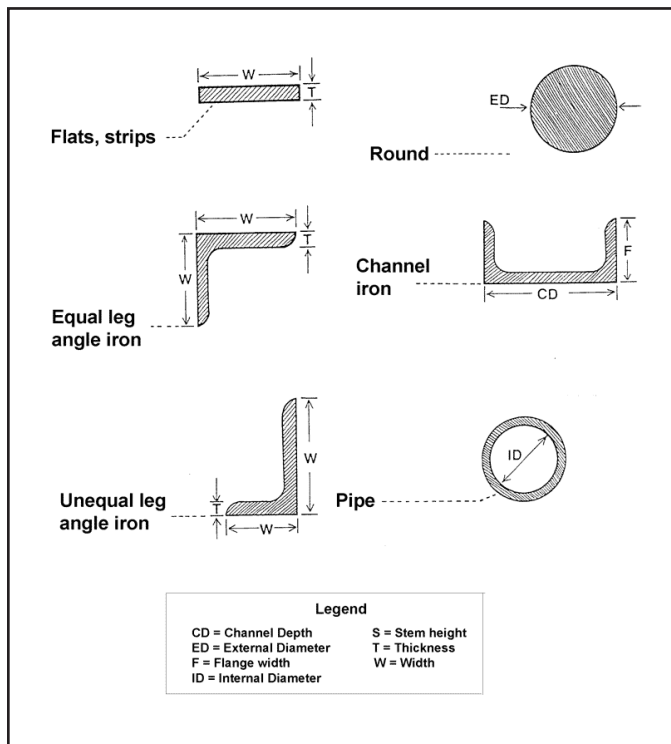
Plywood is sold by the sheet or square foot. The standard sheet size is 4' x 8' and it is available in various thicknesses (e.g., 1/4", 3/8", 1/2", 5/8", 3/4", and 1"). To calculate the square feet of a sheet of plywood, multiply the length in feet by the width in feet. A 4' x 8' sheet has 32 sq ft. The cost of a sheet of plywood can be calculated by multiplying the length by the width by the price per square foot. The formula below is for a one 4' x 8' sheet that costs \$0.39 per square foot.

$$4' \times 8' \times \$0.39 = \$12.48$$

Measurements and Specifications for Metal

Metal is another common material used in building. Knowing the names, shapes, and standard sizes of metal is useful for selecting the correct metal for a project. See Figure 3.3. This knowledge is also important when preparing a bill of materials and communicating information about metal to others on the job. Common names and sizes of steel building materials are as follows:

Figure 3.3 – Shapes and Dimensions of Steel Stock



- **Rounds:** These are bars of solid metal. The external diameter should be specified when ordering. The standard length is 20 ft.
- **Angle iron:** An angle iron has two legs that are set at a 90-degree angle to each other. The width of each leg and the thickness should be specified when ordering. The standard length for angle iron is 20 ft.
- **Flats and strips:** Flats and strips are flat pieces of metal. Flats are 1/4 in. or more thick and strips are 3/16 in. or less thick. The width and thickness should be specified when ordering. They are commonly available in 20-ft lengths.
- **Channel iron:** A channel iron is shaped like a C. The depth of the channel and width of the flange should be specified when ordering. The standard length is 20 ft.
- **Black or galvanized steel pipe:** This pipe has a tubular shape and a standard length of 21 ft. The inside diameter of the pipe should be specified when ordering.

Measurements and Specifications for Other Common Building Materials

The following list includes other common building materials and how they are measured and sold.

- **Molding and dowel rod:** These are measured and sold in linear or running feet. A measurement in linear feet is the actual length of the material and does not include the thickness.
- **Roofing:** This is sold by the square (1 square equals 100 sq ft). A bundle of shingles contains 1/3 of a square.
- **Hardware cloth and screening:** These are sold by the running foot.
- **Hardboard, waferboard, and particle board:** Like plywood, these are generally manufactured in 4' x 8' sheets and are measured in square feet.

Summary

Knowing how common building materials are classified, measured, and sold helps to ensure the correct materials are chosen and the bill of materials is prepared correctly. Wood is grouped as a softwood or hardwood, depending

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on the type of tree from which it is cut. Softwood and hardwood lumber, as well as softwood and hardwood plywood, are classified by grading systems established by various manufacturer and trade associations. Lumber is measured and sold by the board foot. Plywood is measured and sold by the square foot. Construction metal is available in different shapes and sizes. Sizes should be specified in the standard units of measurement used for the metal.

Credits

Agricultural Construction: Volume II. University of Missouri-Columbia: Instructional Materials Laboratory, July 1989.

Agricultural Mechanics Unit for Agricultural Science II. University of Missouri-Columbia: Instructional Materials Laboratory, June 1983.

Agricultural Structures. University of Missouri-Columbia: Instructional Materials Laboratory, July 1999.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Cutter, B.E. *Hardwood Lumber Grades.* University Extension. University of Missouri-Columbia, October 1993.

Cutter, B.E. *Softwood Lumber Grades.* University Extension. University of Missouri-Columbia, October 1993.

Feirer, J.L. *Furniture and Cabinet Making.* Peoria, IL: Bennett Publishing Company, 1983.

Grading Hardwood Lumber. Forestry Extension. Iowa State University. August 1998.

Pastoret, J. *Measurements and Pricing of Primary Wood Materials.* University Extension. University of Missouri-Columbia, October 1993.

Phipps, L.J., Reynolds, C.L. *Mechanics in Agriculture* (4th ed). Danville, IL: Interstate Publishers, Inc., 1992.

Umstattd, W.D., Davis, C.W. *Modern Cabinetmaking.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Wagner, W.H., Kicklighter, C.E. *Modern Woodworking.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1996.

Zimmerman, F.W., McWard, L.J. *Exploring Woodworking: Fundamentals of Technology.* Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1999.

Unit VII – Painting and Finishing

Lesson 1: Spray Painting and Finishing

Spray painting is a fast way to apply a uniform finish. Students in agricultural mechanics should be familiar with spray equipment and its operation, and they should practice spray painting to develop the correct technique. This lesson provides basic guidelines for spray painting. Your instructor must be present to demonstrate the step-by-step procedures for spray painting and guide you through them.

Safety Precautions for Spray Painting

As with all tasks in agricultural mechanics, safety considerations must come first. If not used properly, paints and solvents can cause fire, poisoning, eye and skin irritation, and respiratory problems. Improper use of painting equipment can lead to fire and other accidents. The following safety precautions should be observed in the painting process.

- **Follow safety procedures for all equipment and materials used in preparation or for painting.** This includes spray equipment, steam cleaners, sanders, and ladders, as well as paints and solvents. Read the labels on finishing materials to check for warnings about toxicity and flammability. Follow the manufacturer's instructions for safe operation of equipment.
- **Wear appropriate protective clothing and gear.** Wear safety glasses or goggles to protect eyes from splattered paints or solvents. Be aware of the location of an eye-washing station in case of an accident. Wear an approved respirator to protect the respiratory system from paint particles or toxic fumes. Wear rubber gloves to protect hands from burns and irritation when handling bleaches, solvents, or other caustic materials.
- **Work in a well-ventilated area.** Apply finishing materials outdoors if weather permits. If indoors, apply spray paint in a booth that is equipped with proper ventilation.
- **Keep sparks and flames out of the work area.** Many of the materials used in painting, including the cleanup rags, are flammable. The vapors and gases these materials produce are flammable as well. Do not smoke or allow others to smoke in the area.

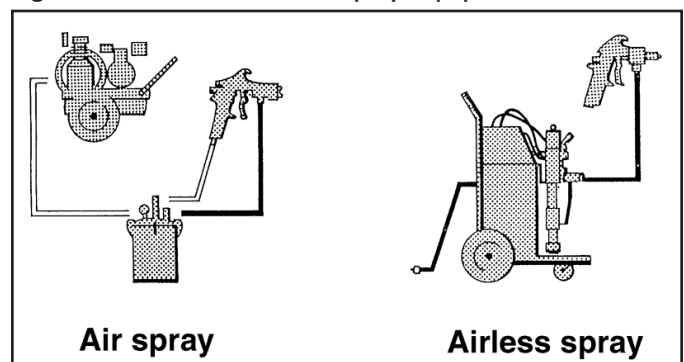
Keep equipment that can cause a spark away from finishing materials and the work area.

- **Have an approved fire extinguisher readily available.** Know the location of the fire extinguisher and how to use it.
- **Do not point a spray gun, especially the airless type, at any part of the body or at anyone else.** An airless gun is especially hazardous because it maintains liquids at high pressure. If the liquid is sprayed on the skin, it has sufficient force to penetrate the skin and cause damage. Seek medical attention immediately if this occurs. Remember that shutting off the pump of an airless spray system does not release the pressure. The system remains under pressure until the pressure is discharged through the spray gun.
- **Observe safe cleanup procedures.** Clean spills as they happen to prevent accidents. Use the appropriate solvent or cleaning solution for the task. Store chemicals in approved containers and flammable finishes and solutions in a fireproof cabinet. Keep the work area clear of debris and dispose of cleanup rags properly. Wash hands after working with chemicals that are toxic or could harm skin.

Types of Spray Equipment

Spray painting saves time and labor when compared with using a paintbrush or roller, especially for large surfaces. This method also produces a smoother finish, without brush or roller marks. A variety of spray equipment is available for various applications. The two basic types that are commonly used in agricultural mechanics shops are air and airless spray equipment. See Figure 7.1.

Figure 7.1 – Air and Airless Spray Equipment



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Air Spray Equipment

Air spray equipment uses compressed air to atomize (form into a fine spray) the paint and propel it through a spray gun to the surface being painted. This type of system produces a high-quality finish and can be used with most finishes, including stain, sealer, and topcoat. A disadvantage of air spray as compared with airless spray is the finish is transferred to the surface less efficiently. The large quantity of air mixed with the paint causes paint to be lost through overspray and by bouncing off the surface.

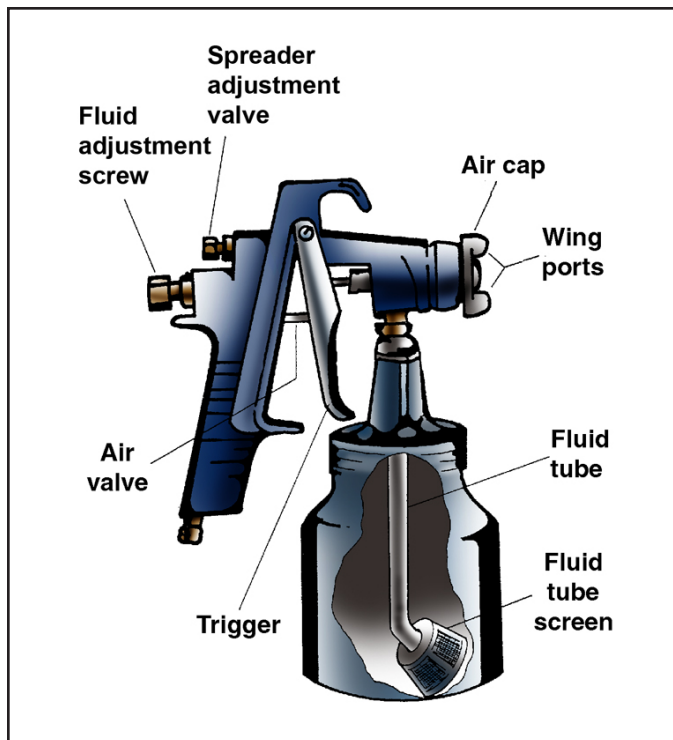
Main parts of a typical spray gun and their functions are as follows. See Figure 7.2.

- **Trigger:** A trigger controls the flow of the liquid or both the liquid and the air depending on the type of gun.
- **Air valve:** Pulling the trigger depresses the air valve and releases air. If the trigger is pulled halfway, only

air flows through the gun. This feature can be used to remove dirt and debris from the surface to be painted. If the trigger is pulled all the way back, finish will also flow through the gun.

- **Fluid adjustment screw:** This screw controls the amount of paint that flows through the gun.
- **Spreader adjustment valve:** This valve sets the shape or pattern of the paint by controlling airflow through the wing ports (see definition below).
- **Air cap:** The air cap directs compressed air into the stream of paint to break it up into the desired spray pattern. Air flows through three sets of holes (ports) in the cap.
- **Wing ports:** These are holes in the wings of the air cap. The amount of air flowing through these holes controls the spray pattern.
- **Fluid tube:** This tube is located in the paint supply and is used to feed the paint up into the gun.
- **Fluid tube screen:** This screen, located at the bottom of the fluid tube, screens out foreign material and lumps to prevent them from entering the gun.

Figure 7.2 – Parts of a Spray Gun



Airless Spray Equipment

Airless spray equipment uses high pressure instead of air to atomize paint. In this system, a fluid pump, powered by electricity or gas, is used to force paint up into the nozzle of the spray gun, where high pressure breaks it up into a fine spray. Advantages of an airless spray system over an air spray system include 1) less overspray because the paint is not mixed with air and 2) faster delivery and heavier coating of the paint because of the high degree of pressure. It is especially useful in covering large surfaces quickly and penetrating porous surfaces such as concrete. A disadvantage is the paint particles are coarser and therefore may produce a lower quality finish.

Preparing Surfaces for Paint

For best adherence, durability, and appearance of the paint, the surface must be properly prepared before it is painted. The type of preparation depends on whether the surface is metal or wood and whether it is new or previously finished.

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Metal

New welds should be cleaned using a chipping hammer and a wire brush. Surface dirt, grease, and rust on metal should be removed with a steam cleaner, high-pressure washer, or approved cleaning solution. Gasoline should not be used because it is too hazardous. Loose paint and rust can be removed from previously finished metal by wire brushing, hand or power sanding, or a combination of both. Pitted areas can be smoothed by these methods as well. The edges of chipped paint can be feathered with sandpaper. Feathering means tapering the uneven areas of a surface until no roughness or edges can be felt. If the paint is badly damaged, the paint can be stripped off to produce a smooth finish for the new paint. The metal is then cleaned with a preparatory solvent, wiped with a cloth, and allowed to dry. Areas that are not to be painted are covered with masking tape. Finally, the surface is coated with an appropriate primer coat, which inhibits rust formation.

Wood

For new wood surfaces, dirt and grease should be removed using approved cleaning solutions. If the wood has surface marks and defects, such as mill marks or dents, these should be sanded or filled as well. Ensure that the wood is dry before sanding and follow the grain of the wood when sanding. Apply a sealer to new wood to prevent moisture from warping or rotting the wood. Ensure that repair defects such as holes are sealed before filling them with caulk or wood filler. Unsealed wood can dry out the filler, causing it to shrink, come loose, and crack the paint. Remove any excess glue from surfaces as well.

With painted surfaces, sometimes only loose paint may need to be removed. However, if the paint is in bad condition, it should be removed using a paint stripper, a wire brush, or sandpaper. Power sanding, such as a wheel mounted on a power drill, can make this process quicker. If a very smooth finish is desired, a thorough sanding is done or a chemical paint remover is used to remove all residue. After the paint is removed, the wood is washed with detergent and water. The wood is sanded if a smooth finish is desired and then dusted off with a tack rag (cloth

that has been chemically treated so that it will pick up dust and grit). The last step in preparing the surface is the application of an appropriate primer coat to seal the wood and improve the durability of the paint.

Choosing Primer and Paint

Applying a primer, an undercoating that prepares the surface for painting, is an essential step in the painting process. Priming a surface before painting has many benefits, including less surface absorption of paint, improving the surface's ability to hold paint, and improving the paint's ability to adhere to the surface. Paints are opaque finishes composed mainly of vehicles (usually oil- or water-based fluids) and pigments (substances that add color and opacity).

A wide variety of primers and paints are available for different surfaces and purposes. Manufacturers' instructions on the product labels provide valuable information about recommended use. When selecting a primer and paint, the following factors should be considered.

- **Intended use:** Think about whether the painted surface will be indoors or outdoors. Paints that are formulated for inside use have the word "interior" on the label and paints formulated for outside use have the word "exterior" on the label. Also think about whether the finish needs to withstand water, acids, solvents, or other agents.
- **Compatibility:** Choose a primer and paint that are compatible with each other and appropriate for the surface.
- **Drying time:** Check the product labels for the drying time of the primer and paint. The drying time needed between applying a primer and a finish coat or between coats of finish can vary greatly. It is also important to consider the temperature when the primer or paint was applied, which can affect the drying time.
- **Type of finish:** Decide which finish is best for the job. Paints are available in various finishes, such as flat, satin, semigloss, and high gloss. These finishes vary in the amount or type of shine, with flat having no shine and high gloss producing the most shine.

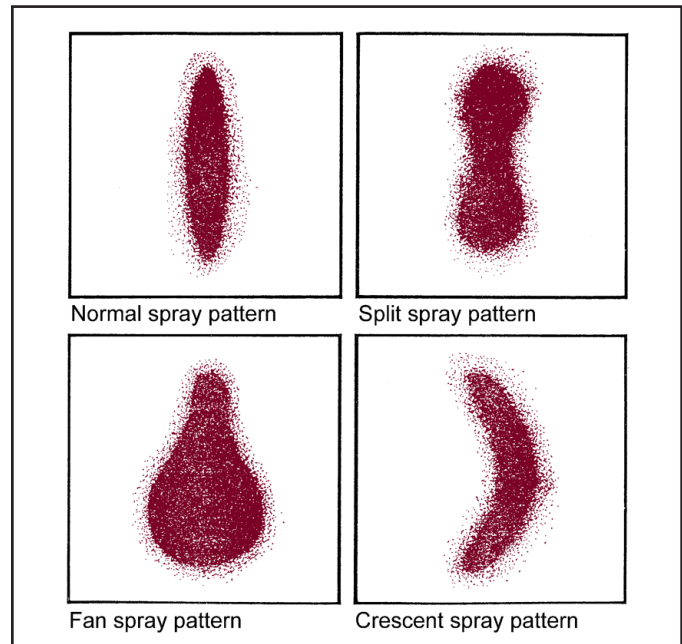
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General Procedures for Using Spray Equipment

Painters must understand and practice the correct procedures and techniques to produce a good finish with spray equipment. The following general procedures should be followed.

- Preparing the work area: Whether spray painting outside or inside in a booth, it is important to remove or protect items in the area so they will not be damaged by overspray. Droplets of paint can float for long distances, settle where they are not wanted, and ruin a finish.
- Preparing the finish: Finishes require thorough mixing by stirring or agitation because the ingredients settle. If multiple cans of the same color are used, mix them together to ensure that all the finish will be the same color. Many finishes are made with a viscosity (tendency to flow) suitable for use with a brush. Such finishes must be thinned with the appropriate thinner so they can be used in spray equipment. Follow the manufacturer's instructions for the correct ratio of finish to thinner. A viscosimeter can be used to determine if the thinned finish is the correct consistency. A viscosimeter is an instrument that measures the rate of flow of a fluid. After mixing and thinning, the finish should be strained to remove any lumps or debris that may clog the spray equipment. Examples of materials used for straining are paper, nylons, and cheesecloth.
- Adjusting the spray gun: The spray equipment should first be set up by following the procedures for safe and correct use. Use a test surface such as a piece of paper, cardboard, or scrap material to determine the spray pattern of the gun. The gun should be held the proper distance from the surface, which is approximately 8 in. for air spray systems. Pull the trigger all the way back and release it. Evaluate the shape of the spray pattern and make any necessary adjustments. See Figure 7.3 for common spray patterns.
 - o Normal spray pattern: This oval-shaped pattern is recommended for best results.
 - o Split spray pattern: This pattern is heavy at the top and bottom and weak in the middle. It is usually caused by the air pressure being too high or by trying to get too wide a spray with thin material. Reduce the air pressure if it is too high.

Figure 7.3 – Spray Patterns



Too wide of a spray can be corrected by opening the fluid adjustment screw slightly and closing the spreader adjustment valve slightly.

- o Fan spray pattern: This top- or bottom-heavy pattern generally indicates that finish is clogging the nozzle and blocking airflow. Cleaning the nozzle and fluid tip with thinner can correct this problem. Do not use metal tools to clean nozzle openings because they can cause damage. Other causes of a fan spray pattern are a loose air nozzle or a bent fluid nozzle or needle tip. Tightening the air nozzle or replacing the fluid nozzle or needle tip can solve these problems.
 - o Crescent spray pattern: This pattern is heavy on one side. It is caused by dried finish blocking airflow through a wing port. Cleaning the port with thinner can correct this problem. Do not use metal tools to clean nozzle openings because they can cause damage.
- Painting a flat surface: The spray gun should be held at a right angle to the surface and at a distance of approximately 8 in. from the surface. Holding the gun steadily at this angle and distance prevents sags and runs or an uneven finish. See Figure 7.4 and Figure 7.5. To begin painting, pull the trigger and move the spray gun parallel to the surface being painted. Moving the

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Figure 7.4 – Correct and Incorrect Angles for Holding the Spray Gun

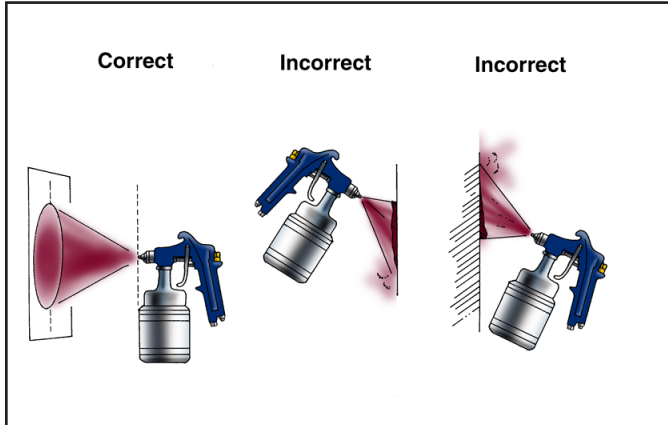
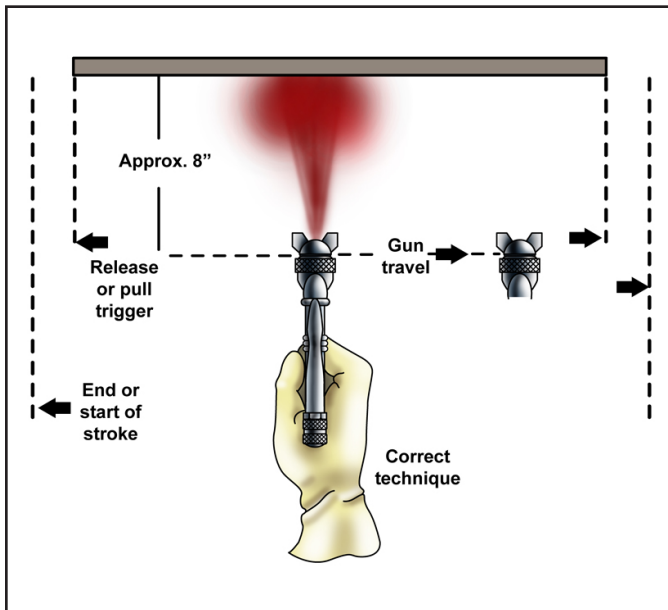


Figure 7.5 – Technique for Moving the Spray Gun

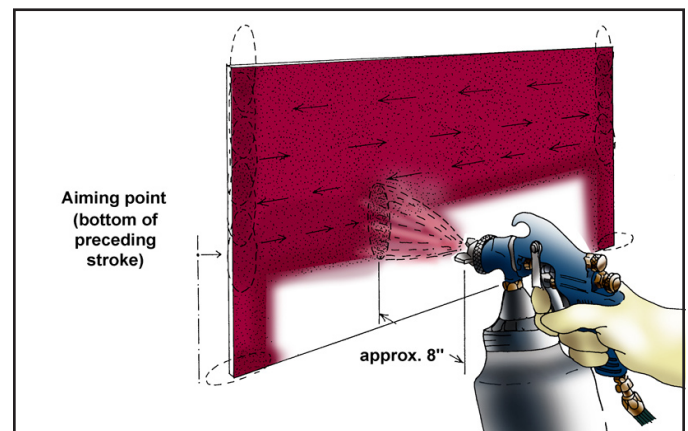


gun in an arcing motion rather than parallel produces an uneven finish. There will be thin spots at the points where the gun is farther away from the work and thick spots where it is close to the surface. The following are guidelines for spray painting a large, flat surface such as a panel.

- o Paint difficult-to-cover areas, such as edges and corners, first. To paint the edges of the panel, turn the wing ports so the spray pattern is horizontal and make one pass from top to bottom on each edge.

- o After the edges are painted, turn the wing ports back to the vertical position and start the first pass at the top left of the panel. Be sure that the middle of the spray pattern is at the top edge of the panel. Each pass should start and end at a point 2 to 3 in. outside the panel. While the gun is in motion, pull the trigger and move across the panel at a constant rate of speed. Release the trigger while the gun is still moving. Starting and stopping the paint flow while the gun is in motion prevents an excessive buildup of paint where passes overlap. To make the second pass, aim the gun so that the middle of the spray pattern is at the bottom of the spray pattern from the previous pass. The pass should overlap the previous pass by about 50%. Continue making alternating left and right passes using the same technique until the panel is completed. See Figure 7.6.

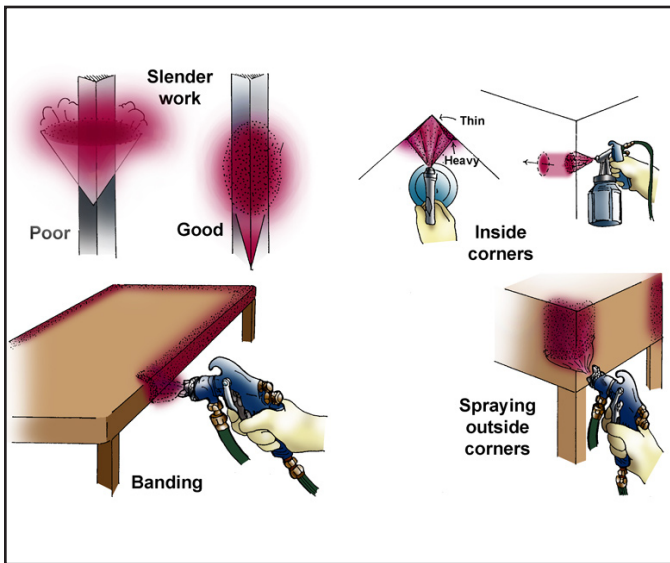
Figure 7.6 – Movement of Spray Gun for Each Pass, With Each Pass Overlapping the Previous Pass



- Painting other surfaces: Surfaces other than flat are more difficult to paint, so special techniques are used on these surfaces. See Figure 7.7. When spray painting thin, vertical pieces such as chair legs, it is more efficient to adjust the wing ports for a vertical spray pattern. Corners, such as those in a room, should be painted as though they were two separate panels. Spraying directly into the corner causes excessive paint buildup in the corner. To paint outside corners, use a horizontal spray pattern and aim the gun so that the middle of the spray pattern is at the edge

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Figure 7.7 – Special Spray-Painting Techniques



of the corner. Use a vertical spray pattern to paint narrow edges, such as the edge of a tabletop. This technique is called banding.

- **Cleaning the spray gun:** Spray equipment must be cleaned thoroughly after every use to ensure it will operate properly for the next painting job. It is important to follow the manufacturer's recommendations and instructor's directions for the correct cleaning procedure for the equipment used. General guidelines include emptying the paint cup into an appropriate container that is labeled and can be tightly sealed. If the finish is not going to be saved, it should be discarded properly. A cleaning solution, which is designed for the type of finish used, is then run through the gun to remove the finishing material. The air cap is also cleaned with the solution. Metal tools should not be used to clean spray gun openings because they can cause damage. All parts of the spray gun are dried and the gun is reassembled. If the sprayer has been used to spray water-based material such as latex paint, mineral spirits should be run through the gun to remove any moisture and keep the gun from rusting. After the cleaning process is complete, all cleaning materials should be disposed of safely and properly and all materials and equipment should be returned to their proper places.

Common Spray-Painting Defects

When paint fails, it is a waste of time, money, and effort. The object is not protected and the work must be done again. Painters in agricultural mechanics should be able to recognize common spray-painting defects and make adjustments in technique, finish preparation, and equipment settings to prevent these problems. Common spray-painting defects are as follows:

- **Runs and sags**
 - Possible causes of this defect include applying finish too heavily, holding the spray gun too close to the surface, using finish that is too thin, setting the fluid pressure too high, and moving the gun too slowly.
 - Ways to correct this defect include learning to calculate the depth of wet finish, holding the spray gun farther from work, adding enough finish to thicken it to the correct viscosity, using the fluid control knob to reduce fluid pressure, and increasing the speed of operation.
- **Streaks**
 - Possible causes of this defect include holding the spray gun too far from the surface, not overlapping passes properly, setting the air pressure too high, and moving the spray gun too quickly.
 - Ways to correct this defect include holding the gun closer to the surface, overlapping the previous pass more accurately, reducing the air pressure, and decreasing speed of operation.
- **Orange peel**
 - Possible causes of this defect include not using enough thinner, allowing overspray to strike a tacky finish, and operating at pressures that are too high or too low.
 - Ways to correct this defect include adding enough thinner to produce the correct viscosity, adjusting the spraying sequence or procedure, and adjusting pressure as needed.
- **Rust under the finish**
 - A possible cause of this defect is not preparing the surface properly for the finish.
 - This defect can be corrected by removing the finish and the rust, coating the surface with the appropriate primer, and reapplying the finish.

Unit VII – Painting and Finishing

Summary

Spray painting is a fast and efficient way to apply a protective coating on a surface. Safety must be the first consideration when working with finishing materials and using spray-painting equipment. The two common types of spray equipment used in agricultural mechanics are air and airless spray equipment. Achieving good paint adherence, durability, and appearance depends on several factors: properly preparing the surface, choosing the correct primer and paint, operating spray equipment properly, and making adjustments to prevent paint failures.

Credits

Agricultural Mechanics Unit for Agricultural Science II. University of Missouri-Columbia: Instructional Materials Laboratory, June 1983.

Althouse, A.D., Turnquist, C.H., Bowditch, W.A., Bowditch, K.E. *Modern Welding*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Cooper, E.L. *Agricultural Mechanics: Fundamentals and Applications* (3rd ed). Albany, NY: Delmar Publishers, 1997.

Engineering and Design – Painting: New Construction and Maintenance. U.S. Army Corps of Engineers, 1995. Accessed April 10, 2002, from <http://www.usace.army.mil/inet/usace-docs/eng-manuals/em110-2-3400/toc.htm>.

Feirer, J.L. *Furniture and Cabinet Making*. Peoria, IL: Bennett Publishing Company, 1983.

Phipps, L.J., Reynolds, C.L. *Mechanics in Agriculture* (4th ed). Danville, IL: Interstate Publishers, Inc., 1992.

Scharff, R., Duffy, J.E. *Motor Auto Body Repair* (3rd ed). Albany, NY: Delmar Publishers, 1998.

Umstattd, W.D., Davis, C.W. *Modern Cabinetmaking*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 2000.

Wagner, W.H., Kicklighter, C.E. *Modern Woodworking*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1996.

Zimmerman, F. W. McWard, L.J. *Exploring Woodworking: Fundamentals of Technology*. Tinley Park, IL: The Goodheart-Willcox Company, Inc., 1999.

