Applying Fuel Gas Welding (FGW) Processes and Techniques

UNDER A SPECIFIC HEAT PROCESS, two pieces of material can be fused or joined together. This is the principal function of welding. Metal is commonly used in the welding process. However, other materials, such as plastics, can be welded. Materials are fused together once a melting point is achieved. The bond is completed as the materials cool. The bond will be as strong as the original material if the process is accomplished properly.

Objective:

Explain the fundamentals and techniques of fuel gas welding.

Key Terms:

acetylene
blowpipe
carburizing flame
flash arrestors
flashback
neutral flame
oxidizing flame
oxygen
regulator

Understanding Gas Welding

Several forms of gases will burn. Acetylene and propane are commonly used for heating, cutting, and welding metals. These gases are compressed and are stored in cylinders. The fundamentals and techniques available for fuel gas welding allow for using the gases safely. The process is built upon two fundamental principles. Acetylene burned with oxygen produces a flame so intensely hot that it can be used to melt and fuse metals. A stream of oxygen directed against a piece of iron or steel, which has been heated to its kindling temperature, causes the metal to burn away so it can be used to cut or shape the metal as desired.

FUEL GASES

Acetylene, C2, H2, is a fuel gas made of carbon and hydrogen that is produced from the chemical reaction between calcium carbide and water. Acetylene is colorless, but it has a dis-

tinct odor. The flame produced by acetylene can generate a theoretical temperature of 6300°F and a measurable temperature of 5800°F. It is stored in a free state under pressure greater than 15 psi.

Methylacetylene propadiene (MAPP) is a stabilized methylacetylene. It combines the high energy characteristics of acetylene with the handling and storage features of liquefied petroleum gases. MAPP gas is more stable than acetylene, making it safer. C3H4 has a flame temperature of 5300°F. The bushy flame makes welding difficult with MAPP gas.

Propane, C3H8, has a maximum flame temperature of 5300°F. The volume of oxygen required for that temperature produces an oxidizing flame unacceptable for iron and steel welding.

Oxygen

The oxygen used in the oxyacetylene process is manufactured from liquid air and is stored in hollow steel cylinders. **Oxygen** is a nonflammable, tasteless, colorless, and odorless gas that is slightly heavier than air. When combined with other elements, it will support combustion.

Commercial oxygen is supplied to users in seamless steel cylinders charged with oxygen to a pressure of about 2200 psi at 70°F. The pressure will increase and decrease as the temperature changes. The oxygen cylinder has a valve made of tobin bronze. Since bronze is soft, protection must be provided to prevent it from being broken or knocked off.

EQUIPMENT AND SUPPLIES

Several pieces of equipment are used for fuel gas welding. Cylinder tanks, regulators, hoses, and an appropriate torch provide a basic framework. The equipment should be provided in good condition and from a reliable dealer who guarantees service on all equipment and supplies.

BROADENING AWARENESS...

AMAZING ASPECTS: Be Safe

Because of the intense heat and other opportunities for accidents, safety is of extreme importance in fuel gas welding. This form of welding can cause metal to spark, drop, or fly. As a result, serious injuries can occur. The following are some suggested practices for proper protective clothing.

- Wear goggles or a face shield approved for fuel gas welding.
- Wear leather welding gloves when welding or cutting. Do not touch hot metal with gloves.
- Wear protective clothing, such as material that will resist flames and heat.
- Wear leather shoes that will resist burns and provide protection from heavy pieces of metal.

Oxygen and acetylene fittings are not interchangeable. Oxygen fittings have right-handed threads, while acetylene fittings have left-handed threads or a smaller size right-hand connection. A regulator is attached to each of the tank valves. A **regulator** is a device used to vary line pressure on a tank. Each regulator has a diaphragm adjusting screw to vary the line pressure and two gauges: one showing cylinder pressure and one showing line pressure.

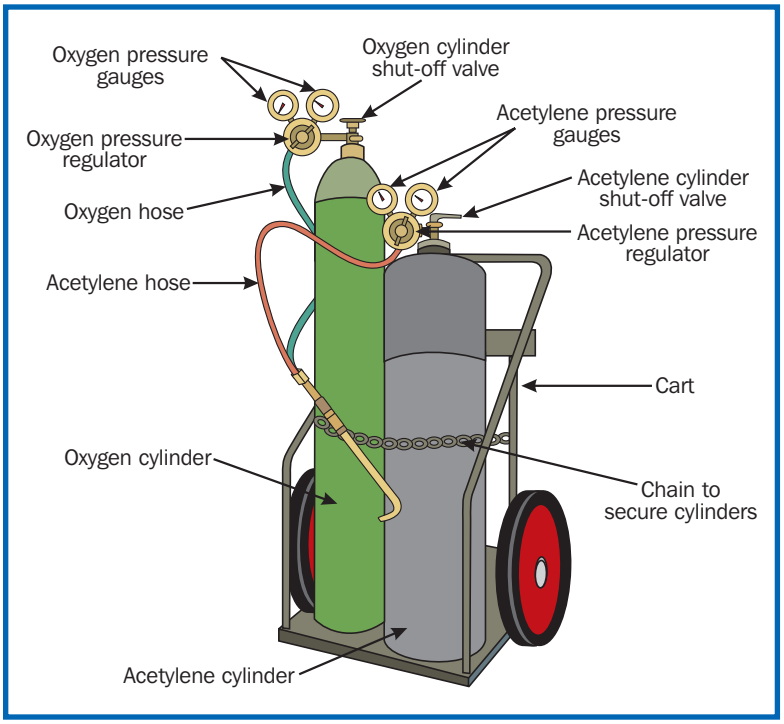


FIGURE 1. Major parts of an oxyacetylene welding and cutting outfit.

The hoses used are colored: one green and one red. The green hose is used for oxygen and has fittings with right-handed threads. The red hose is used for the fuel gas and has left-handed fittings. The hoses connect the blowpipe to the regulators. The **blowpipe** is a mixing chamber. The two gases are mixed and delivered to the tip ready to burn. The blowpipe has a valve to control the oxygen and a valve to control the acetylene.

A variety of tips are attached to the blowpipe for different tasks. A welding tip is used for welding pieces together, and a cutting attachment with a tip is used to cut metal. Special tips are available to perform other tasks, such as heating.

TABLE 1. Other Pieces of Fuel Gas Welding Equipment

Type of Equipment	Purpose
Welding goggles or face shields	They filter out ultraviolet and infrared rays to protect the operator's eyes. A No. 4 lens should be used.
Friction lighter	It is used to light the blowpipe.
Gauntlet gloves	They are worn when welding or cutting to protect skin.
Cart	Cylinders should be chained in an upright position when used and stored.
Safety caps	They should be positioned on top of the cylinders and should not be removed until the cylinders are secured.
Flash arrestors are devices that will extinguish any flame that attempts to go through them due to a flashback.	They should be mounted on the oxygen and acetylene lines at the regulators. A **flashback** is a fire inside the blowpipe. When a flashback occurs in an oxyacetylene unit, flame physically travels up the welding tip and through one or both of the hoses to the regulator.

SET-UP

Following proper procedures when setting-up the fuel gas welding equipment will insure that there are no gas leaks. Therefore, accidents can be minimized and, hopefully, avoided. General procedures are as follows:

1. Place the cylinders in a cart. Fasten them together with a chain, or fasten the cylinders in some other manner to prevent them from being tipped over during use or storage. If an acetylene cylinder is tipped on its side, it should be set upright for at least 30 minutes before it is used.
2. All oxygen and some acetylene cylinders have iron caps to protect the cylinder valves. Remove the caps. Stand to one side so you are not directly in line with the tank valves. "Crack" the cylinder valves slightly. Then close them quickly, which will blow out all dust and other foreign matter.
3. Connect the acetylene regulator to the acetylene cylinder and the oxygen regulator to the oxygen tank. It should not be possible to interchange the regulators. To avoid confusion, the regulator with the larger numbers belongs on the oxygen tank.
4. Connect one end of the green hose to the outlet connection on the oxygen regulator and the other end to the oxygen connection on the blowpipe. Be sure the flash arrestor is attached to the regulator and the hose is attached to the arrestor. If the unit does not have a built-in check valve, be sure one is put between the hose and the blowpipe.
5. Connect one end of the red hose to the outlet connection on the acetylene regulator and the other end to the acetylene connection on the blowpipe. Repeat the flash arrestor step in the same manner as conducted for the oxygen regulator.
6. Close both regulator valves by turning the regulator diaphragm screw counterclockwise until the screw is loose. Always close the regulator valves before opening the cylinder valves to prevent the tank pressure from damaging the regulator.
7. While standing to one side, not directly in front of the regulator, open the oxygen cylinder valve slowly. Wait until the cylinder pressure has registered on the high-pressure gauge before completely opening the valve. The oxygen tank valve is double seated, and it should be opened completely to prevent loss of the high-pressure oxygen around the tank valve.
8. Standing to one side, not directly in front of the regulator, open the acetylene valve slowly. This valve should never be opened more than one turn so it can be shut off quickly. Always leave the T-wrench on the valve while you are working in case the fuel gas needs to be shut off quickly.
9. Open the oxygen valve on the blowpipe about one-eighth of a turn. Turn the screw on the oxygen regulator clockwise until the desired pressure is reached on the oxygen low-pressure gauge. Close the oxygen valve on the blowpipe.

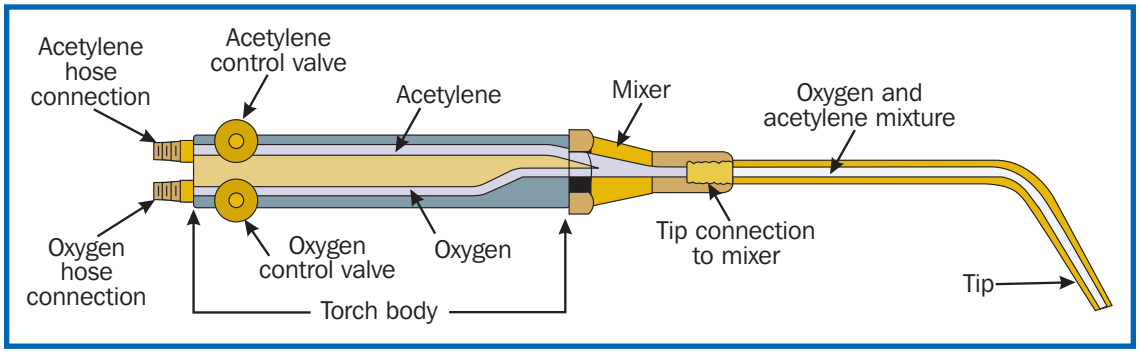


FIGURE 2. Blowpipe detail.

10. Open the acetylene valve on the blowpipe about one-eighth of a turn. Turn the screw on the acetylene regulator clockwise until the desired pressure is reached on the acetylene low-pressure gauge. Close the acetylene valve on the blowpipe.

Testing for Leaks

A good shop maintenance practice should include testing for leaks on fuel gas welding equipment. This practice should be conducted when the equipment is first set up, when cylinders are changed, and when an odor is present (when the equipment is not being used).

Test for leakage by applying soapy water around the valves and connections. If a bubble appears at a valve or a connection, a leak has been detected. It should be corrected before using the equipment. It is important to use grease-free soap.

OPERATING

Fuel gas welding requires precise settings on gauges and valves. These settings assist the operator in achieving proper lighting of the torch and a neutral flame. The correct lighting and shutting down procedures should be followed at all times.

TABLE 2. Lighting Procedure for Welding or Cutting Torch

Correct Lighting Procedure
1. Place goggles or safety glasses and face shield on your forehead.
2. Be sure regulator adjusting screws are turned out. The screw should turn freely.
3. Standing to one side, not directly in front of the regulator, open the oxygen cylinder valve slowly. Then open it all the way. Set the regulator at the correct working pressure. Open the oxygen blowpipe valve, and fine tune the operating pressure. Close the oxygen blowpipe valve.
4. Standing to one side, not directly in front of the regulator, open the acetylene cylinder valve slowly. Only open the tank valve ½ to ¾ of a turn. Set the regulator at the correct working pressure. Open the acetylene blowpipe valve, and fine tune the operating pressure. Close the acetylene blowpipe valve.

(Continued)

TABLE 2 (Continued)

5. Put on gloves, and lower the goggles or face shield over your eyes.
6. With the friction lighter in your left hand at the tip of the blowpipe and the blowpipe in your right hand, open the acetylene blowpipe valve, with your right thumb and forefinger, one-eighth to one-quarter turn. Strike the friction lighter, and adjust the acetylene level.
7. Adjust the acetylene by opening the blowpipe valve until the flame leaves the tip about ¼ inch. Close the valve very slowly until the flame is pulled back to the end of the tip. Open the valve slowly again, stopping just before the flame leaves the tip. This is the proper adjustment for most welding.
8. Open the oxygen blowpipe valve, and set the desired flame type.

Flames

There are three types of oxyacetylene welding flames: neutral, oxidizing, and carburizing. The neutral flame is usually used for welding. A **neutral flame** is a flame that will produce a smooth, shiny bead of the best quality. Meanwhile, the **oxidizing flame** is a flame caused by an excessive amount of oxygen, which produces a short white inner cone and a short envelope flame. An oxidizing flame will produce sparks that shower the weld area with droplets of metal and slag, leaving the weld zone weak and porous. In contrast, the **carburizing flame** is a flame caused by an excessive amount of acetylene and has a long, bluish outer flame. A carburizing flame will cause the puddle to foam and boil, leaving a brittle, porous, and scaly weld area. The carburizing flame is used for hard-surfacing.

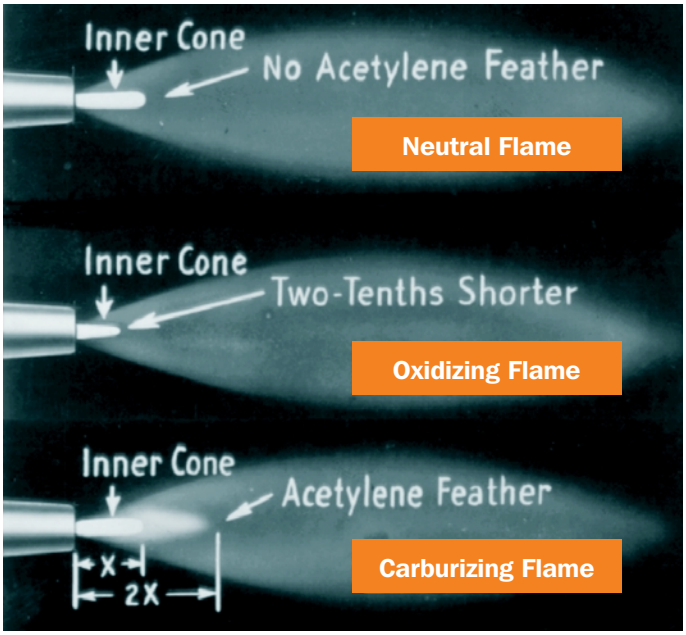


FIGURE 3. Flames.

TECHNIQUES

The techniques of fuel gas welding include setting the proper flame, preparing the pieces to be welded, knowing the common weld types, holding and using the blowpipe and rod, and completing the different weld types by using braze or fusion welding. Braze welding (formerly referred to as bronze welding) referred to the use of a bronze filler rod. In braze welding, as

TABLE 3. Shutting Off Procedure for Welding or Cutting Torch

Correct Shut-Down Procedure
1. Close the acetylene blowpipe valve.
2. Close the oxygen blowpipe valve.
3. Close the acetylene tank valve.
4. Close the oxygen tank valve.
5. Open the acetylene blowpipe valve to drain the hose and to release all pressure from the hose and regulator.
6. Turn out the pressure-adjusting screw on the acetylene pressure regulator by turning it counterclockwise.
7. Close the acetylene blowpipe valve.
8. Open the oxygen blowpipe valve to drain the hose and to release all pressure from the hose and regulator.
9. Turn out the pressure adjusting screw on the oxygen pressure regulator by turning it counterclockwise.
10. Close the oxygen blowpipe valve.
11. Wrap up the hoses, and put the welding accessories in their proper place.

the melting point of the filler rod is achieved, the metal surfaces are joined together. Fusion welding allows for the base metal to be melted and mixed together; it forms a joining. Fusion welding can be completed with or without a filler rod.

Preparing the Metal

Metal should be cleaned before any form of welding is conducted. The cleaning procedure allows for the removal of oxides or any other form of impurities. Using mechanical means (e.g., a wire brush, grinder, file, sander, or steel wool) allows for the removal of oxides, such as rust. A chemical could be used to remove any remaining impurities.

The edges of metals over $^1/_8$ inch should be cut to form a V, with approximately a 45-degree angle to permit complete fusion of the pieces. If the pieces are $^3/_8$ inch or more in thickness, it is usually desirable to cut a V on the top and bottom sides of the two pieces of metal being welded. The pieces to be welded should be

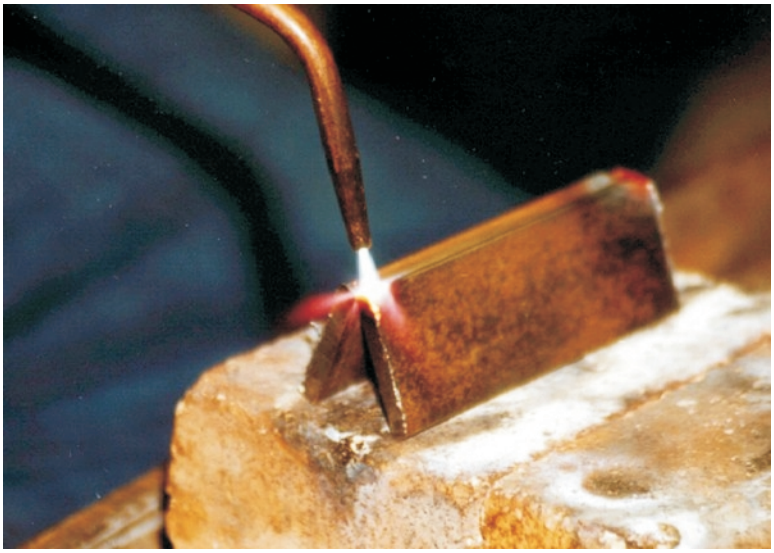


FIGURE 4. Forming a V in preparation of fuel gas welding.

placed about 1/16 inch apart to provide for the expansion and contraction of the metals and to permit the weld to penetrate deeply, through the bottom, if possible.

Types of Welds

The two most common weld types are the butt weld and the fillet weld. Types of welded joints frequently used are the butt joint, tee joint, corner joint, lap joint, and edge joint. The common welding positions are downhand, horizontal, vertical, and overhead. The downhand weld is used most frequently and is the easiest weld to make.

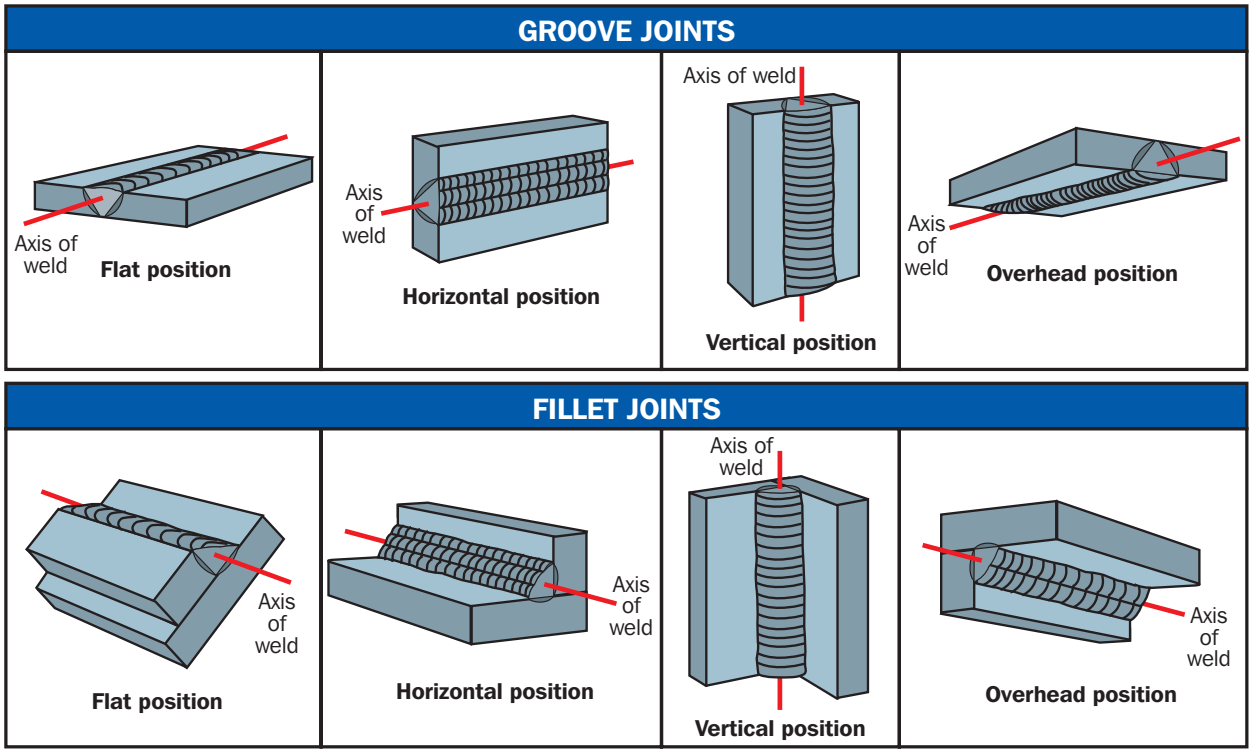


FIGURE 5. Welding joints and positions.

Position of Equipment

The blowpipe is usually held in the same say as a hammer or a fishing pole when the operator is welding while standing. It is held in the same manner as a pencil when the operator is welding while seated. The operator should hold the blowpipe in a comfortable way.

The recommended blowpipe position allows for the tip to be inclined at a 45-degree angle to the welded surface point directly along the line of the weld. Hold the tip so the inner cone of the flame is about 1/8 to 1/16 inch above the surface of the metal.

Before lighting the blowpipe, practice holding it and moving it in the motion used in welding. The blowpipe may be moved in a straight line, in a zigzag, or in a circular motion. The circular motion is most frequently used. Move the blowpipe in a series of connected ovals in a left-to-right direction and along the line of welding. Advance each successive oval about 1/16 inch. Make the oval about 1/4 inch wide and 5/16 inch long.

Learning How to Form a Molten Puddle

To weld with oxyacetylene, learn how to melt the base metal and how to control the molten puddle. Start the flame at the edge of the steel piece, and form a molten puddle about 1/4 inch in diameter and about 1/8 inch from the edge of the piece of steel. The width of the puddle is about twice the thickness of the metal.

After learning to control the molten puddle, learn how to make a bead. A welding rod is added to the process. The rod melts as it is added to the molten metal. As it progresses across the metal, it is called "making a bead."

If you are right-handed, hold the welding rod in your left hand at a 45-degree angle so the end of the rod will be within the outer envelope of the flame. Move the blowpipe in a circular motion, and dip the rod into the center of the puddle each time the flame reaches the back of the circle. Raise the rod out of the puddle slightly as the flame is passed toward the front to the puddle, thus synchronizing the motions of the flame and the rod.

Maintain a molten puddle about 1/4 inch in diameter, and move the rod and blowpipe slowly, straight ahead about 1/16 with each oval motion of the blowpipe. Raise the rod out of the flame's way to permit the flame to heat the metal ahead of the bead. Lower the rod so the flame will melt it, causing the welding rod to flow into the molten puddle. The end of the welding rod should touch the puddle on the downward stroke. The rod should not dip into the puddle.

Fusion Welding

A fusion weld is the next step after learning to make a bead. Two pieces of metal are welded together using a filler rod. Select two pieces to be welded, and space them so the edges of the metal are 1/16 inch apart at one end and approximately 1/8 inch apart at the other. Make a tack weld at each end of the pieces to hold them together. Follow the same procedure and motion used in making a bead.

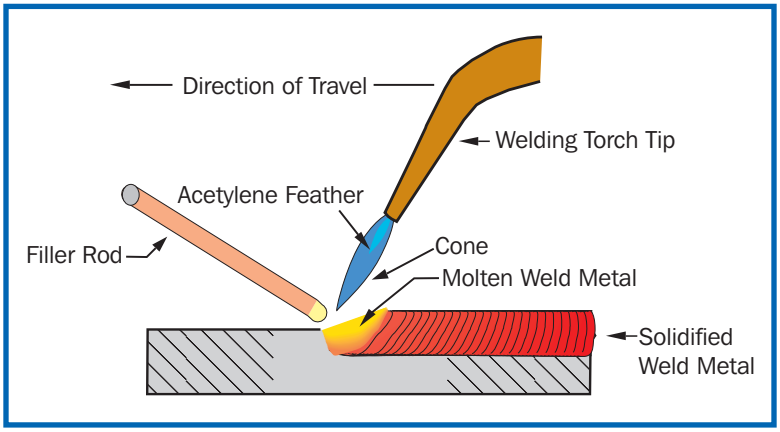


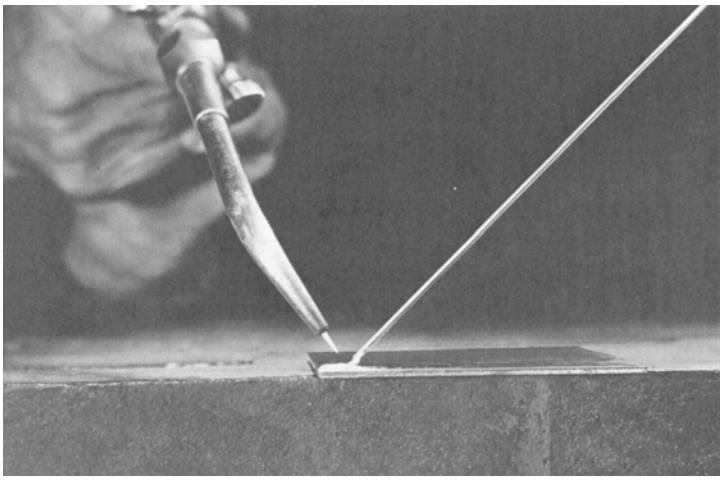
FIGURE 6. Fuel gas welding structure.

Braze Welding

Braze welding has some advantages over fusion welding. Brazing and soldering are conducted at low temperatures, can be completed faster, show little damage to parts, can join different metals, and allow for easy disassembly.

Heat the base metal to a salmon red color. The bronze rod should not remain in the inner cone of the flame. In addition, the inner cone of the flame should not stay in one spot of the

molten bronze because the intense heat will burn the bronze. The same technique and movement used with fusion welding should be followed.



The correct position of a blowpipe and rod when the rod is lowered.

FIGURE 7. Fuel gas welding position.

SAFETY PRACTICES

The following safety practices should be conducted at all times when working with fuel gas welding.

1. To prevent oxygen and fuel cylinders from being tipped over accidentally, fasten them securely in an upright position with a chain or a similar device before removing the safety cap.
2. Keep oil and grease away from oxygen cylinders and equipment.
3. Check equipment connections periodically for any leaks by using the soapy water method.
4. Check regulator gauge operation pressures carefully, and follow recommendations.
5. Clear the area of all combustible materials before lighting the torch.
6. Cover your eyes with welding goggles or a colored face shield, and put on gauntlet welding gloves before lighting the torch. Wear clothes suitable for the work being done.
7. Stand to one side, not directly in front of the regulator, when opening the cylinder valve.
8. Do not open the blowpipe valves more than ½ turn when lighting the torch.
9. Never use a match to light the torch.
10. Always use a spark igniter or a friction lighter to light a welding torch. When lighting a torch, keep the tip facing downward and away from you.
11. Light the acetylene first, and add oxygen to the flame. Make no attempt to relight a torch from hot metal.
12. Be sure that other workers are in the clear before relighting a torch.

13. Do not walk with a lighted torch or lay down a lighted torch. Before you light the torch, get into position for welding or cutting, and remove all obstacles between you and the shut-off controls.
14. Before opening a cylinder valve, be sure the regulator valve is closed by turning it counterclockwise until it is loose.
15. If a flashback should occur, turn off the torch immediately, close the cylinder valves, and notify your instructor. A flashback has occurred when the flame disappears and burns back inside of your equipment. There is a hissing, squealing sound. Smoke may come out the torch tip, and the handle may become hot. If the torch is not turned off promptly, fire may reach the hoses or the cylinder. Do not relight after a flashback until the equipment has been inspected closely. The equipment may require repairs.
16. Never open the acetylene cylinder valve more than ½ to ¾ of a turn. Leave the T-handle wrench in position at all times while welding. You should be able to turn off the acetylene cylinder valve promptly in case of a fire.
17. Never do any welding on containers that may have held flammable substances.
18. When welding or cutting zinc or galvanized metals, make a special effort to avoid breathing the fumes because they can make you feel ill.
19. Never use acetylene at a pressure greater than 15 psi. Follow the manufacturer's recommendations for the correct operating pressures for the metal being welded and for the tip size being used.
20. Do not smoke or allow anyone else to smoke near the oxy-fuel gas welder.
21. Keep the flame and heat away from the cylinder, hoses, and people. Be alert for fires at all times. Use the proper fire extinguisher or a fire blanket if necessary.
22. For most oxyacetylene welding, you will need a lens with shade No. 5.
23. Cylinders should not be stored near open fires, furnaces, or other heating devices or in direct rays of the sun.
24. Keep cylinders away from electric wiring and away from the danger of striking an arc on them with an electric welder.
25. Oxygen cylinders are equipped with a double seating valve. Open the valve all the way to prevent oxygen from escaping around the valve stem.
26. Wear welding gloves to protect the hands against burns, sparks, and molten metal.
27. Wear flame-resistant clothing.
28. Low shoes are not recommended because sparks or slag may get into them.
29. Make certain that reverse flow-check valves and flash arrestors are installed on the oxygen and acetylene lines.

30. Be sure the cylinder valves are closed and the pressure is relieved from the hoses before you leave the work area.
31. Remove regulators and replace protective caps before transporting cylinders.
32. Store oxygen cylinders away from fuel gas cylinders.
33. Never use oxygen as compressed air to dust clothing because clothing saturated with pure oxygen is highly combustible.
34. Handle hot metal with pliers or tongs. Do not leave hot metal on the welding table because unsuspecting people may touch it and may be burned.

Summary:

Oxyacetylene welding is a process by which two pieces of metal are joined. Acetylene and propane are commonly used fuel gases. Oxygen is used to support combustion. Cylinders, regulators, hoses, a blowpipe, and tips are common equipment used in the set-up of fuel gas welding.

Safety is extremely important during fuel gas welding. Materials used can damage eyes, skin, hands, and feet. Therefore, protective clothing and proper procedures must be followed and conducted during shop exercises.

Following proper procedures when setting up the fuel gas welding equipment should help avoid gas leaks and minimize accidents. A common way to test for leaks is to use soapy water around valves and connections. If a bubble appears, a leak has been detected.

Using proper techniques (e.g., achieving a desired neutral flame) will ensure quality welding. Other techniques include cleaning metal surfaces, preparing edges, identifying weld types, and positioning of equipment. The final steps in fuel gas welding are learning how to control the molten puddle and making a bead.

Checking Your Knowledge:

1. What are three advantages of acetylene?
2. What are the key safety factors when setting up cylinders?
3. What is a flashback, and what safety practices should be followed immediately?
4. What are the procedures for fuel gas welding equipment set-up?
5. What are the differences between neutral, oxidizing, and carburizing flames?

Expanding Your Knowledge:

Practice fuel gas welding (FGW) processes and techniques. First, view the following video: http://www.youtube.com/watch?v=YjwsKjqWiS8. Practice forming a bead on a piece of steel ($^1/_8$" × 2" × 2"). Then watch the following video: http://www.youtube.com/watch?v=mMADiAMfe00&feature=related. Prepare a blowpipe/torch, two steel pieces (16 gauge × $1^1/_2$" × 6), flux, and a $^1/_{16}$-inch welding rod. Butt weld the two pieces by using the filler rod.

Web Links:

Welding Technology Machines
http://www.welding-technology-machines.info/index.htm

Brazing/Welding Procedures and Techniques
http://www.brazing.com/techguide/procedureMain.asp

Braze Welding
http://www.tandtlanco.com/index_files/Page4045.htm