

Fuel Gas Welding (FGW) Processes and Techniques

FUEL GAS WELDING is an early form of welding that dates back to the early 1800s. It utilizes an oxyfuel torch to melt metal and create a weld. Typically, filler rod is added with additional metal to intermix the molten pools. Fuel gas welding is performed without the use of electricity, which makes it useful for work in the field.



Objective:



Identify fuel gases and equipment used to safely weld and braze during the fuel gas welding process.

Key Terms:



acetylene

blowpipe

carburizing flame

flash arrestors

flashback

neutral flame

oxidizing flame

oxygen

regulator

Understanding Fuel Gas Welding

Oxyacetylene welding is a process by which two pieces of metal are joined.

FUNDAMENTAL PRINCIPLES

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 GAS PROS AND CONS

Each of the fuel gases has advantages and disadvantages.

Acetylene

Acetylene (C_2H_2) 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 distinct odor. The acetylene flame produces a theoretical temperature of $6,300^\circ F$ and a measurable temperature of $5,800^\circ F$. Acetylene is able to be stored in a free state under pressure greater than 15 psi. However, it can be made to break down by heat or shock. Then it may explode. When used at pressures greater than 15 psi, it becomes unstable and can become self-explosive. As a result, the slightest shock will set it off. Acetylene, when dissolved in acetone, can be compressed into cylinders at pressures up to 250 psi.

The acetylene cylinder is filled with porous materials (e.g., balsa wood, charcoal, shredded asbestos, organic pith, and Portland cement). These materials are used to decrease the open spaces in the cylinder. Acetone—a colorless, flammable liquid—is added until about 40 percent of the porous material is filled. The filler material acts as a sponge and absorbs the acetone, which in turn absorbs the acetylene. The acetylene cylinder is equipped with safety plugs with a low-melting alloy center that melts at $212^\circ F$. Holes are too small to permit a flame to burn back into the cylinder should the escaping acetylene become ignited. One limitation to acetylene is the high cost of transporting the cylinders.

MAPP

MAPP gas is the trade name for a stable liquefied mixture of methylacetylene and propadiene. These are also called MPS gases. MAPP gas combines the high energy characteristics of acetylene with the handling and storage features of liquefied petroleum gases. The secondary flame of MAPP gas burns at a high temperature, almost twice as hot as acetylene. This excessively hot and bushy flame makes welding difficult with MAPP gas. Propane, C_3H_8 , has a maximum flame temperature of $5,300^\circ F$. The volume of oxygen required to develop the $5,300^\circ F$ produces an unacceptable oxidizing flame for welding iron and steel.



FURTHER EXPLORATION...

ONLINE CONNECTION: Fuel Gas

With so many choices in fuel gases, it is not possible to learn all there is to know in one short lesson. Use the Internet to research the different kinds of fuel gas used. Listed below is a Web site to help get you started:

<http://eastern.usu.edu/welding/files/uploads/11400FW.pdf>

The oxygen used in the oxyacetylene process is manufactured from liquid air and is stored in hollow steel cylinders. **Oxygen** is a tasteless, colorless, odorless gas that is slightly heavier than air and is nonflammable. When combined with other elements, oxygen will support combustion. Commercial oxygen is supplied to users in seamless steel cylinders charged with oxygen to a pressure of about 2,200 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. Protection is provided by a steel cap threaded to the top of the cylinder that covers the valve during transportation and storage. The oxygen cylinder valve has a double-seat. The second seat serves to prevent leakage around the valve stem and the valve when it is fully opened.

FUEL GAS WELDING EQUIPMENT

High-quality equipment should be purchased from a reliable dealer. Several pieces of equipment and procedures are necessary for safe fuel gas welding.

Several cylinder sizes are available for use in fuel gas welding. Large cylinders hold 244 cu. ft.; medium cylinders hold 122 cu. ft.; and small cylinders hold 80 cu. ft. of oxygen. Common acetylene cylinders have volumes of 125 to 250 cu. ft.

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. The **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 has two gauges: one showing cylinder pressure and one showing line pressure.

The hoses used are colored: one green and one red. The green hose is used for oxygen and has fittings with right-hand 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 one to control the acetylene. Various tips are attached to the blowpipe to perform different tasks. A welding tip is used for welding pieces together. In contrast, a cutting attachment with a tip is used to cut metal. Special tips are available to perform other tasks, such as heating.



FIGURE 1. These cylinders are secured in a safe upright position on an oxyacetylene welding cart.

Safety Tips

- ◆ Welding goggles or face shields filter out ultraviolet and infrared rays and protect your eyes.
- ◆ A No. 4 lens is satisfactory for light-duty oxyfuel gas welding.
- ◆ Use a friction lighter to light the blowpipe.
- ◆ Wear gauntlet gloves—made of leather, asbestos, or other material that does not burn readily—when welding or cutting. The gloves must be free from oil or grease because such materials are dangerous when in contact with oxyacetylene equipment.
- ◆ Chain the cylinders in an upright position when used and stored. Also, do not remove the safety caps until the cylinders are secured. Oxyfuel gas welders should be equipped with reverse flow check valves and flash arrestors. Check valves prevent the reverse flow of gases into the acetylene and oxygen hoses when the line pressure of one gas is greater than the other.
 - **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, the flame physically travels up the welding tip and through one or both of the hoses to the regulator.
- ◆ Because of the intense heat and other opportunities for accidents, safety is of extreme importance in fuel gas welding. The following are some suggested practices and tips to eliminate shop accidents when fuel gas welding:
 - 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.
 - Keep oil and grease away from oxygen cylinders and equipment. Oil and grease may catch fire or explode spontaneously in the presence of oxygen escaping from the cylinder or the equipment.
 - Check equipment connections periodically with a clean paint brush and grease-free, soapy water to be sure there are no leaks of oxygen or fuel gas. Test hoses by putting them in a pail of water and watching for bubbles. After making any new connections, test equipment immediately.
 - Check regulator gauge operation pressures carefully, and follow recommendations.
 - Clear the area of all combustible materials before lighting the torch. Doing this may avoid an explosion or serious fire.
- ◆ 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 you are going to do.
- ◆ Stand to one side, not directly in front of the regulator, when opening the cylinder valve. A defect in the cylinder valve may cause the gas to blow out, shattering the glass and blowing it into your face. The valve should be opened slowly. If the gas in the tank is per-

mitted to enter the regulator suddenly, it may cause damage to the equipment, particularly to the regulator diaphragm.

- ◆ Do not open the blowpipe valves more than $\frac{1}{2}$ turn when lighting the torch.
- ◆ Never use a match to light the torch. Using matches brings your fingers too close to the tip. The sudden ignition may cause burns.
- ◆ Always use a spark igniter or friction lighter to light a welding torch. When lighting a torch, keep the tip facing downward and away from you. Lighting the torch while it is facing upward or outward may result in burns.
- ◆ Make no attempt to relight a torch from hot metal. The gas does not always ignite instantly, and the accumulating gas may ignite violently. Light the acetylene first and add oxygen to the flame.
- ◆ Be sure that other workers are in the clear before relighting a torch.
- ◆ Do not walk with a lighted torch or lay down a lighted torch. Be certain the flame is out before laying down the torch. Never walk around with 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.
- ◆ Before opening a cylinder valve, be sure the regulator valve is closed by turning it counterclockwise until it is loose.
- ◆ 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 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 and perhaps repaired.
- ◆ Never open the acetylene cylinder valve more than $\frac{1}{2}$ to $\frac{3}{4}$ of a turn. Leave the handle wrench in position at all times while you are welding. You should be able to turn off the acetylene cylinder valve promptly in case of fire.
- ◆ Never do any welding on containers that may have held flammable substances. Leave this work to professionals.
- ◆ When welding or cutting zinc or galvanized metals, make a special effort to avoid breathing the fumes, which can make you feel ill.
- ◆ 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.
- ◆ Do not smoke or allow anyone else to smoke near the oxyfuel gas welder. If fuel gas were to leak from the unit, smoking could provide ignition and cause a fire or an explosion.
- ◆ 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.
- ◆ For most oxyacetylene welding, you will need a lens with shade No. 5.
- ◆ Cylinders should not be stored near open fires, furnaces, or other heating devices or in direct rays of the sun.

- ◆ Keep cylinders away from electric wiring and away from the danger of striking an arc on them with an electric welder.
- ◆ Oxygen cylinders are equipped with a double seating valve. Open the valve all the way to prevent oxygen from escaping around the valve stem.
- ◆ Wear welding gloves to protect your hands against burns, sparks, and molten metal.
- ◆ Wear flame-resistant clothing. Never gas weld while you are wearing polyester clothing. Oily or greasy clothing may burn quickly if oxygen is fed into them. Ragged clothing is likely to catch fire because sparks may lodge in cuffs and rolled sleeves, so turn trouser cuffs down and button sleeves at the wrist.
- ◆ Low shoes are not recommended because sparks or slag may get into them.
- ◆ Make certain that reverse flow-check valves and flash arrestors are installed on the oxygen and acetylene lines.
- ◆ Be sure the cylinder valves are closed and the pressure is relieved from the hoses before you leave the work area.
- ◆ Remove regulators and replace protective caps before transporting cylinders.
- ◆ Store oxygen cylinders away from fuel gas cylinders.
- ◆ Never use oxygen as compressed air to dust clothing because clothing saturated with pure oxygen is highly combustible.
- ◆ Handle hot metal with pliers or tongs. Do not leave hot metal on the welding table because unsuspecting people may touch it and be burned.

SET UP, SHUT DOWN, AND MAINTENANCE

By following the proper procedures when setting-up the fuel gas welding equipment you will insure that there are no gas leaks and accidents can be avoided. General procedures are as follows:

- ◆ Place the cylinders in a cart. Fasten them together with a chain or 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 being used.
- ◆ All oxygen and some acetylene cylinders have iron caps to protect the cylinder valves. Remove the caps and stand to one side so you are not directly in line with the tank valve. “Crack” the cylinder valves slightly. Then close them quickly to blow out all dust and other foreign matter.
- ◆ 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.
- ◆ 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. Check for a flash arrestor, and check the valve.

- ◆ 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.
- ◆ 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.

- ◆ Stand to one side, not directly in front of the regulator, and 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.



FIGURE 2. Acetylene tanks.

- ◆ Stand to one side, not directly in front of the regulator, and 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.
- ◆ 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.
- ◆ 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.
- ◆ Test for leakage by applying soapy water around the valves and connections. If a bubble appears at a valve or connection, a leak has been detected. It should be corrected before using the equipment. Be sure to use a grease-free soap.

Shut Down

After you have made your weld, follow the shut-down procedure:

- ◆ Close the acetylene blowpipe valve.
- ◆ Close the oxygen blowpipe valve.
- ◆ Close the acetylene tank valve.
- ◆ Close the oxygen tank valve.

- ◆ Open the acetylene blowpipe valve to drain the hose and release all pressure from the hose and regulator.
- ◆ Turn out the pressure-adjusting screw on the acetylene pressure regulator by turning it counterclockwise.
- ◆ Close the acetylene blowpipe valve.
- ◆ Open the oxygen blowpipe valve to drain the hose and release all pressure from the hose and regulator.
- ◆ Turn out the pressure-adjusting screw on the oxygen pressure regulator by turning it counterclockwise.
- ◆ Close the oxygen blowpipe valve.
- ◆ Wrap up the hoses, and put welding accessories in their proper place.

SAFELY USING YOUR EQUIPMENT

To use your equipment to weld or braze, all the previously stated rules and procedures need to be followed. Once you have everything ready, it is time to light the torch and work. First, follow the set up rules but do not shut anything down. Then put on your gloves, and lower your goggles or face shield to cover your eyes. With the friction lighter in the left hand at the tip of the blowpipe and the blowpipe in the right hand, open the acetylene blowpipe valve with the right thumb and forefinger one-eighth to one-quarter turn. Strike the friction lighter and adjust the acetylene level. Adjust the acetylene by opening the blowpipe valve until the flame leaves the tip about $\frac{1}{4}$ inch. Close the valve 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 and the black sooty smoke disappears. Next, open the oxygen blowpipe valve, and set your desired flame type. Once you have completed your weld, follow the shut-down procedures.

FUSION WELDING AND BRAZING

When not using the torch for cutting, use the oxyfuel torch for fusion welding and brazing. These are similar processes in how they are performed and in the equipment used. Both are used for joining different metal parts, filling gaps in metal, surfacing, and fixing broken parts. They also use the same techniques and equipment and both work well with thin metal. Yet there are some big differences in the processes.

Fusion welding is a process in which the base metal is melted and mixed together with a filler metal and requires very high temperatures. Brazing does not melt the base metal. It is a form of joining in which the temperature is only raised high enough to melt a filler metal that through a process called wetting spreads and adheres the filler metal to the pieces.

FUSION WELD PROCESS

The fusion weld process involves various steps. You need to know about all of them to be successful.

Welding Flames

Three types of oxyacetylene welding flames exist: neutral, oxidizing, and carburizing.

Neutral Flame

A **neutral flame** is a flame that will produce a smooth, shiny bead of the best quality and is usually used for welding.

Oxidizing Flame

An **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.

Carburizing Flame

A **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.

Steps

The first step in learning fusion welding with oxyacetylene is to learn how to melt the base metal and how to control the molten puddle. First, make sure your metal is clean. Then start the flame at the edge of the steel piece and form a molten puddle about $\frac{1}{4}$ inch in diameter and about $\frac{1}{8}$ inch from the edge of the piece of steel. After learning to control the molten puddle, learn how to make a bead by adding molten metal from a filler rod as you move the puddle across the metal.

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



FIGURE 3. FGW pipe.

slightly as the flame is passed toward the front to the puddle, thus synchronizing the motions of the flame and the rod. Continue this process as you work across the metal trying to maintain about a $\frac{1}{4}$ inch wide bead.

Once you can make a bead, you can try a fusion weld. First, select two pieces of metal to weld and space them so the edges of the metal are $\frac{1}{16}$ inch apart at one end and approximately $\frac{1}{8}$ inch apart at the other. Make a tack weld, or small temporary weld, at each end of the pieces to hold them together. Then follow the same procedure and motion used in making a bead. When fusion welding, it is good practice to make the point at which the two pieces of metal come together the center line of the bead and maintain equal weld puddle on each piece.

BRAZING AND BRAZE WELDING

Brazing is bonding metals with alloys that melt at or above 840°F. When you braze, capillary action occurs, drawing braze into a tightly fitted area. Braze welding occurs when bonding occurs with alloys that melt at or above 840°F, but capillary action does not occur. With braze welding, the alloy melts and bonds to the base metal and fills the voids between the parts.

When brazing and braze welding, a neutral flame is preferred. MAPP gas is preferred over acetylene. When brazing and braze welding, flux is required. Flux cleans the base metal, removes tarnish and corrosion, and promotes wetting and movement of the molten alloy.

When brazing, apply heat to the joint until it reaches a dull red. Add flux to the joint using the filler rod. Continue heating the joint while placing the filler rod in and out of the flame. Once both pieces of the assembly are dull red, touch the filler rod to the joint and feed the filler into the joint. Apply more heat to the piece of which the filler should be pulled. Once cooled, examine it for quality.

When braze welding, start by heating the tip of the filler rod and dipping it in the flux. Then heat the base metal to a salmon red color. The brazing rod should not remain in the inner cone of the flame nor should the inner cone of the flame stay in one spot of the molten braze. Remember when brazing and braze welding that the base metal should not be melted. The base metal should only be taken to a temperature at which the brazing rod and flux melt.

Summary:



Fuel gas welding and brazing can be a useful skill to acquire, but safety should be your biggest concern. Always follow the safety rules listed, and learn the proper safety rules and procedures your instructor wants you to follow. Learn the difference between a neutral flame, an oxidizing flame, and a carburizing flame.

Checking Your Knowledge:



1. What is acetylene?
2. What is MAPP gas?

3. Explain what a flash arrestor does.
4. Why do you stand away from the regulator when opening the cylinder valve?
5. What is the difference between brazing and braze welding?

Expanding Your Knowledge:



Visit a local welding shop, and ask someone to demonstrate FGW for you. Take notes of the procedures and safety practices followed. Watch closely as welds are performed, and note how the person achieves the welds. After your visit, write a short reflection about what you learned.

Web Links:



Gas Cylinder Safety

<https://www4.uwm.edu/usa/safety/chem/gascyl.cfm>

OHSA: Compressed Gas and Equipment

<https://www.osha.gov/SLTC/compressedgasequipment/>

Oxyfuel Welding

<http://www.weldguru.com/OFW.html>