IDAHO Agricultural
Extension Service

BULLETIN 449
JULY, 1965
T-6

ELECTRICITY

for the 4-H scientist

Safety
Uses
Economy

DIVISION VI
4-H ELECTRIC
WELDING

TEACHING RESEARCH SERVICE

UNIVERSITY OF IDAHO
College of Agriculture

4-H Electric, Division VI

Welding

The 4-H member may do all five parts of this 4-H Electric Welding Project in one year for a total of 22 credit points.

Also, any of the five parts of this welding project may be used to supplement work in the other 4-H Electric Divisions crediting the indicated number of points to that year's work.

Advanced 4-H Electric credit points may be gained for further welding projects under SPECIAL PROJECT page 48 Division IV.

EXHIBITS:

Examples of welds made in exercises may be exhibited. It is suggested they be mounted on a board with descriptive captions. See the sketch at the beginning of YOU CAN WELD ELECTRICALLY—Part three, page 12.

Name ....

Address ....

UNIVERSITY OF IDAHO
COLLEGE OF AGRICULTURE
AGRICULTURAL EXTENSION SERVICE

Eric B. Wilson, Extension Agricultural Engineer

1965

Published and distributed in furtherance of the Acts of May 8 and June 30, 1914, by the University of Idaho Extension Service, James E. Kraus, Director; and the U.S. Department of Agriculture, Co-operating.

YOU CAN WELD ELECTRICALLY—Part One

Every day you see the jobs about you that arc welding does. Bridges, sky-scrapers, homes, pipelines, giant earth moving machines—all are built with the help of arc welding. Arc welded wagons, combines, balers, elevators, tractors, and plows speed the work of the farmer. Arc welding puts broken machines back into operation. Equipment for arc welding comes in many types, sizes, and prices to fit the needs of all, from the small home workshop to the biggest industry.

What to Do

1. Learn how electric welders work.

2. Know the different types of electric welders and what they're suited for.

3. Learn to strike an arc and run a bead.

Tools and Materials You'll Need

The use of an electric arc welder and accessories

A supply of E6011 or E6014 electrodes of 5/32" or 1/8" diameter

One or more pieces of scrap steel plate, 3/16" or more in thickness

How Do Arc Welders Work?

Arc welding is done by completing an electrical circuit from the welding machine through the metal being welded, and back to the welding machine. The welding electrode is held away from the metal, causing an arc in the circuit at this point. The arc heats and melts both the metal being welded and the end of the electrode. These metals flow together, forming a bead.

There are two basic types of welders: those that provide alternating current (AC), and those that provide direct current (DC).

The AC Welder

AC welders are basically step-down transformers which reduce the line voltage and raise the amperage. This higher output amperage provides the necessary heat for welding.

The 180 ampere capacity AC welder is most popular for farm and home shops and small repair shops. It is designed for limited input, so that it can draw no more than 37-1/2 amperes from the line when in operation. This makes it possible to operate the welder on 230-volt rural and residential lines from the sizes of transformers normally provided.

The "open-circuit" voltage—that is, the voltage across the two output leads when the welder is turned on but not in use—is 65 volts or less. This relatively low voltage eliminates the danger of harmful shock. The voltage across the arc when welding is usually 25 volts—the most satisfactory load voltage for general purpose welding.

The DC Welder

One type supplies direct welding current from a generator which is part of its equipment. An alternating current motor, internal combustion engine, or tractor power takeoff turns the DC generator.

The most technically advanced DC welder converts 230-volt alternating line current into direct welding current by passing the AC through a rectifier.

Universal Type Welder

This type welder combines both AC and DC. It operates on single phase 230-volt line current, and provides either alternating transformer welding current or direct rectified current. Available sizes range from 180 to 500 amperes.

Which Is Best?

DC welders may be used with a wider variety of electrodes than AC welders. They are better for welding thin metal. Also, models driven by gas engines can furnish welding current where there is no electric power line. Generally, though, the AC welder is more popular for farm and home use because of:

1. Low initial cost

2. Low cost of operation and upkeep

3. Convenient to use

4. No moving parts

5. Uses readily-available single-phase current

6. Operates quietly

Here's What Completes The Outfit

Two cables are necessary to carry the current from the welder to the work and back to the welder, thus completing the electrical circuit.

The insulated electrode holder grips the electrode. You weld by manipulating the holder.

The ground clamp connects the ground cable to the work or to the metal welding table that the work is on, completing the circuit back to the welder.

The shield for the eyes and face is necessary protection from the rays of the electric arc and the heat and spatter of molten metal. Arc rays are intense and will produce a sunburn if the skin is not adequately protected. The shield should have a No. 10 or 12 filter glass for general purpose welding. This glass is expensive, and should be protected by a plastic cover lens so that the glass doesn't become covered with arc spatter.

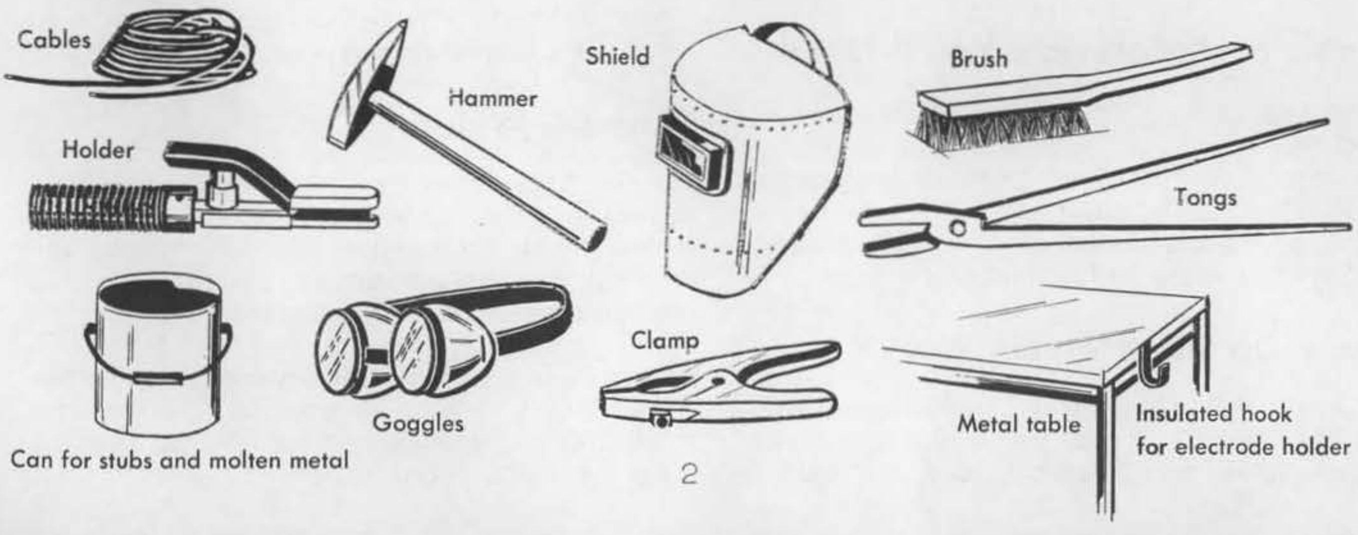
A chipping hammer to remove slag from the weld bead.

Safety goggles to protect the eyes from stray particles when chipping or brushing the weld with the headshield raised.

A wire scratch brush to clean the beads after chipping.

Tongs or pliers for handling hot metal. Avoid picking up hot metal with leather gloves. The heat will harden and shrink the leather.

A special welding table should be used for welding practice and small jobs. An ordinary work bench soon becomes spattered and burned. The table should be made of iron or steel, to be fireproof, and to provide grounding for the electrical circuit with the welder.



Welding IS SAFE, If You:

Use a shield with proper filter glass for both welding and observing. (Check the helmet for leaks or cracked lenses by holding it up to a bright light.) Considerable harm may result from exposing the naked eye to an arc flash.

Wear goggles to protect the eyes when headshield is up.

Caution those around you before striking an arc or chipping slag.

Wear gloves and adequate clothing to protect the skin against heat, spatter, and arc rays. Trouser cuffs should be turned down.

Keep a fire extinguisher nearby.

Remove flammable materials (gasoline, grease, oily rags) from the welding area. Matches and cellophane wrappers in the pockets are a hazard.

Zinc, tin, brass, and lead fumes are dangerous to breath and should be ventilated or blown away. Grind or file galvanizing from the weld path to minimize fumes.

Protect wood floors with asbestos or sand.

Assume a comfortable position for free movement during welding.

When chipping slag use short strokes and chip away from you.

To see if metal is hot before touching it, hold palm of hand close to it for evidence of heat.

Don't weld containers or tanks until you know what they have contained. If they have held flammable materials, steam clean them, or fill with water during welding—or use some other approved method of removing explosive fumes.

Be careful in disposing of electrode stubs. They are a hazard on the floor, and they can burn badly if touched or flipped against bare skin. It's best to drop them in a metal container.

Preparing To Weld

1. Put on the safety goggles, gloves, and headshield in raised position.

2. Make sure the welder is turned off. Then clamp the bare end of an electrode in the holder at a 90-degree angle to the jaws.

3. Keep the electrode clear of work table until you're ready to start. It should be placed on an insulated hanger when not in use.

4. Place a piece of scrap steel plate in a flat position on work table. Clamp the ground cable securely to the table (if the table is metal), or to the work at a point free of paint and scale. If the scrap plate is rusty or dirty, first scratch brush it clean.

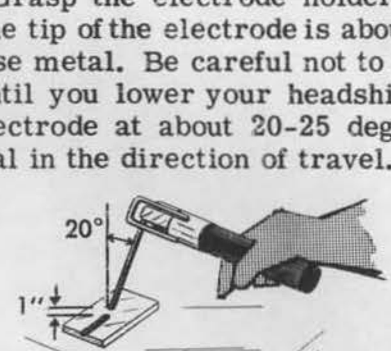
5. Check to see that all connections between cables, welder terminals, electrode holder, and ground clamp are tight.

6. Set the welding machine to produce about 100 amperes for a 1/8" electrode, or about 130 amperes for a 5/32" electrode. (A welder can be set while on, but never when someone is welding.)

7. Turn the welder on.

Strike An Arc

1. Grasp the electrode holder and lower it so the tip of the electrode is about 1" above the base metal. Be careful not to make contact until you lower your headshield. Lean the electrode at about 20-25 degrees from vertical in the direction of travel.

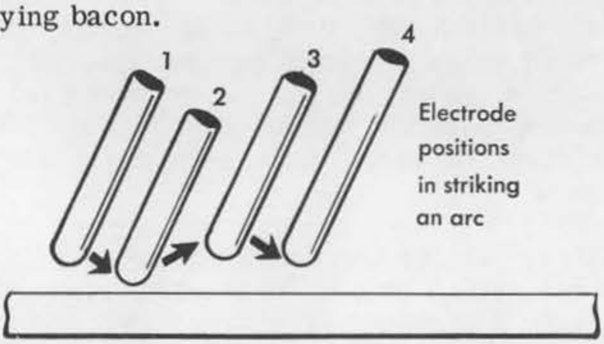


2. Lower the headshield and strike the arc. Scratch the tip of the electrode over the surface of the base metal with a wrist motion as if striking a large match. The arc will start with a sudden burst of light and sparks.

(If you are using an E6014 electrode, do not raise it, but lightly drag the coating across the work to maintain the proper arc length.)

3. Raise the tip of the electrode to about 3/16" above the base metal. This action forms a long arc which should be held a second or two to establish the arc and molten puddle.

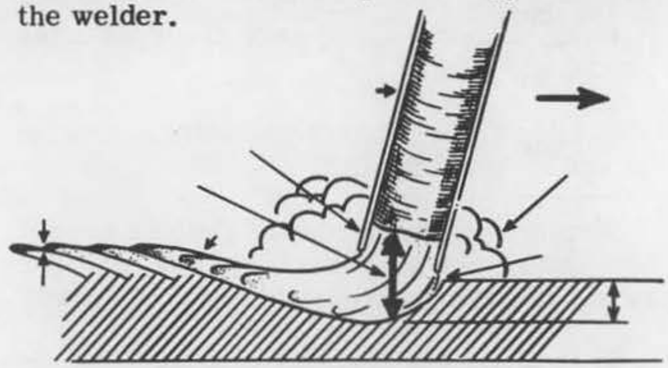
4. After holding this 3/16" arc length for a second or two, lower the electrode to 1/16" or 1/8" from the surface of the molten puddle. This is the desired arc length to maintain while welding, and it sounds like frying bacon.



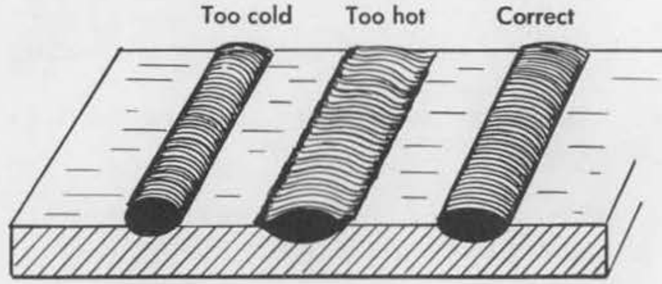
5. Repeat this arc striking procedure several times until you can control it every time. If the arc will not restrike on the partially burned electrode, the flux has probably run over the end, insulating it. A sharp rap on the base metal will break the drop of flux and establish contact again. In striking the arc, be sure to pull the electrode slightly away again. Otherwise, it will fuse with the base metal and stick. To free a frozen electrode, snap the holder backward from the direction of travel to break it loose. If it will not break loose, release the electrode from the holder. Never remove your headshield until the electrode is free, either from the holder or base metal. There will be an arc flash when it comes loose.

Running A Bead

When you can strike an arc and form a molten puddle, practice running beads. A bead is made by moving the electrode at a uniform rate of speed over the plate. The correct arc length of 1/16" to 1/8" is maintained by feeding the electrode down as it melts off. (If you are using an E6014 electrode, you maintain the arc simply by "dragging" it lightly across the work.) Steadying the elbows against the body or table will help keep the feeding motion steady. **Remember to lean the electrode about 20-degrees from vertical in the direction of travel. This way you can see the arc, tell whether you are getting good penetration, and control your molten flux.** With a little practice, you'll be able to move the electrode downward and across the base metal at a steady speed. When you've finished practicing, turn off the welder.



When your beads have cooled to less than red heat, take the chipping hammer and chip away the slag (impurities that spoil the appearance and encourage corrosion). Show your practice work to someone with welding experience. Compare your work with some professional welding. Where do you stand? If yours isn't as good, it means you need more practice.



When you're through, put all the accessories back where you found them, and clean the work bench.

What Did You Learn? True or False

1. Arc welding requires the completion of an electrical circuit.

2. An AC arc welder steps up voltage.

3. Safety goggles should always be worn while chipping slag from a weld.

4. Exposure of the eyes to an arc is not the only danger when welding.

Oxy-Acetylene Cutting Equipment

Oxy-acetylene cutting is fast, economical and time saving. If the equipment is available and you wish to use it for preparing material for arc welding projects, here are some instructions:

Tools and equipment necessary for oxy-acetylene welding and cutting consists of a cylinder of oxygen, a cylinder of acetylene, two regulators, two lengths of hose, a welding blowpipe and a cutting attachment.

Note: In this lesson we will deal only with cutting as an aid in preparing material for arc welding. To learn about oxy-acetylene welding obtain a good book on that subject and practice the methods indicated.

MATERIALS YOU WILL NEED

The oxy-acetylene outfit, a pail of soapy water and a paint brush.

SETTING UP THE EQUIPMENT

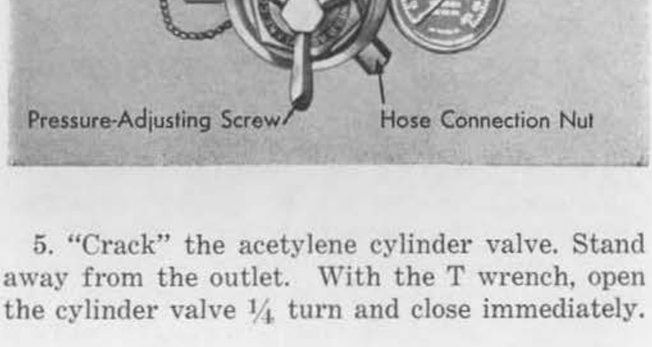
1. Fasten cylinders firmly. If cylinders are not on a cart or otherwise firmly held, tie them to a workbench, wall or post. Knocking these tanks over can be very dangerous.

2. "Crack" the oxygen cylinder valve. Stand away from the outlet and open the valve lightly and then close it—to blow out dust or dirt.

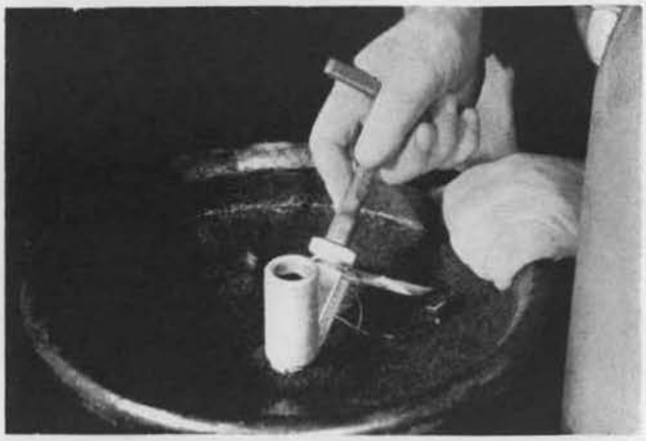
3. Connect the oxygen regulator. The oxygen regulator and cylinder have RIGHT HAND thread connectors. Tighten the union nut with the regulator wrench.

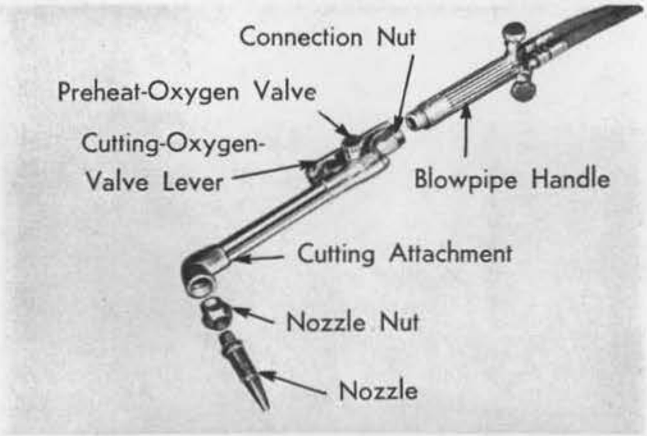
4. Open the cylinder valve slowly. Turn out the pressure—adjusting screw of the regulator counter-clockwise until loose. Then open the cylinder valve—SLIGHTLY AT FIRST—then all the way.

Caution: DO NOT USE OIL. OIL OR GREASE MAY IGNITE VIOLENTLY in the presence of high pressure oxygen.



5. "Crack" the acetylene cylinder valve. Stand away from the outlet. With the T wrench, open the cylinder valve 1/4 turn and close immediately.





PHOTOS — Courtesy **Union Carbide Corporation, Linde Division**

Caution: Do not crack acetylene cylinder valve near sparks or flame.

6. Connect the acetylene regulator. Acetylene regulators and cylinders have LEFT HAND threads. Tighten the nut with a regulator wrench. Turn out the pressure-adjusting screw of the regulator (counter-clockwise) until loose.

7. Open the acetylene cylinder valve—SLIGHTLY AT FIRST—then one and one-half ($1\frac{1}{2}$) turns, but NO MORE. Leave the T wrench in place while cylinder is in use.

8. Make hose connections. OXYGEN hoses are GREEN and have RIGHT HAND threads. ACETYLENE hoses are RED and have LEFT HAND threads.

9. Attach the blowpipe to the other ends of the hoses and attach the cutting head to the blowpipe.

10. Test for leaks.

   a. First close the blowpipe oxygen valve and turn the oxygen pressure-adjusting valve in (clockwise) to give about 25 psi (pounds per square inch). Using the paint brush and soapy water test all of the oxygen connections from the cylinder valve to the blowpipe. If any leaks are found (soap bubbles) tighten the connection or have it repaired.

   b. Close the blowpipe acetylene valve and adjust the acetylene pressure up to about 10 psi. Test with soapy water all the connections in the acetylene line.

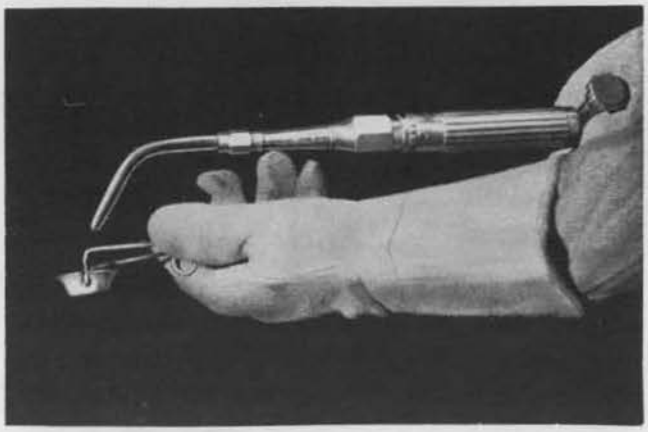
11. Release some acetylene and adjust oxygen and acetylene pressures. Proper pressures vary for various makes and models so it will be necessary to consult the instruction book for the equipment available.

12. Lighting the blowpipe.

   a. Put on gloves and goggles.

   b. Open the blowpipe oxygen valve wide.

c. Open the blowpipe acetylene valve one-eighth (1/8) turn.



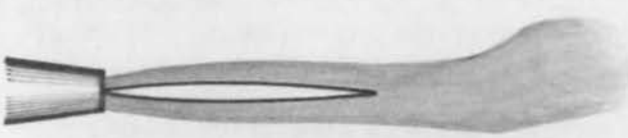
d. Light with a lighter.

(1) Point the blowpipe cutting tip down and away from you.

(2) Hold the lighter by the finger rests, so the flint is about 1 inch below the tip and "strike."

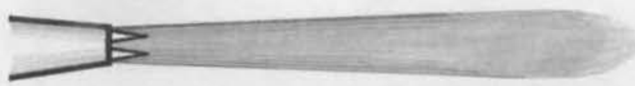
e. Adjust the flame for cutting.

(1) When first lighted it will be a yellow flame producing black carbon soot. Open the acetylene valve more and the soot will disappear.



Acetylene Burning in Atmosphere.

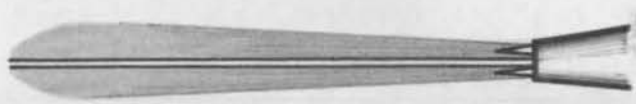
(2) Open the oxygen valve to obtain a blue flame with short points of white flame from the acetylene holes in the tip.



Neutral Flame. Proper Adjustment.

(3) Adjust the "White points" for maximum length but remaining close to the tip. Re-adjust the oxygen for a clear blue (neutral) flame.

(4) Depress the oxygen lever and re-adjust the acetylene for distinct "white points."



Neutral Flame with Cutting Jet Open.

(5) Hold the "white points" 1/16 inch above the cutting mark, preferably on the edge of the metal until a pool of molten metal appears—move the tip away momentarily—then squeeze the cutting-oxygen-valve lever and begin the cut.

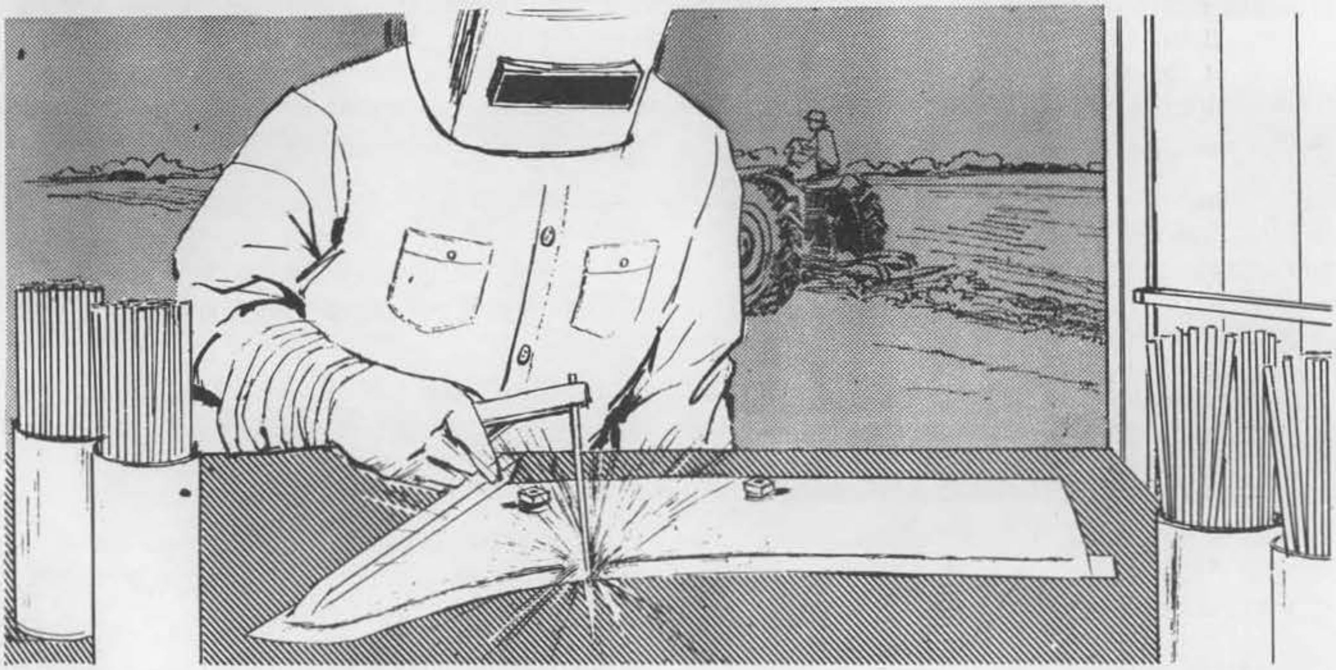
f. Move the tip along the mark at a uniform rate as fast as it will cut and clean out molten metal.

g. Holes can be cut by starting in the center and using a circular motion.

h. Maintenance: Follow maintenance suggestions in the instructions with the equipment. One main point is to keep the orifices in the cutting-tip clean.

4-H ELECTRIC GUIDE SHEET
LESSON NUMBER 82
Credit Points 4

YOU CAN WELD ELECTRICALLY—Part Two



In Part One, you learned something about welders and how they work. You learned how to strike an arc and a little about running a bead. If you have practiced enough, you can maintain the proper arc length of 1/16" to 1/8", and can move the electrode across the base metal at a steady rate. Now that you've acquired this skill, let's learn some more about beads.

What to Do

1. Learn the requirements for a good bead.

2. Restart an interrupted bead.

3. Learn how to cover wide areas by weaving, and how to build up by padding.

4. Build up and hardsurface a part worn from contact with the soil.

Tools and Materials You'll Need

The use of a 180-amp AC arc welder and accessories.
A supply of 5/32" or 1/8" E6011 or E6014 electrodes, and some hardsurfacing electrodes (for metal-to-ground wear).
Several scrap steel plates 3/16" and 1/4" thick.
A worn part from a machine or tool that contacts the ground. (Example: plowshare, cultivator shovel, or shoe from a field mower or a power lawn mower.)

Five Things Make A Good Bead

A good bead depends on the correct amperage setting, the proper electrode, the right arc length, and the correct electrode angle and speed of travel.

Use The Right Amperage

Too little amperage causes a weak arc that is difficult to strike and maintain. The bead will stand up like a loaf of bread rising out of a pan because there has not been enough heat to fuse the edges with the base metal.

Too high a setting produces the opposite effect. The bead will be wide and flat, with excessive spatter. The bead will be undercut at the edges of the "crater." This is because the force of the arc removes the base metal but doesn't replace it with filler metal.

The correct heat (amperage) produces a bead that is evenly rippled, slightly higher in the center, and tapered off evenly to fuse with base metal on either side.

Pick The Proper Electrode For The Job You're Doing

Electrodes are classified in various ways, but the two most important factors are diameter (in inches of the actual core wire) and coating.

The diameter determines the amount of metal that will be deposited in one normal pass, but we are limited in this by the amperage rating of the welder we use. Electrodes 5/32" are about the largest that can be used successfully with a 180-amp limited-input welder. The sizes most commonly used are 1/8" and 5/32".

The coating, applied to the outside of the rod, forms a gaseous shield and protects the molten metal from oxygen and nitrogen in the air. Variations in the make-up of the coating determine the penetration, slag control and removal, and spatter of the electrode.

Here is a table giving some of the characteristics of rods suitable for your use.

Type	Identification	Use for	Characteristics	Amperage			
Mild steel					Flat	Vertical	Overhead
E6011	Blue spot	Construction and repair of mild steel, incl. sheet metal	Deep penetration	1/8"	100	90	80
E6014	Brown spot*		Medium penetration, use "drag" technique	5/32"	130	120	110
Cast iron							
Non-machinable	Orange end	Where repair does not have to be machined	Can be smoothed by grinding	80-90			
Hardsurfacing							
for metal-to-ground wear	Black coating	Plowshares, other tillage parts	Can be hot forged or ground	1/8"	70-100		
				5/32"	150-250		
for metal-to-metal wear	Gray coating	Shafts, gears	Machinable	5/32"	150-180		

*Can be distinguished from other brown spot rods (E6013) by its size—has an extra-heavy flux coating carrying particles of powdered iron. Its advantage is that it can be used simply by dragging the coating lightly across the work. The thickness of the coating maintains the right arc. Its disadvantage is the cost—about twice that of the E6011.

Keep Arc Length Right

With the correct amperage, it is up to the operator to keep a constant arc length to provide even heat. If the arc is too short, the electrode will freeze—fuse with the base metal and stick. Too long an arc will cause large droplets of electrode metal to drip off and blow and spatter. The bead will be uneven, with poor penetration and slag holes.

Maintain Electrode Angle

The electrode should be held about 20-degrees from vertical in the direction of travel. Holding it nearly perpendicular may cause slag to be trapped in the weld. Too wide an angle lessens the penetration and produces elongated ripples.

Not Too Fast--Or Too Slow

Too fast travel produces a thin bead with little strength or penetration. Slow travel builds up the bead excessively, with edges overlapping the base metal. Slow travel may burn through the metal. Practice will teach you the right speed.

Now Let's Do Some Welding

Set up the welding equipment as when you practiced before. Be sure to observe the safety precautions you learned last time. See that the skin is well protected with clothing. Put on safety goggles first, then your headshield. Make sure the welder is "off" until you are ready to weld.

Restart An Interrupted Bead

Sometimes you have to restart a bead because the electrode freezes to the base metal, or because you've had to put in a new electrode. You should practice so you can restart a bead properly every time.

1. Set the welding machine for about 100 amperes if you have a 1/8" electrode, or about 130 amperes for 5/32" electrode.

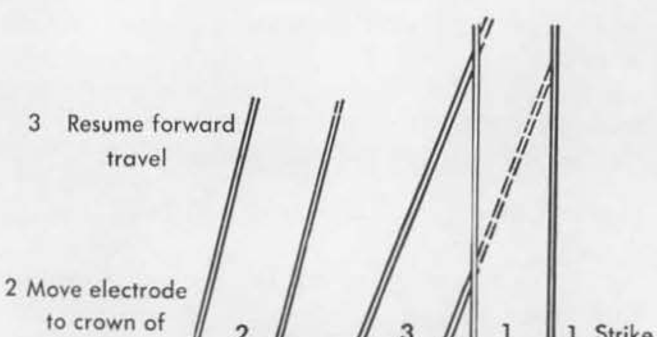
2. Place an E6011 or E6014 electrode in the holder at a 90-degree angle. Then place the holder on its hanger.

3. Turn on the welder.

4. Pick up the holder and hold it in position so that the electrode is about an inch above the scrap metal. Lower your headshield.

5. Now strike an arc and start running a bead. Remember to hold the electrode at about a 20-degree angle from vertical, tilted in the direction of travel. Your arc length should be from 1/16" to 1/8". Run a few inches of bead. Withdraw the electrode and stop.

6. Wait a few moments, then restart the bead. Do this by striking the arc slightly ahead of the crater, move back into the crater, then move ahead with the bead. At the end of the bead, pause momentarily to fill the crater and withdraw the arc to extinguish it.



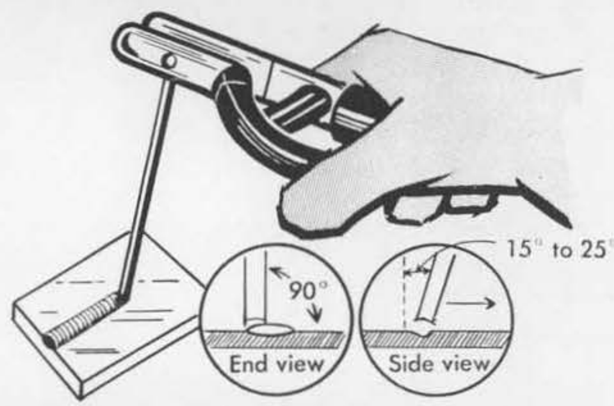
7. Place the holder on the hanger and turn off the welder. When the bead has cooled below red heat, chip off the slag with a chipping hammer (chip away from you) and brush clean. Examine to see if you have a good bead.

Practice starting, stopping, and restarting a bead until you have made several good beads in succession.

Let's Try Some Weaving

Sometimes you'll want to cover large areas. This is called weaving.

1. Prepare to weld as in steps 1 to 4 for running a bead.



A good weaving motion

2. Strike an arc over an unused portion of scrap steel. Run a wide bead, weaving the electrode from side to side as you move forward. Follow a pattern like one of those shown for your motion. You will find from practice which suits you best. If there is a tendency to undercut along the edge of the weave, hesitate momentarily on the edge of the bead to build up the weld in this area. Practice weaving a wide bead until you get uniform results every time. Chip and brush the weld after each pass so you can inspect your bead. Always wait until the bead has cooled below a red heat before you chip.

3. Place the holder on its hanger, then turn off the machine.

Now Try Padding

Padding is the building up of large areas with one or more layers of material. It is very useful in building up and hardsurfacing plowshares, shafts, and other wearing parts.

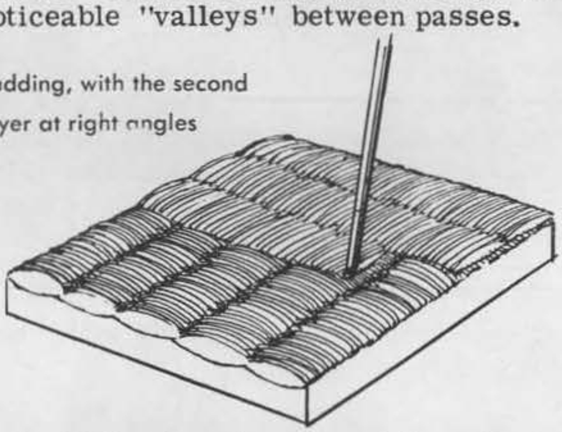
For this you'll need a piece of steel plate about 2-1/2" by 4", and 1/4" thick.

Make ready to weld by following steps 1 to 4 in running a bead.

1. Lay a straight bead along one side of the steel plate. Let it cool below red heat, chip, and clean. Then run another pass next to and overlapping it slightly. Clean each bead before overlapping with another. Each pass should fuse with the base metal and with the previous pass.

2. After a complete layer of passes has been made, chipped and wire brushed clean, examine for slag pockets or holes. The surface should be fairly smooth, without noticeable "valleys" between passes.

Padding, with the second layer at right angles



3. Following steps 1 and 2, make a second layer of passes at right angles to the first. For practice, make one layer of straight passes, and the next, weaving passes. The beads should improve as you go along. Skill will have to be developed in building up the edges of the pad. This requires good control over the molten puddle which is something you'll gain by practice.

4. With successive layers, each at right angles to the one below it, build up the pad to about 3/4" or 1". If the edges of the pad are built up square, the last layer of passes will be the same width and length as the first.

5. After you have built up the pad, let it cool down in the air (this is called "normalizing") and saw through it with a power hacksaw (or hacksaw) to examine a cross-section cut. Each layer should be fused solid, with no slag pockets or holes.

When you rebuild a worn piece by padding, usually it is built up to oversize, then ground or machined to size.

Build Up And Hardsurface A Worn Part

A good way for you to get the practice you'll need to do a good job is to build up a part worn down by the abrasive action of the soil. This can be a plowshare, cultivator shovel, or even the wearing shoe from a power lawn mower.

By padding or weaving or both, build up the wearing surfaces of one or more such parts to the approximate shape they had when new. Use E6011 or E6014 electrodes.

Then, use a hardsurfacing electrode to put a wear-resistant layer on the part you've restored.

What Did You Learn?

(Underline the right answer)

1. A good welding bead depends on (two) (five) factors.

2. A standing-type bead is a result of (too little) (too much) amperage.

3. Too fast travel produces a (thin) (thick) bead.

4. To restart an interrupted bead, strike the arc (ahead of) (behind) the crater.

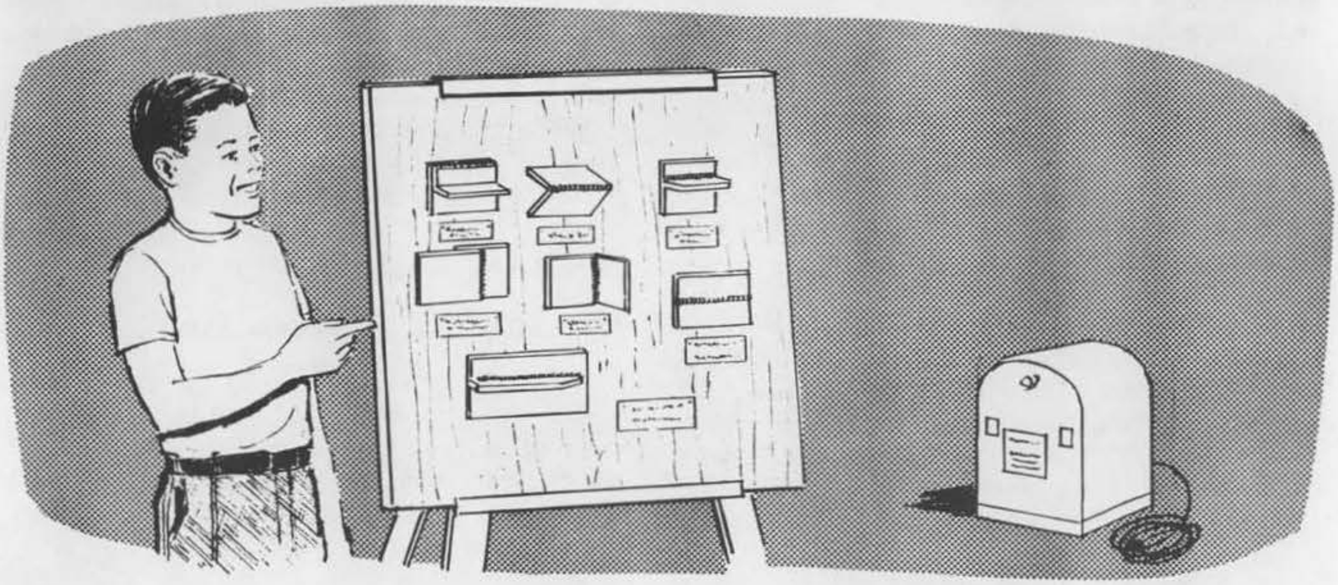
5. Building up an area is called (weaving) (padding).

For More Information

Have an experienced welding man show you how he handles the electrode in beading, weaving, and padding.

4-H ELECTRIC GUIDE SHEET
LESSON NUMBER 83
Credit Points 5

YOU CAN WELD ELECTRICALLY—Part Three



Now that you're familiar with beading, and have some skill in handling the electrode, you're ready to begin welding different types of joints. There are just a few basic types, and when you've mastered these, you'll be ready to do some worthwhile welding jobs.

What to Do

1. Learn when to use, and how to make: butt welds, lap welds, fillet welds, corner welds, and edge welds.

2. Practice these five types of welds until you make them well.

3. Prepare an exhibit or give a demonstration including each type.

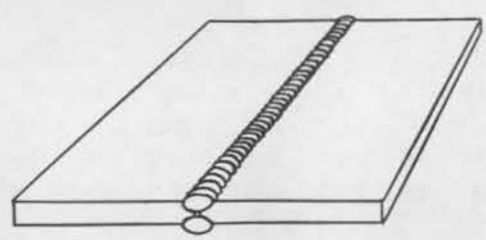
Tools and Materials You'll Need

The use of 180-amp AC arc welder and accessories.
A supply of E6011 or E6014 electrodes.
Several scrap steel plates, bars, or angles—3/16" and 1/4" thick.

The Butt Joint

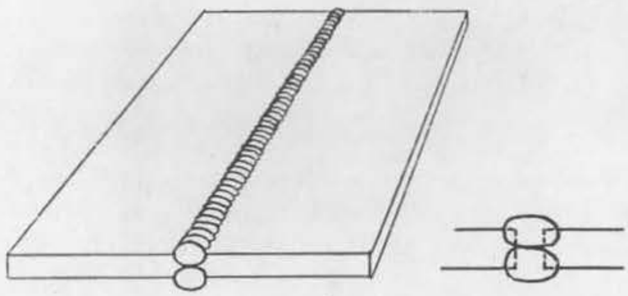
Repair and maintenance of equipment often requires joining two pieces of metal at a point where a crack or break has occurred. The butt weld is used for repairing this type of damage. It is also used in building new equipment when two pieces of metal on the same plane need to be joined.

The simplest butt joint is the "closed" or "square" butt type. This is used where two pieces of metal are placed tightly together, then welded with a bead on both sides of the joint. Sometimes a bead is used on one side only, particularly if the metal is thin. Whether a single or double bead is used, the strength of the joint lies in the two pieces of metal being completely fused together during the welding process.



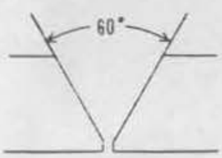
"Closed" or "square" butt weld

Another type is the "open butt" joint. Only thin sheet metal should be welded this way. This is similar to the closed butt, except that the pieces are kept apart a distance of 3/32" to 1/8". This makes it easier to get a stronger weld, because it's easier to secure penetration and fuse all the way through the joint. Whenever possible, the weld should be made on both sides of the joint. If welded only on one side, a backup strip of steel or copper should be placed under the joint. This prevents burn-through, and allows a higher amperage setting for deeper penetration.

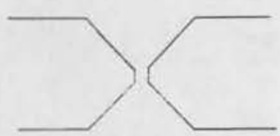


"Open butt" joint

Metal under 1/4" thick is usually welded with an open butt weld. Over 1/4", a "vee butt" is preferable. For this, the edges are beveled to make a 60-degree included angle.



Vee joint



Double vee joint

Metal for a vee joint is usually beveled with a cutting chisel, a cutting torch, or by a grinding wheel. With metal over 3/8" thick, a double vee joint is best. It can be welded from both sides for greater strength.

If material is thick, and veed out, make a multiple pass weld. Make the first pass deep in the vee, and take care that complete fusion is obtained. After this pass, chip and brush the weld, and make as many more passes as needed to make a crown slightly above the base metal. In a wide vee, it's usually necessary to weave the last pass.

Make An Open Butt Weld

Make ready your welding equipment as before, when you practiced beading. Always observe the safety precautions you have learned. If there's some doubt about safety, always find out first, before you proceed. Go back to Part One and re-read the safety tips.

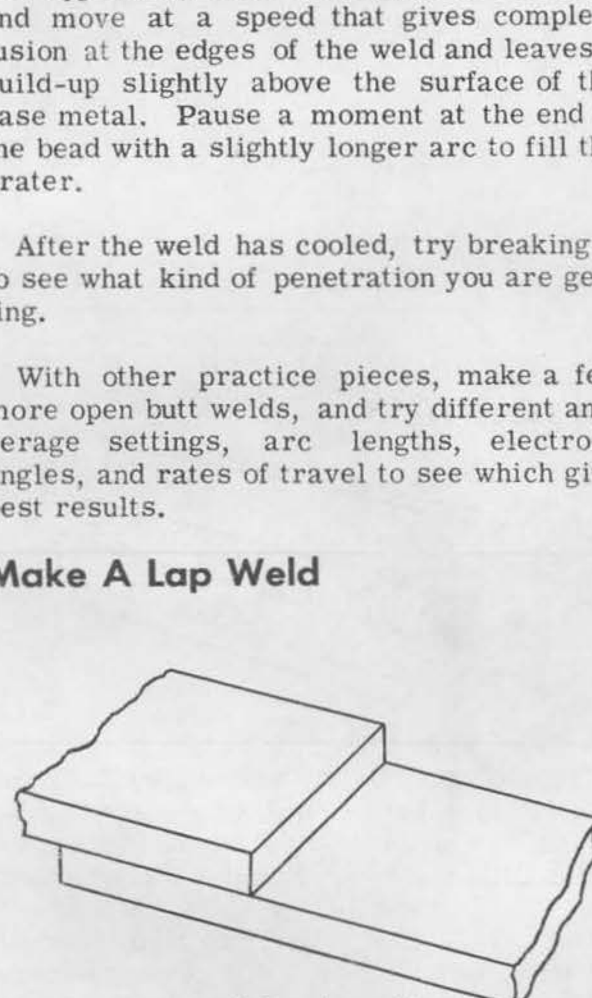
With an amperage setting of 130, turn on the welder, and tack weld the two pieces of practice plate together. Leave a gap about 1/16" at the left hand end, and 1/8" at the right. This will give you experience in making open butt welds with varying distances between them. The tack welds will hold the two pieces in place, and prevent the joint from closing as the metal heats and expands.

Chip the slag from the tack welds, and run a straight bead along the gap, from left to right. (For left handers, all directions are opposite.) Hold a medium arc length, and move at a speed that gives complete fusion at the edges of the weld and leaves a build-up slightly above the surface of the base metal. Pause a moment at the end of the bead with a slightly longer arc to fill the crater.

After the weld has cooled, try breaking it to see what kind of penetration you are getting.

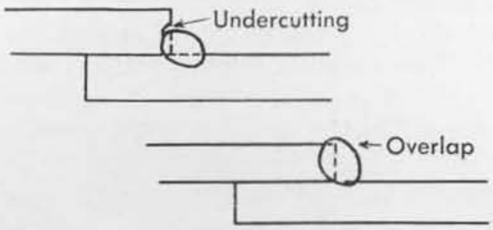
With other practice pieces, make a few more open butt welds, and try different amperage settings, arc lengths, electrode angles, and rates of travel to see which give best results.

Make A Lap Weld



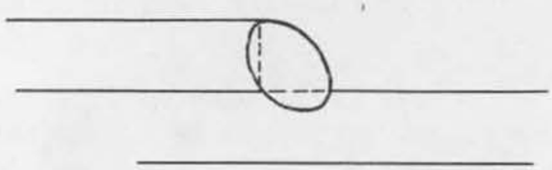
Ready for a lap weld

With two practice pieces of steel 3/16" to 1/4" thick, make a lap weld. Tack weld the two pieces in position. Chip and brush the tacks clean. Strike the arc at the left and weld to the right. The width of deposit on the lower plate should be about equal to the thickness of the upper plate. Surface of the bead should be slightly concave. Point the electrode more directly at the lower plate, since more heat is required to melt the lower plate than the edge of the upper.



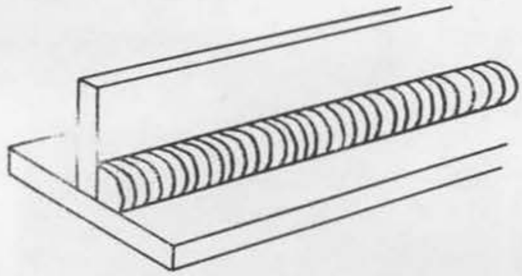
Undesirable lap welds

This drawing shows undesirable lap welds. Did you get any of these types? Practice making lap welds, until you get the type of bead shown below.

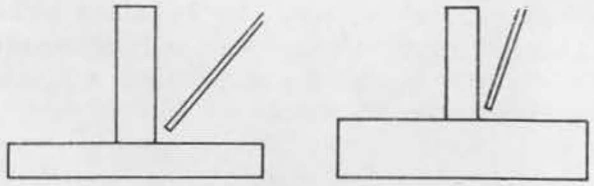


Desirable lap weld

The Fillet Weld



A fillet weld is shown here. It is commonly used when flat iron or angle iron stock is used in fabrication. Repair and maintenance of machines and equipment also requires fillet welding. For the fillet weld, a short arc is kept all the time. A long arc causes metal in the vertical plate to melt and flow down into the weld, causing undercutting. Generally the electrode should be held so it divides the angle between the plates. When the pieces are of different thickness, though, a greater portion of the arc should be placed on the heavier metal.

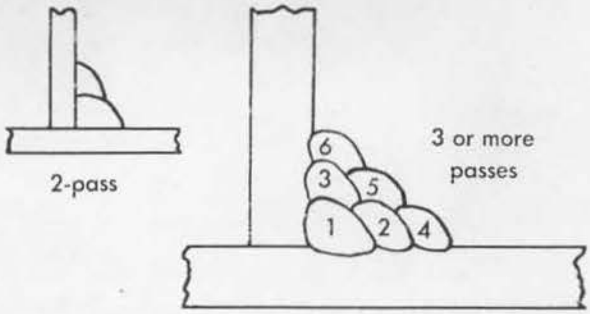


Electrode angles for metal of like and unlike thicknesses

Make A Fillet Weld

Tack weld two pieces of practice steel into position, and chip the tacks. Point the electrode into the center of the 90-degree angle. Proceed along the joint with a short arc. Watch carefully to avoid undercutting the vertical plate. You may have to tilt the arc slightly toward the bottom plate to avoid this.

When you have completed the pass, chip and brush the bead and inspect it for uniformity. Was there undercutting on the vertical plate, or overlap on the horizontal plate? Practice the fillet weld until you have good penetration, with the width of the weld on each plate about equal to the thickness of the base metal.

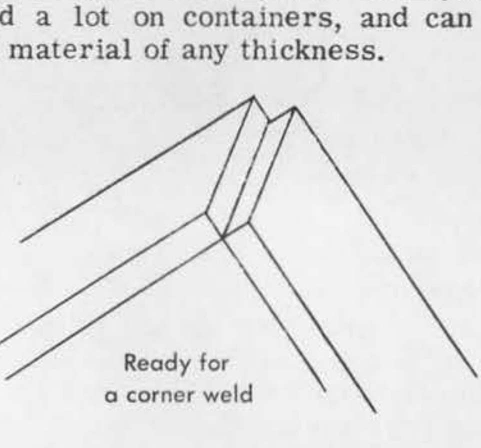


Multiple-pass fillet welds

Two and three-pass fillet welds and multiple pass fillet welds are made in the order shown. The stronger the joint will have to be, the more passes required.

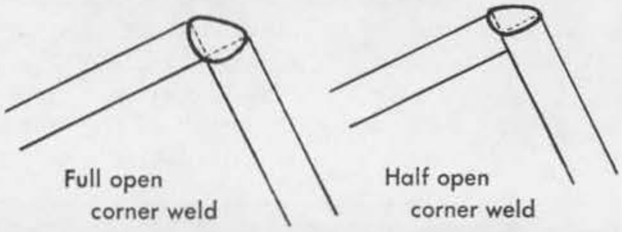
Make A Corner Weld

Corner welds are made by joining two pieces of material at an angle and placing a bead on the outside of the joint. Such joints are used a lot on containers, and can be made on material of any thickness.



Take two pieces of practice steel and tack weld into position, forming a vee. Chip and brush the tacks, then run a bead along the vee. A slight sidewise motion will help round corners and fuse the edges of the bead into the base metal.

After you've made the weld, chip and brush it clean. Inspect your work. Do you have a uniform bead, with good penetration? If not, keep trying until you do.



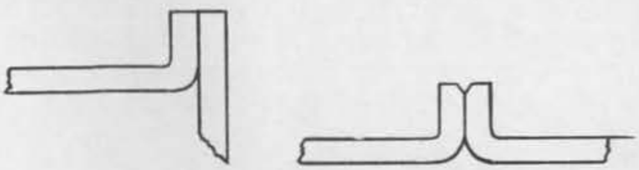
Full open corner weld — Half open corner weld

The weld you made is the full open joint. Sometimes you might need a half open joint or a closed joint where less strength is required.

Corner welds on thin metal tend to warp or spread apart, and need to be tack welded at closer intervals before running the bead.

Make An Edge Weld

Edge welds are used on metals under 1/8" thick. They are made by placing two pieces of metal side by side, and welding the adjoining edges. The edge weld is often used to join thin metals at a right angle.



Right angle edge weld — Straight edge weld

Take two pieces of practice steel, 1/8" thick. Bend one of the pieces in a vise, so the fit will look like the one shown. Tack weld, clean the tacks, then run a bead. Inspect your work. Make enough edge welds so that you can do a good job every time.

Practice Makes Perfect

Now that you've become acquainted with the five basic types of welds, can you name them? They are: butt, lap, fillet, corner, and edge. There are many adaptations of these types, but if you practice enough with scrap steel plates, you'll be able to do the job right when it comes along. Practice what you know about welding as much as you can. Make a satisfactory sample of each type of weld.

What Did You Learn?

(Underline the right answers)

1. Butt welds are used to join two pieces of metal that (are in the same plane) (butt together to form a tee).

2. The surface of the bead on a lap weld should be (convex) (concave) (perfectly flat).

3. When fillet welding, your arc should be (short) (long).

4. To weld the end on to a tank made of 1/8" or less steel plate, you would use (butt weld) (lap weld) (edge weld).

5. Once you've mastered welding, safety rules (are of no consequence) (should be followed to the letter).

Demonstrations You Can Give

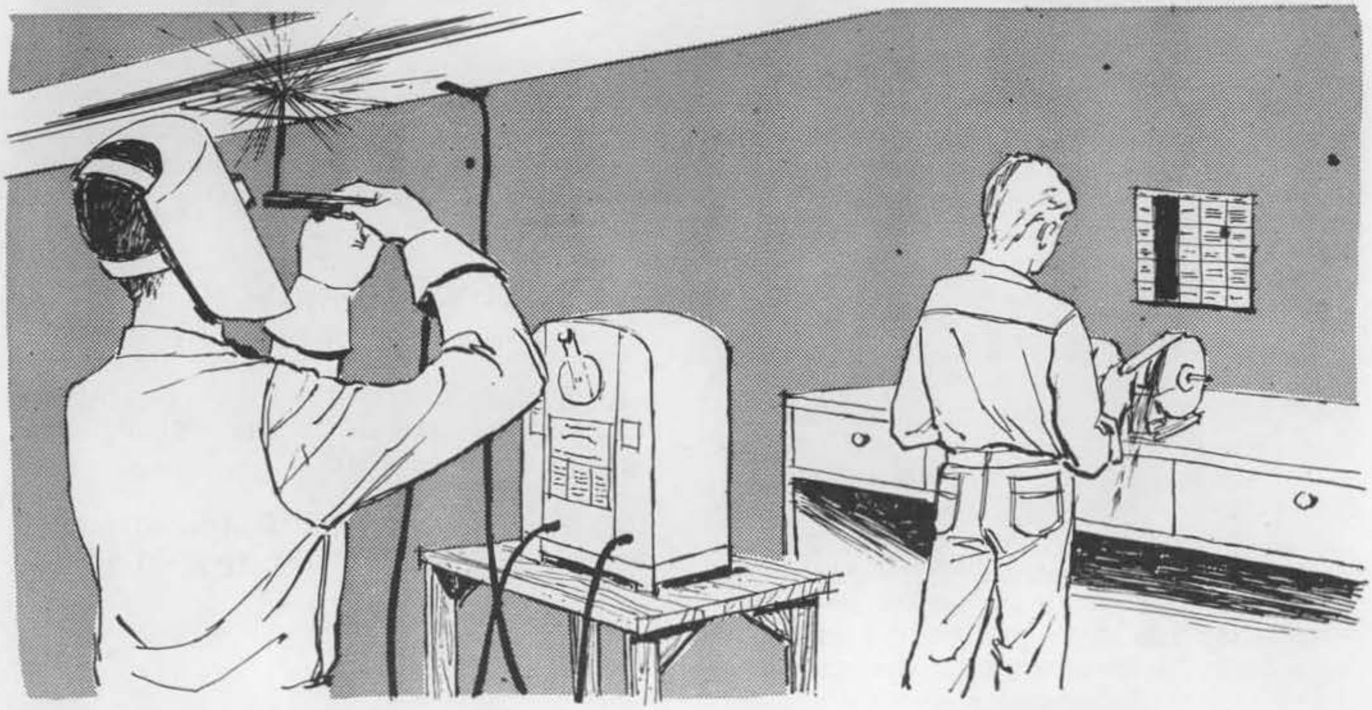
Show correct examples of the five basic types of welds. Tell all you know about each type—where it might be used, and how you made the weld. Do not try to weld in front of your audience—there's too much danger of damage to their eyes. (Or, prepare an exhibit of all five types with cards or signs telling where each should be used.)

For More Information

Ask your leader or power supplier representative to try to show a movie about welding. Major manufacturers of welding equipment have such movies which they will loan to a group for viewing.

4-H ELECTRIC GUIDE SHEET
LESSON NUMBER 84
Credit Points 5

YOU CAN WELD ELECTRICALLY—Part Four



There's a lot more to welding than just making the basic welds. Many times you will need to weld in overhead positions, or will have to make horizontal and vertical welds in addition to basic types such as butt welds or fillet welds.

By now you've become used to handling the electrode, and should be able to make basic joints well enough. But all of what you've done so far has been in the "down-hand" position. Let's branch out and try some horizontal, vertical, and overhead welding.

What to Do

1. Learn to make good horizontal, vertical, and overhead welds.

2. Learn to tell the different metals.

Tools and Materials You'll Need

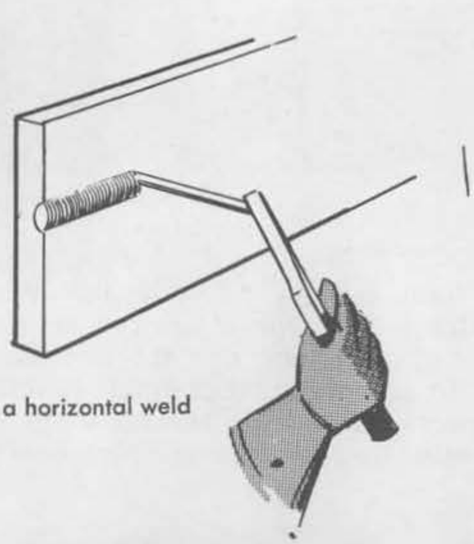
The use of a 180-amp AC arc welder and accessories
Several pieces of steel plate 1/4" thick, about 3" x 4" or larger.
A supply of E6011 or E6014 electrodes, 5/32" or 1/8".

Make A Horizontal Weld

1. Set up a piece of plate in an upright position in a clamp jig, or tack-weld it upright to a heavy piece to steady it.

2. Make ready to weld. Set the machine to 100 to 105 amperes for a 1/8" electrode, or about 130 amperes for a 5/32" electrode. Turn on the welding machine.

3. Lean the electrode about 15 to 20-degrees in the direction of travel, and point it upward about 5 degrees.



Making a horizontal weld

4. Strike the arc as in the downhand position and carry the bead forward with a straight motion. Keep the arc short—about 1/16". If the force of the arc causes undercutting at the top of the bead, drop the electrode holder a little, until you get a normal bead.

5. When the bead has cooled, chip and brush, then inspect it for penetration and evenness.

6. Run several horizontal beads until you get two good ones in succession. Experiment with different amperage settings until you get the best work.

7. Now run a horizontal bead with a weaving motion. Move the electrode in and out of the crater almost every second with a slight pause each time it is returned.

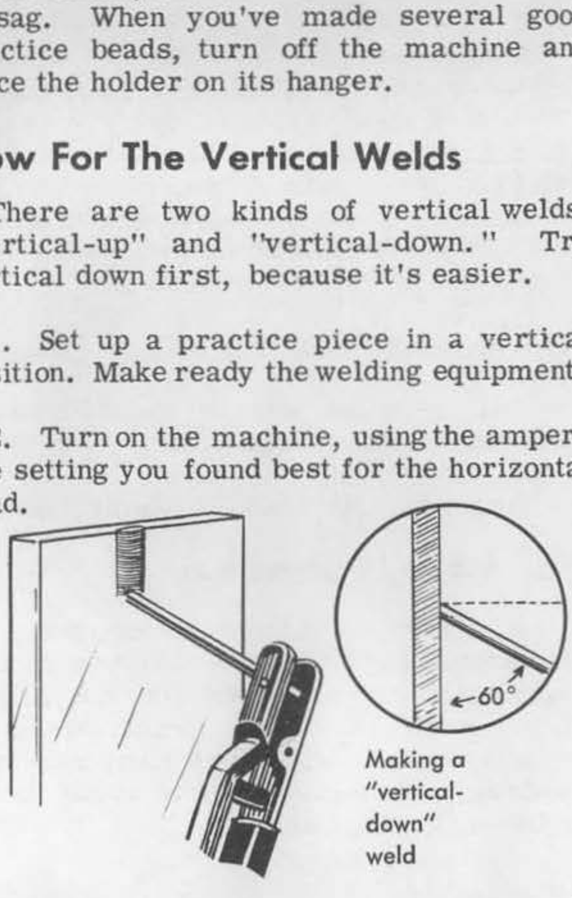
8. Chip and brush the bead. Is it smoother than the beads you made with a straight forward motion? Practice running horizontal beads with a weaving motion until you get the knack. The weaving motion keeps the crater small, and the bead has less tendency to sag. When you've made several good practice beads, turn off the machine and place the holder on its hanger.

Now For The Vertical Welds

There are two kinds of vertical welds: "vertical-up" and "vertical-down." Try vertical down first, because it's easier.

1. Set up a practice piece in a vertical position. Make ready the welding equipment.

2. Turn on the machine, using the amperage setting you found best for the horizontal bead.



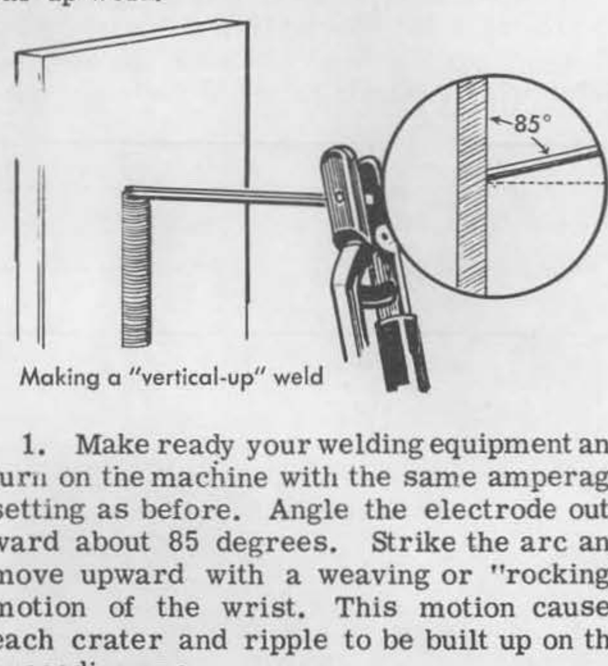
Making a "vertical-down" weld

3. Angle the electrode outward about 60 degrees from the vertical plate. Strike the arc, and draw the electrode downward to form the bead. Keep the arc length short to medium. Travel as slowly as you can—but fast enough to keep molten metal and slag from running into and shorting the arc.

4. When your bead has cooled, chip and brush so you can inspect it. Run several vertical-down beads until you make an even bead with good penetration.

5. Make a vertical-down bead with a slight weaving motion to carry more metal and make a heavier bead. Make as many beads as necessary until you can get a good heavier bead. When you are through practicing, turn off the machine.

Set up another practice piece in the vertical position, like the last one. Now for the vertical-up weld.



Making a "vertical-up" weld

1. Make ready your welding equipment and turn on the machine with the same amperage setting as before. Angle the electrode outward about 85 degrees. Strike the arc and move upward with a weaving or "rocking" motion of the wrist. This motion causes each crater and ripple to be built up on the preceding one.

2. Practice vertical-up beads with the "rocking" wrist motion until you get several good ones in a row.

3. When you've finished, turn off the welder and rest a while.

Nothing is gained by practicing too long and running too many beads unless each bead shows improvement over the one before it.

Overhead Welding

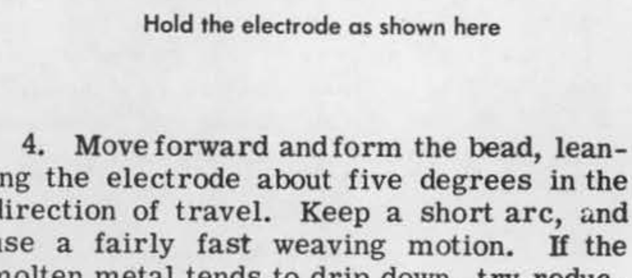
When possible, all jobs are welded in a normal flat position. Many jobs, though, such as broken frames on machinery can only be welded in the overhead position. This position is tricky, and you have to be careful of sparks and falling molten metal. Before welding overhead, make sure that trousers are extended over shoe tops, and that pockets are buttoned and sleeves rolled down. Use gauntlet type leather gloves and a leather apron. Protect your head with a welding cap.

Make An Overhead Weld

1. Fasten a piece of practice plate in an overhead position with a clamp and standard, or tack-weld it to an upright piece.

2. Set the machine for the amperage you've been using, and turn it on.

3. Hold the electrode in both hands, with the backs of the hands up so that spatter will roll off your gloves. Strike an arc and establish the puddle as in the flat position.



Hold the electrode as shown here

4. Move forward and form the bead, leaning the electrode about five degrees in the direction of travel. Keep a short arc, and use a fairly fast weaving motion. If the molten metal tends to drip down, try reducing the amperage slightly.

5. Run several practice beads in the overhead position until you make two good ones in succession. When you have finished practicing, turn off the machine and replace the equipment as you found it.

Learn To Tell Different Metals

Before building or repairing something, you have to know the kind of metal you're dealing with. Electrode makers put out guide books which recommend the type of electrode to use on different kinds of metal. When you know the metal, you'll know the right electrode to use.

Ferrous And Non-Ferrous Metals

Ferrous metal contains a predominant amount of iron. Non-ferrous, such as aluminum, copper, nickel, and their various alloys, contain little or no iron. Special electrodes are used for non-ferrous metals, and are usually supplied with special instructions for their use. Most of your welding will be done on ferrous metals.

How Can You Identify Metals?

One way is by their sight and feel. The white color and light weight of aluminum, and the yellow colors of the copper family can be identified by their sight and feel. Color and texture of the surface and of fractures are also helpful in telling ferrous metals apart.

Another way the various kinds of ferrous metals can be identified is by the spark test. They have an identifying spark when touched to a grinding wheel. (Non-ferrous metals yield no spark, with the exception of nickel.) Comparing the spark of an unknown metal to the like spark of a known metal will give you a clue for welding ferrous metals.

Demonstrations You Can Give

Tell the right way to make horizontal, vertical, and overhead welds.

Show and tell how you identify metals.

For More Information

Get a guide sheet from an electrode manufacturer, and study the different kinds of electrodes recommended for the different types of metals. There are dozens of good welding books. Get one and learn more about welding procedures, types of welds, and the different kinds of metals.

Common Types of Ferrous Metals	Spark Color and Pattern	Characteristics	Uses	Welding Technique
Cast Iron	 Red; Straw yellow	Rough surface. Brittle, not ductile. Gray iron appears gray when fractured. White or chilled iron appears silvery white when fractured.	Gray: soil pipe, plow shares, pump housings, engine blocks and heads. White: where resistance to wearing action of dirt and dust is required.	Braze, or if arc welding is to be used, part must be thoroughly preheated, and cooled slowly at room temperature
Malleable Iron	 Straw yellow	Rough surface with evidence of sand mold. Fracture dark gray with light outer layer.	Machinery parts subject to bending stresses.	Braze, or arc-weld using machinable cast-iron electrodes. Extra heat may be necessary.
Mild (machine) Steel and Cast Steel	 White	Mild: dark gray, smooth surface, with rolling marks. Cast: sand mold evidence, bright gray fracture.	Mild: bars, angles, rods, structural shapes. Cast: machinery parts subject to bending stresses.	As described elsewhere in "You Can Weld Electrically"
High Carbon (tool) Steel	 White	Dark gray surface. Light gray fracture.	Chisels, punches, harrow discs, files, drills.	Use D.C. welders, or A.C. industrial-type welders. Electrodes required do not give good results with 180-amp or smaller A.C. welders.
Wrought Iron	Long orange tracer-type sparks	Fracture has fibrous appearance.	Pipe, ornamental work.	Same as for mild steel.

What Did You Learn?

True or False

1. When possible, you should weld downhand, or in a flat position.

2. With horizontal welding, you lean the electrode ahead only five degrees.

3. You use a "rocking" wrist motion when making a vertical-down weld.

4. Your body needs maximum protection when you are welding overhead.

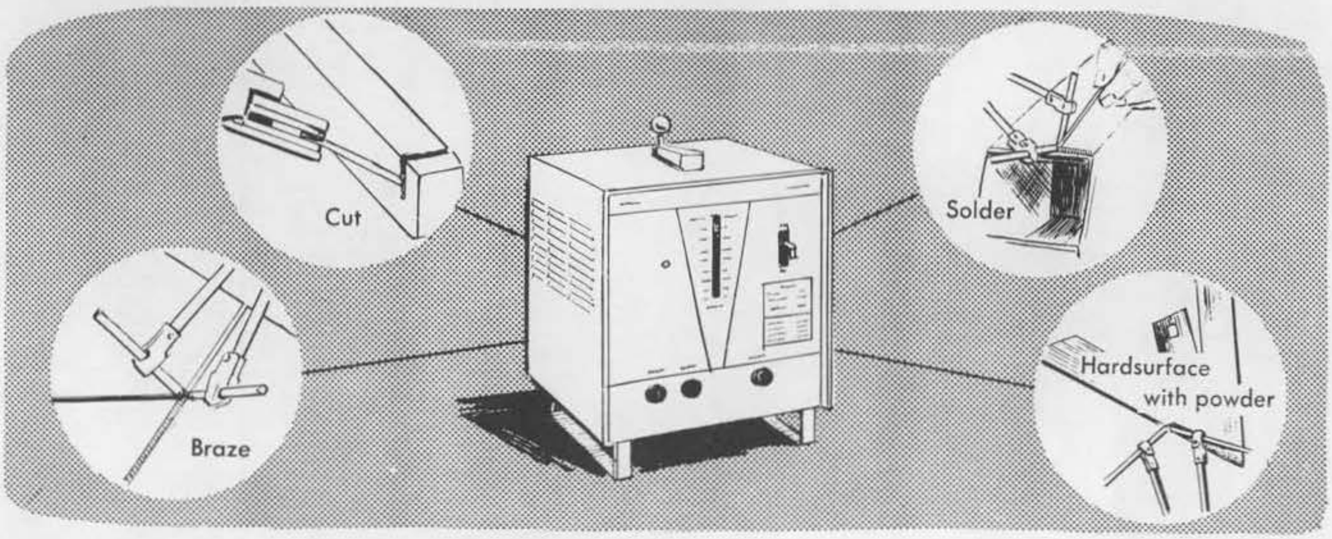
5. Weight is of no help in identifying metals.

6. Cast iron usually has a smooth surface.

7. Malleable iron can be brazed.

8. You can weld a broken punch successfully with a 180-amp welder.

YOU CAN WELD ELECTRICALLY—Part Five



Versatile is a word that means "competent in many things" and it applies to the AC arc welder that you have been learning to use.

With such a welder you can also cut and make holes in steel and cast iron, and you can solder and braze. You can also hardsurface sharp-edged tools with a powder.

What to Do

1. Learn to cut and pierce steel and cast iron, using a mild steel electrode.

2. Learn how to solder, using the carbon arc torch and a single carbon electrode.

3. Learn how to repair sheet metal by brazing with an electric welder.

4. Hardsurface a sharp-edged part using hardsurfacing powder.

Tools and Materials You'll Need

The use of a 180-amp AC arc welder and accessories
A 1/8" E6011 electrode
A carbon-arc torch, with 3/16" and 5/16" carbons
Plain wire solder and paste flux
A supply of 1/8" brazing rods and brazing flux
Hardsurfacing powder
Five-gallon pail or other large metal container, preferably with sand in the bottom
C-clamp or vise
Some pieces of flat 1/8" mild steel, and 2 pieces of galvanized sheet
Cold chisel, drift punch
A cultivator sweep or other sharp-edged part that will be subject to wear from the soil.

Cutting And Making Holes

Because there are many times when you will find it necessary to cut metal quickly and economically, you will want to know how to use an electric welder to do this.

This method is not as precise as some other ways, but in many cases this is not an important factor. With cast iron, it is better than most other ways.

Because the temperature of an arc is about 6500 degrees F., and steel melts at about 2400 degrees, you can see why you can use the arc to cut and make holes.

Use Mild Steel Electrode

The E6011 electrode is regarded as one of the best for cutting and piercing. Select the size, and the amperage at which you'll set the welder, from this table:

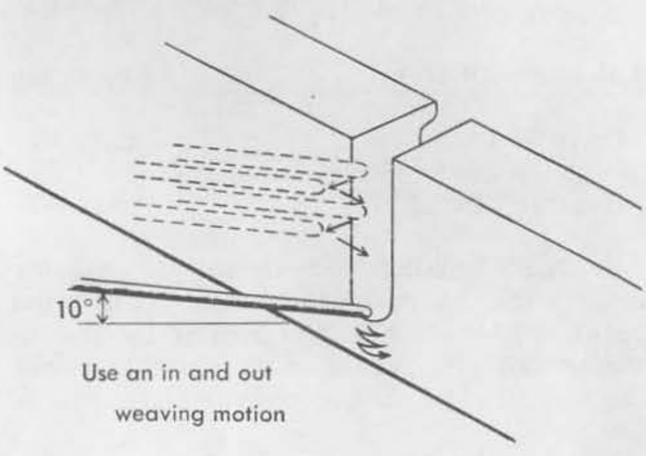
Electrode Size	Amperage Range	Metal Thickness
3/32"	75-100	up to 1/8"
1/8"	125-140	up to 1/4"
5/32"	140-180	over 1/4"

Cut A Piece Of Flat Stock

Prepare yourself, the work area, and the welder for action, being careful to observe all of the safety rules. Place the large metal container beneath the proposed cut to catch the molten metal.

Put a piece of 1/8" steel in a vise or clamp it to the edge of your welding table in either vertical or flat position. Start the cut by striking an arc near the edge of the plate. As soon as the base metal melts, move the electrode back and forth across the edge of the plate. Each time you do this a thin section of metal is removed.

Keep the electrode at the angle shown, so that the arc is directed toward the metal, not away from it. Use a slight weaving motion to keep the kerf (the cut) wider than the electrode to allow room to work.



The same general pattern is used when cutting round stock, but it usually is done from both sides toward the center, instead of from one side straight through.

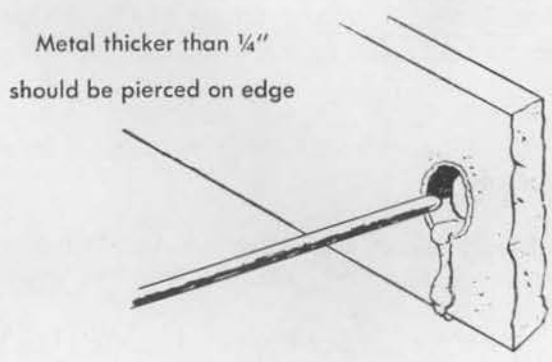
Cast iron may be cut, and rusty bolts and rivets may be removed, using this same general technique.

Making Holes

Using the same rod and amperage, you can make holes of various sizes in sheet metal and flat stock. It is to your advantage to make holes this way when the material is difficult to drill either because of its hardness or position, or when the hole required is larger than you can make with the equipment at hand.

Some people prefer to soak the electrode in water for this purpose. Do not soak for more than 10 minutes, because this may cause the coating to come off.

Using the same piece of scrap stock as before, strike and maintain a long arc at the location desired. Move the electrode in a circular motion and bring the arc right into the molten pool. When the base metal melts, follow through with the arc and use a circular motion to true up the hole. Use a punch of the proper size to further smooth the edges of the hole, while the metal is still hot.

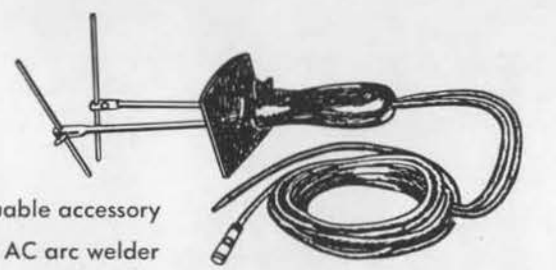


On metal thicker than 1/4" you can do the job easier if you place the metal on edge. This allows the molten metal to run out of the hole as you work the arc in. Metal which sticks to the surface can be knocked off with a chisel.

The Carbon Arch Torch

The carbon arc torch gives you the heat of an arc without the melting of the electrodes. It uses two carbon electrodes in a holder that permits a fixed relationship between them, yet which allows the size of the arc to be regulated. The torch also permits the carbons to be moved down as they slowly burn off, and allows various sizes to be used. Two cables from the welder are connected to the torch, with the circuit completed through the carbons and the arc rather than through a ground clamp and the work itself.

In addition to the uses you'll try here, a carbon arc torch may be used to heat metal for bending and shaping.



A valuable accessory for an AC arc welder

Because the rays and heat from the torch can be more damaging than from an ordinary electrode, you will want to be doubly sure that your eyes and skin are properly protected.

Solder With The Torch

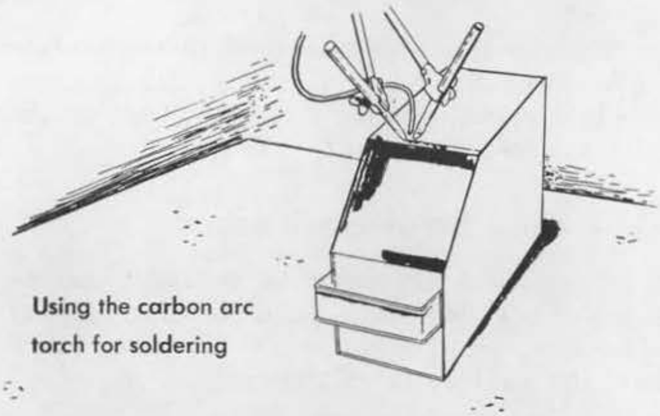
Because solder melts at a much lower temperature than steel, small (3/16") electrodes and low (20 to 30) amperage settings are used.

The rules for successful soldering must be followed:

1. Make sure that the work is clean—free from paint, dirt, oil, grease, or rust.

2. Use a flux, Commercial paste flux is good on new tin plate or galvanized metal. Black iron requires powdered sal ammoniac.

3. The metal to be soldered must be heated so that the solder will melt upon contact with it and will make a bond by flowing into the pores of the metal.



Using the carbon arc torch for soldering

Start the arc by bringing the tips together, and then widen the gap to about 1/16" or until a small, quiet flame results. Apply solder directly to the metal after fluxing and heating. If metal is heavy, the flame can be directed from the opposite side.

A single small carbon in an electrode holder also can be used to supply heat for soldering. In this method, the work is grounded as when welding, and the carbon is rubbed in a circular motion directly over the surface without making an arc. Use 20 to 30 amperes.

Using your scrap piece of galvanized sheet, apply some solder with this method.

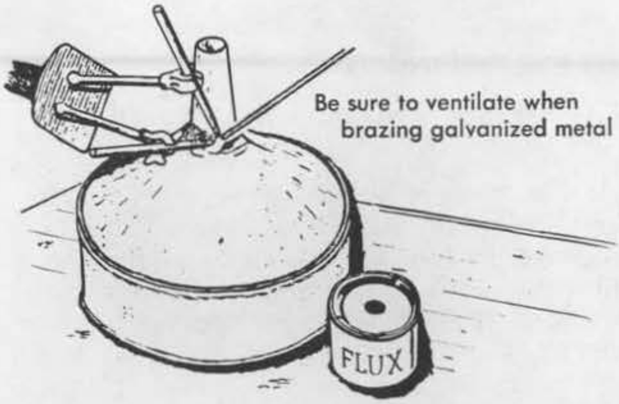
Repair By Brazing

The best method of repairing sheet metal, especially of the gauge used on farm equipment, is by brazing—that is by building up the surface with bronze. This metal is strong and ductile, and it bonds quickly with almost all ferrous metals.

The carbon arc torch makes a good source of heat for this work. Use 5/16" or 3/8" carbons, and amperage settings as follows:

Thickness Of Metal	Amperage
Up to 18 ga.	up to 40
16 ga.	60
Heavier gauges	75 to 80

A 1/8" brazing rod should be used for most work. A powdered brazing flux must be used also. Since it is applied by dipping the heated rod into it, a pencil-sized hole can be punched in the cover of the can of flux.



Braze two pieces of your galvanized sheet together at the edges. (Provide plenty of ventilation to protect yourself from the fumes that will result.) Start the arc and adjust the gap for a fairly small flame. Heat the end of the rod slightly so that the flux will stick to it.

Apply the flame to the base metal until the metal begins to "sweat." Then remove the flame to a few inches above the base metal and apply it to the end of the rod. When the rod shows signs of melting, lower both flame and rod to the metal at the end of the joint. The bronze will flow, bonding with the base metal. Hold the end of the rod close to the molten pool and apply the flame. Dip the rod again in flux when it sputters and pops.

Hardsurfacing With Powder

Another job which you can do with the carbon arc torch is hardsurfacing—in this case with the hardsurfacing material in the form of powder instead of rods.

The advantage of this method is that a hardened surface may be made while still keeping a sharp thin edge. The powder is spread on the face of the work as a powder or mixed with water as a paste. The arc causes it to bond with the base metal right out to the thin cutting edge.

To begin, grind off all dirt, paint, and rust from the leading edge of the cultivator sweep or other part you plan to hardsurface.

Mix only enough paste to cover the surface 1/16" thick and one inch back from leading edge. Smooth the paste after putting it on.

Use 3/16" carbons, with the current setting as follows:

Thickness Of Metal	Amperage
1/16"	50-60
1/8"	70-80
1/4"	90-120

Apply the flame near one end of the paste but not on it. As the paste starts to "ball up", move the arc back and forth over the paste. As bonding temperature is reached, the paste will smooth out. It is important to keep the flame away from the edge as much as possible. Heat each area only enough to make a smooth deposit.

What Did You Learn? True or False

1. Cutting cast iron with an arc is one of the best ways known.

2. The thicker the metal to cut or pierce, the higher the amperage you need.

3. To pierce thick metal, you lay it flat for best results.

4. No ground clamp is needed when using the carbon arc torch.

5. You should always roll down your sleeves when using the carbon arc torch.

6. Brazing is not a good method of repairing a cracked fender.

7. The chief advantage of hardsurfacing with powder is that it saves rod storage space.

Demonstrations You Can Give

After you have developed your skill, share your knowledge with others.

Demonstrate three ways in which a carbon arc torch can be used without actually operating it. Or, set up an exhibit of work done by these three techniques.

For More Information

Ask the librarian in your school or town for books on arc welding.

HOW TO USE THIS BOOK IN FULFILLING THE GOALS OF THE 4-H ELECTRIC PROJECT FOR THE FIRST AND SUCCEEDING YEARS

The minimum goals for credit in the 4-H Electric project vary according to the 4-H member's age and the number of years he or she has taken the electric project. For example, if you are a 4-H member beginning the 4-H Electric project at the age of 10, you will not be required to earn as many credit points as a 14-year-old 4-H member beginning the 4-H Electric project. However, if you are a 12-year-old in your second year of electricity you must earn as many credit points in that year as a 14-year-old does in his or her first year.

Each lesson or goal has been designated a certain number of credit points. These are shown near the title of each lesson or goal. You decide on the lessons you want to study, list them, and add up the credit points.

For a full year's 4-H project credit, the total of your credit points should be at least as many as shown in the following table:

Examples of reading the table below are as follows: (a) An 11-year-old member is required to complete 13 credit points the first year. (b) A 14-year-old is required to complete 17 credit points his first year. (c) A 14-year-old taking the electric project for the third year must complete 21 credit points that year.

There are enough lessons in this book to give you credit for two or more years in the 4-H Electric Project. Do at least all of the lessons that interest you. If you wish, and your leader approves, you may combine any of the lessons in this Division with those in other Divisions to earn credits for a year's work.

Minimum Number of Credit Points
Required for Each Year's Work in the 4-H Electric Project

4-H Member's Age	4-H Member's Year in 4-H Electric Project			
	1st Year	2nd Year	3rd Year	4th or Later Years
10 - 11	13	15		
12 - 13	15	17	19	20
14 - 15	17	19	21	21
16 & over	19	21	21	21

This system of credit points makes it possible for you to do the things you want to do with electricity and get credit for them in the 4-H Electric project.

Supplemental Information Available

Leaders Idea Book
Members Idea Book

See your County Extension Office concerning the availability of electrical kits, films and other information.

NR 8791—1M—8-65