

Fuel Gas Welding (FGW) Processes and Techniques

Unit: Structural Systems

Problem Area: Metal Fabrication

Lesson: Fuel Gas Welding (FGW) Processes and Techniques

■ **Student Learning Objectives.** Instruction in this lesson should result in students achieving the following objectives:

- 1** Compare and contrast the various types of fuel gases used for welding purposes.
- 2** Identify oxyacetylene welding equipment and safety practices.
- 3** Identify and demonstrate oxyacetylene welding equipment set-up, maintenance, and shut-down procedures.
- 4** Operate oxyacetylene welding equipment properly and safely.
- 5** Compare and contrast fusion welding and brazing.
- 6** Demonstrate proper fusion welding techniques and safety in completing assigned exercises.
- 7** Demonstrate proper brazing techniques and safety in completing assigned exercises.



■ **Resources.** The following resources may be useful in teaching this lesson:

E-unit(s) corresponding to this lesson plan. CAERT, Inc. <http://www.mycaert.com>.

Herren, Ray V. *Agricultural Mechanics: Fundamentals & Applications*, 7th ed. Cengage Learning, 2015.

Jeffus, Larry. *Metal Fabrication Technology for Agriculture*, 2nd ed. Cengage Learning, 2012.

■ **Equipment, Tools, Supplies, and Facilities**

- ✓ Overhead or PowerPoint projector
- ✓ Visual(s) from accompanying master(s)
- ✓ Copies of sample test, lab sheet(s), and/or other items designed for duplication
- ✓ Materials listed on duplicated items
- ✓ Computers with printers and Internet access
- ✓ Classroom resource and reference materials

■ **Key Terms.** The following terms are presented in this lesson (shown in bold italics):

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

■ **Interest Approach.** Use an interest approach that will prepare the students for the lesson. Teachers often develop approaches for their unique class and student situations. A possible approach is included here.

Have an arc welder and fuel gas welder exhibited side by side. Ask students to determine the difference between them. Lead a discussion regarding the differences (e.g., physical, heat generated, and processes).

CONTENT SUMMARY AND TEACHING STRATEGIES

Objective 1: Compare and contrast the various types of fuel gases used for welding purposes.

Anticipated Problem: What are the different types of fuel gasses used for welding?

- I. Oxyacetylene welding is a process by which two pieces of metal are joined.
 - A. The process is built upon two fundamental principles.
 1. Acetylene burned with oxygen produces a flame so intensely hot that it can be used to melt and fuse metals.
 2. 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.
 - B. Each of the fuel gases has advantages and disadvantages.
 1. **Acetylene** (C₂, H₂) is a fuel gas made of carbon and hydrogen that is produced from the chemical reaction between calcium carbide and water.
 - a. Acetylene is colorless, but it has a distinct odor.
 - b. The acetylene flame produces a theoretical temperature of 6,300°F and a measurable temperature of 5,800°F.
 - c. 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.
 - d. 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.
 - e. Acetylene, when dissolved in acetone, can be compressed into cylinders at pressures up to 250 psi.
 - f. The acetylene cylinder is filled with porous materials (e.g., balsa wood, charcoal, shredded asbestos, organic pith, and Portland cement).
 - (1) These materials are used to decrease the open spaces in the cylinder.
 - (2) 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.
 - (3) The acetylene cylinder is equipped with safety plugs with a low-melting alloy center that melts at 212°F. Holes are too small to permit a flame to burn back into the cylinder should the escaping acetylene become ignited.
 - g. One limitation to acetylene is the high cost of transporting the cylinders.

2. MAPP gas is the trade name for a stable liquefied mixture of methylacetylene and propadiene. These are also called MPS gases.
 - a. MAPP gas combines the high energy characteristics of acetylene with the handling and storage features of liquefied petroleum gases.
 - b. 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.
 - c. 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.
- C. The oxygen used in the oxyacetylene process is manufactured from liquid air and is stored in hollow steel cylinders.
 1. **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.
 2. Commercial oxygen is supplied to users in seamless steel cylinders charged with oxygen to a pressure of about 2,200 psi at $70^{\circ}F$. The pressure will increase and decrease as the temperature changes.
 3. 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.
 - a. Protection is provided by a steel cap threaded to the top of the cylinder that covers the valve during transportation and storage.
 - b. 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.

Teaching Strategy: Use VM–A. You may want to use a multimedia presentation. Use text material to strengthen student understanding of concepts.

Objective 2: Identify oxyacetylene welding equipment and safety practices.

Anticipated Problem: What equipment is used in fuel gas welding, and how is it safely used?

- II. High-quality equipment should be purchased from a reliable dealer. Several pieces of equipment and procedures are necessary for safe fuel gas welding.
 - A. Several cylinder sizes are available for use in fuel gas welding.
 1. Large cylinders hold 244 cu. ft.; medium cylinders hold 122 cu. ft.; and small cylinders hold 80 cu. ft. of oxygen.
 2. Common acetylene cylinders have volumes of 125 to 250 cu. ft.
 - B. 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.

- C. A regulator is attached to each of the tank valves.
 - 1. The **regulator** is a device used to vary line pressure on a tank.
 - 2. 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.
- D. The hoses used are colored: one green and one red.
 - 1. The green hose is used for oxygen and has fittings with right-hand threads.
 - 2. The red hose is used for the fuel gas and has left-handed fittings.
 - 3. The hoses connect the blowpipe to the regulators. The **blowpipe** is a mixing chamber.
 - a. The two gases are mixed and delivered to the tip ready to burn.
 - b. The blowpipe has a valve to control the oxygen and one to control the acetylene.
 - 4. 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.
- E. Safety practices
 - 1. Welding goggles or face shields filter out ultraviolet and infrared rays and protect the operator's eyes. A No. 4 lens is satisfactory for light-duty oxyfuel gas welding.
 - 2. A friction lighter should be utilized to light the blowpipe.
 - 3. Gauntlet gloves—made of leather, asbestos, or other material that does not burn readily—should be worn when welding or cutting. The gloves must be free from oil or grease because such materials are dangerous when in contact with oxyacetylene equipment.
 - 4. The cylinders should be chained in an upright position when used and stored. The safety caps should not be removed until the cylinders are secured.
 - a. Oxyfuel gas welders should be equipped with reverse flow check valves and flash arrestors.
 - b. 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.
 - 5. **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.
 - 6. A **flashback** is a fire inside the blowpipe. When a flashback occurs in an oxy-acetylene unit, the flame physically travels up the welding tip and through one or both of the hoses to the regulator.

7. 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 or at least minimize shop accidents when fuel gas welding.
 - a. To prevent oxygen and fuel cylinders from being tipped over accidentally, they must be fastened securely in an upright position with a chain or similar device before the safety cap is removed.
 - b. Oil and grease should be kept 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.
 - c. Equipment connections should be checked periodically with a clean paintbrush and grease-free, soapy water to be sure there are no leaks of oxygen or fuel gas. Hoses can be tested by putting them in a pail of water and watching for bubbles. After making any new connections, equipment should be tested immediately.
 - d. Regulator gauge operation pressures should be checked carefully and recommendations should be followed.
 - e. The area should be cleared of all combustible materials before lighting the torch to avoid an explosion or serious fire.
8. Eyes should be covered with welding goggles or a colored face shield, and gauntlet welding gloves should be put on before lighting the torch. It is important to wear clothes suitable for the work being done.
9. The weldor should 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, thereby shattering the glass and blowing it into the face of the user. The valve should be opened slowly. If the gas in the tank is permitted to enter the regulator suddenly, it may cause damage to the equipment and particularly to the regulator diaphragm.
10. The blowpipe valves should not be opened more than $\frac{1}{2}$ turn when lighting the torch.
11. A match should never be used to light the torch because using matches brings fingers too close to the tip. The sudden ignition may cause burns.
12. A spark igniter or friction lighter should be used to light a welding torch. When lighting a torch, the tip should be kept facing downward and away from any person. Lighting the torch while it is facing upward or outward may result in burns.
13. No attempt should be made to relight a torch from hot metal. The gas does not always ignite instantly, and the accumulating gas may ignite violently. It is critical to light the acetylene first and to add oxygen to the flame.
14. A person should make sure other workers are in the clear before relighting a torch.
15. A person should not walk with a lighted torch or lay down a lighted torch. The flame should be out before laying down a torch. Also, a person should never walk around with a lighted torch. Before a person decides to light the torch, he

- or she should be in the position for welding or cutting and should remove all obstacles between himself or herself and the shut-off controls.
16. Before opening a cylinder valve, the regulator valve should be closed by turning it counterclockwise until it is loose.
 17. If a flashback should occur, the torch must be turned off immediately. In addition, the cylinder valves must be closed, and the instructor must be notified. A flashback has occurred when the flame disappears and burns back inside the equipment. A hissing, squealing sound can be heard. 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. It is important not to relight after a flashback until the equipment has been inspected closely, and perhaps repaired.
 18. The acetylene cylinder valve should never be opened more than $\frac{1}{2}$ to $\frac{3}{4}$ of a turn. The handle wrench should be left in position at all times while welding. A weldor should be able to turn off the acetylene cylinder valve promptly in case of a fire.
 19. A weldor should never do welding on containers that may have held flammable substances. This work should be left to professionals.
 20. When welding or cutting zinc or galvanized metals, a special effort should be made to avoid breathing fumes that can result in illness.
 21. Acetylene should never be used at a pressure greater than 15 psi. The manufacturer's recommendations should be followed for the correct operating pressures for the metal being welded and for the tip size being used.
 22. Smoking is not allowed near the oxy-fuel gas welder. If fuel gas were to leak from the unit, smoking could provide ignition and cause a fire or an explosion.
 23. The flame and heat should be kept away from the cylinder, hoses, and people. It is necessary to be alert for fires at all times. A proper fire extinguisher or a fire blanket should be used, if necessary.
 24. For most oxyacetylene welding, a lens with shade No. 5 will be needed.
 25. Cylinders should not be stored near open fires, furnaces, or other heating devices, or in direct rays of the sun.
 26. Cylinders should be kept away from electric wiring and away from the danger of striking an arc on them with an electric welder.
 27. Oxygen cylinders are equipped with a double seating valve. The valve should be opened all the way to prevent oxygen from escaping around the valve stem.
 28. Welding gloves should be worn to protect hands against burns, sparks, and molten metal.
 29. Flame-resistant clothing should be worn. Gas welding should never be done while wearing polyester clothing. Oily or greasy clothing may burn quickly if oxygen is fed into them. Also, ragged clothing is likely to catch fire. Sparks may lodge in cuffs and rolled sleeves, so it is necessary to turn trouser cuffs down and button sleeves at the wrist. Low shoes are not recommended because sparks or slag may get into them.

30. It is critical to ensure that reverse flow-check valves and flash arrestors are installed on the oxygen and acetylene lines.
31. The cylinder valves must be closed, and the pressure must be relieved from the hoses before the weldor leaves the work area.
32. Before transporting cylinders, a weldor must remove regulators and replace protective caps.
33. Oxygen cylinders should be stored away from fuel gas cylinders.
34. Oxygen should not be used as compressed air to dust clothing. Clothing saturated with pure oxygen is highly combustible.
35. Hot metal should be handled with pliers or tongs. Hot metal should not be left on the welding table because unsuspecting people may touch it and be burned.

Teaching Strategy: Use VM-B and VM-C. An alternative approach is to transfer the information from the lesson to a multimedia presentation. Use text material to strengthen student understanding of concepts.

Objective 3: Identify and demonstrate oxyacetylene welding equipment set-up, maintenance, and shut-down procedures.

Anticipated Problem: How is fuel gas welding equipment set up, maintained, and shut down?

- III. Following proper procedures when setting up the fuel gas welding equipment will insure that there are no gas leaks, so accidents can be avoided. General procedures are as follows:
 - A. The weldor must place the cylinders in a cart and 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 being used.
 - B. All oxygen and some acetylene cylinders have iron caps to protect the cylinder valves. The caps should be removed and placed (standing) to one side so the weldor is not directly in line with the tank valve. It is necessary to “crack” the cylinder valves slightly and then close them quickly to blow out all dust and other foreign matter.
 - C. The acetylene regulator must be connected 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.
 - D. One end of the green hose should be connected to the outlet connection on the oxygen regulator and the other end to the oxygen connection on the blowpipe.
 1. The flash arrestor must be attached to the regulator, and the hose must be attached to the arrestor.

2. If the unit does not have a built-in check valve, one must be put between the hose and the blowpipe.
- E. One end of the red hose should be connected to the outlet connection on the acetylene regulator and the other end to the acetylene connection on the blowpipe.
 1. The flash arrestor must be attached to the regulator, and the hose must be attached to the arrestor.
 2. If the unit does not have a built-in check valve, one must be placed between the hose and the blowpipe.
- F. Both regulator valves must be closed by turning the regulator diaphragm screw counterclockwise until the screw is loose. The regulator valves must always be closed before opening the cylinder valves to prevent the tank pressure from damaging the regulator.
- G. The weldor should stand to one side, not directly in front of the regulator, and open the oxygen cylinder valve slowly. He or she must 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.
- H. The weldor must 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 that it can be shut off quickly. The weldor should always leave the T-wrench on the valve while he or she is working in case the fuel gas needs to be shut off quickly.
- I. The oxygen valve on the blowpipe must be opened about one-eighth of a turn. The screw on the oxygen regulator must be turned clockwise until the desired pressure is reached on the oxygen low-pressure gauge. The oxygen valve on the blowpipe must be closed.
- J. The acetylene valve on the blowpipe must be opened about one-eighth of a turn. The screw on the acetylene regulator must be turned clockwise until the desired pressure is reached on the acetylene low-pressure gauge. The acetylene valve on the blowpipe must be closed.
- K. It is essential to 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. Grease-free soap should be used.
- L. The correct shut-down procedure is as follows:
 1. The acetylene blowpipe valve must be closed.
 2. The oxygen blowpipe valve must be closed.
 3. The acetylene tank valve must be closed.
 4. The oxygen tank valve must be closed.
 5. The acetylene blowpipe valve must be opened to drain the hose and release all pressure from the hose and regulator.

6. The pressure-adjusting screw on the acetylene pressure regulator must be turned out by turning it counterclockwise.
7. The acetylene blowpipe valve must be closed.
8. The oxygen blowpipe valve must be opened to drain the hose and release all pressure from the hose and regulator.
9. The pressure-adjusting screw on the oxygen pressure regulator must be turned out by turning it counterclockwise.
10. The oxygen blowpipe valve must be closed.
11. Hoses should be wrapped up, and welding accessories should be put in their proper place.

Teaching Strategy: Use VM-B and VM-C to reinforce comprehension. Use text material to strengthen student understanding of concepts.

Objective 4: Operate oxyacetylene welding equipment properly and safely.

Anticipated Problem: How is fuel gas welding equipment operated properly and safely?

IV. The correct lighting and shut-down procedures should be followed at all times.

A. Lighting procedures

1. Goggles or safety glasses and a face shield should be placed on the forehead of the weldor.
2. Regulator adjusting screws should be turned out. The screw should turn freely.
3. The weldor should stand to one side, not directly in front of the regulator, and open the oxygen cylinder valve slowly and then open it all the way. The regulator should be set at the correct working pressure. The oxygen blowpipe valve should be opened and the operating pressure should be fine-tuned. Then the oxygen blowpipe valve should be closed.
4. The weldor should stand to one side, not directly in front of the regulator, to open the acetylene cylinder valve slowly. The tank valve should be opened $\frac{1}{2}$ to $\frac{3}{4}$ of a turn. The regulator should be set at the correct working pressure. It is essential to open the acetylene blowpipe valve and fine-tune the operating pressure. The acetylene blowpipe valve should be closed.
5. Gloves should be put on, and goggles or a face shield should be lowered over the eyes.
6. With the friction lighter in the left hand at the tip of the blowpipe and the blowpipe in the right hand, the weldor should open the acetylene blowpipe valve with the right thumb and forefinger one-eighth to one-quarter turn. It is necessary to strike the friction lighter and to adjust the acetylene level.
7. The acetylene can be adjusted by opening the blowpipe valve until the flame leaves the tip about $\frac{1}{4}$ inch. The valve should be closed very slowly until the flame is pulled back to the end of the tip. The valve should be opened slowly

again, stopping just before the flame leaves the tip. This is the proper adjustment for most welding.

8. The oxygen blowpipe valve must be opened, and the desired flame type must be set.
- B. The correct shut-down procedure
 1. The acetylene blowpipe valve must be closed.
 2. The oxygen blowpipe valve must be closed.
 3. The acetylene tank valve must be closed.
 4. The oxygen tank valve must be closed.
 5. The acetylene blowpipe valve must be opened to drain the hose and release all pressure from the hose and regulator.
 6. The pressure-adjusting screw on the acetylene pressure regulator must be turned out by turning it counterclockwise.
 7. The acetylene blowpipe valve must be closed.
 8. The oxygen blowpipe valve must be opened to drain the hose and release all pressure from the hose and regulator.
 9. The pressure-adjusting screw on the oxygen pressure regulator must be turned out by turning it counterclockwise.
 10. The oxygen blowpipe valve should be closed.
 11. Hoses should be wrapped up, and welding accessories should be put in their proper place.

Teaching Strategy: Use text material to strengthen student understanding of concepts. Have students work in small groups to find videos showing examples of lighting and shut-down procedures.

Objective 5: Compare and contrast fusion welding and brazing.

Anticipated Problem: What are the similarities and differences between oxyfuel fusion welding and brazing?

- V. Oxyfuel fusion welding and brazing are similar in how they are performed and in the equipment used.
 - A. Both are used for joining different metal parts, filling gaps in metal, surfacing, and fixing broken parts. Both oxyfuel processes use the same techniques and equipment. Both are suited for thin metal work.
 - B. Differences between the processes
 1. Welding is a process in which the base metal is melted and mixed together with a filler metal. This process requires high temperatures.
 2. 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 the wet-

ting process spreads and adheres to the pieces. This process requires lower temperatures than welding.

3. Oxyfuel welding is best suited for a cooler secondary flame, which acetylene provides. Brazing requires a hotter secondary flame than acetylene produces. Therefore, MAPP gases are more preferred when brazing.
4. Brazing can be done faster, and less expansion and contraction of the base metal occurs.

Teaching Strategy: Use VM–D through VM–G. Have students discuss the similarities and differences between the processes. Use text material to strengthen student understanding of concepts.

Objective 6: Demonstrate proper fusion welding techniques and safety in completing assigned exercises.

Anticipated Problem: How are fusion welding techniques accomplished safely and properly?

- VI. Fusion welding occurs when the base metals are melted and mixed together with a filler metal. The techniques involved in fuel gas fusion welding are setting the proper flame, preparing the pieces to be welded, knowing the common types of welds, holding and using the blowpipe and rod, and completing the different weld types.
 - A. Three types of oxyacetylene welding flames
 1. 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.
 2. 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.
 3. The **carburizing flame** is a flame caused by an excessive amount of acetylene with a long, bluish outer flame.
 - a. A carburizing flame will cause the puddle to foam and boil, leaving a brittle, porous, and scaly weld area.
 - b. The carburizing flame is used for hard-surfacing.
 - B. When possible, it is desirable to prepare by cutting, grinding, filing, or buffing a clean, bright surface for welding because such surfaces weld more easily than dirty or oxidized surfaces.
 1. All rust and scale should be carefully removed before welding because such impurities have a tendency to weaken a weld.
 2. The edges of metals over $\frac{1}{8}$ inch should be cut to form a V, with approximately a 45-degree angle to permit the complete fusion of the two pieces of metal.
 - a. If the pieces are $\frac{3}{8}$ 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.

- b. The pieces to be welded should be placed about $\frac{1}{16}$ 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.
- C. The two most common types of welds are the butt weld and the fillet weld.
 - 1. Types of welded joints frequently used are the butt joint, tee joint, corner joint, lap joint, and edge joint.
 - 2. The common welding positions are downhand, horizontal, vertical, and overhead. The downhand weld is used most frequently and is the easiest weld to make.
- D. The blowpipe is usually held like a hammer or fishing pole when the operator is welding while standing and like a pencil when the operator is welding while seated. It is desirable for the operator to hold the blowpipe in a comfortable way.
 - 1. The recommended blowpipe position should be as follows:
 - a. The blowpipe should be held so the tip will be inclined at a 45-degree angle to the surface to be welded and will point directly along the line of the weld.
 - b. The tip should be held so the inner cone of the flame is about $\frac{1}{8}$ to $\frac{1}{16}$ inch above the surface of the metal.
 - 2. Before the weldor lights the blowpipe, he or she should practice holding it and moving it in the motion used in welding.
 - 3. The blowpipe may be moved in a straight line, in a zigzag, or in a circular motion.
 - a. The circular motion is most frequently used.
 - b. The blowpipe should be moved in a series of connected ovals in a left-to-right direction and along the line of welding.
 - c. Each successive oval should be advanced about $\frac{1}{16}$ inch. The oval should be made about $\frac{1}{4}$ inch wide and $\frac{5}{16}$ inch long.
- E. Puddle strips, beading, fusion welding, and braze welding are the four basic types of welding.
 - 1. 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.
 - a. The flame must be started at the edge of the steel piece and a molten puddle must be formed about $\frac{1}{4}$ inch in diameter and about $\frac{1}{8}$ inch from the edge of the piece of steel.
 - b. Right-handed people start at the right-edge of the steel piece. Left-handed people should start at the left-hand edge of the metal.
 - c. The width of the puddle is about twice the thickness of the metal.
 - 2. After learning to control the molten puddle, it is necessary to learn how to make a bead. Adding molten metal from a welding rod to the puddle as it progresses across the metal is called making a bead.
 - a. A right-handed person must hold the welding rod in his or her left hand at a 45-degree angle so the end of the rod will be within the outer envelope of the flame. The blowpipe should be moved in a circular motion, and the rod

must be dipped into the center of the puddle each time the flame reaches the back of the circle. The rod should be raised 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.

- b. A molten puddle should be maintained about $\frac{1}{4}$ inch in diameter. The rod and blowpipe should be moved slowly, straight ahead about $\frac{1}{16}$ with each oval motion of the blowpipe.
 - c. The rod should be raised out of the way of the flame to permit the flame to heat the metal ahead of the bead.
 - d. The rod should be lowered 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.
 - e. It is essential to ensure that the secondary flame covers the molten weld pool because this flame shields the weld from atmospheric contamination.
 - f. Torch angle is an important factor and should be kept around 45° .
3. A fusion weld is the next step after learning to make a bead. Two pieces of metal are welded together using a filler rod. Acetylene is preferred when making fusion welds because of the lower temperature of the secondary flame.
- a. It is necessary to select two pieces to be welded and to 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.
 - b. A tack weld should be made, or a small temporary weld, at each end of the pieces to hold them together.
 - c. The same procedure and motion used in making a bead should be followed. When fusion welding, it is a good practice to make the point at which the two pieces of metal come together the center line of the bead and to maintain an equal weld puddle on each piece.

Teaching Strategy: Use VM–D through VM–G. Assign LS–A. Use text material to strengthen student understanding of concepts.

Objective 7: Demonstrate proper brazing techniques and safety in completing assigned exercises.

Anticipated Problem: How is brazing accomplished safely and properly?

- VII. Brazing is bonding metals with alloys that melt at or above 840°F . When brazing, capillary action occurs and draws 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. Follow all safety practices previously mentioned before brazing.

A. Flames

1. The neutral flame is usually used for brazing and welding. A neutral flame will produce a smooth, shiny bead of the best quality.
2. The oxidizing flame is 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 area with droplets of metal and slag, leaving the weld zone weak and porous.
3. The carburizing flame is caused by an excessive amount of acetylene and has a long, bluish outer flame.
 - a. A carburizing flame will cause the puddle to foam and boil, leaving a brittle, porous, and scaly weld area.
 - b. The carburizing flame is used for hard-surfacing.
4. When brazing, it is recommended that a MAPP gas be used in place of acetylene because of the higher secondary flame temperature. The higher temperature provides a larger heat zone on the base metal, making it easier to braze.

B. When possible, it is desirable to prepare by cutting, grinding, filing, or buffing a clean, bright surface for welding and brazing because such surfaces weld and braze more easily than dirty or oxidized surfaces. This is a particularly important step when brazing due to the use of flux and the bonding properties of the alloys used to braze. If the base material is not properly cleaned and prepared, a weak bond will be created.

1. All rust and scale should be carefully removed before welding because such impurities have a tendency to weaken a weld and braze.
2. When braze welding, it is not critical for the base materials to perfectly fit together. A slight gap between parts is beneficial to allow the alloy to completely bond to the edges, thus creating a stronger joint.
3. When brazing, a tight fit of the parts is critical because of the capillary action that will pull the filler into the void, and only a thin layer of filler is needed.

C. The two most common types of welds are the butt weld and the fillet weld.

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

D. The blowpipe is usually held like a hammer or fishing pole when the operator is welding while standing and like a pencil when the operator is welding while seated. It is desirable for the operator to hold the blowpipe in a comfortable way.

1. The recommended blowpipe position
 - a. The operator should hold the blowpipe so the tip will be inclined at a 45-degree angle to the surface to be brazed and point directly along the line of the weld.
 - b. The tip should be held so the inner cone of the flame is about $\frac{1}{8}$ to $\frac{1}{16}$ inch above the surface of the metal.

2. Before lighting the blowpipe, the operator should practice holding it and moving it in the motion used in welding.
 3. The blowpipe may be moved in a straight line, in a zigzag, or in a circular motion.
 - a. The circular motion is most frequently used.
 - b. The blowpipe should be moved in a series of connected ovals in a left-to-right direction and along the line of welding.
 - c. Each successive oval should be advanced about $\frac{1}{16}$ inch. The oval should be made about $\frac{1}{4}$ inch wide and $\frac{5}{16}$ inch long.
- E. When braze welding, it is necessary to start by heating the tip of the filler rod and dipping it in the flux. The base metal should be heated to a salmon red color. The brazing 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 braze. It is important to remember when brazing and braze welding that the base metal should not be melted. It should only be taken to a temperature of which the brazing rod and flux melt. The melted liquid will spread and adhere to the solid base metal. This phenomenon is called wetting.
1. Choosing the proper filler rod and flux for the application is essential. It is best to read manufacturer specifications for particular rods and fluxes. If specifications are not available, the operator may contact an industry professional.
 2. The use of flux is critical when brazing and braze welding. The flux cleans the base metal, removes tarnish and corrosion, and promotes wetting and movement of the molten alloy.
- F. It is important to continue heating the base metal and dipping the filler rod in the flux and to follow the basic procedures of making a bead when braze welding.
- G. If brazing, heat should be applied to the joint until it reaches a dull red. Flux should be added to the joint using the filler rod. It is necessary to continue heating the joint while placing the filler rod in and out of the flame. Once both pieces of the assembly are dull red, the filler rod should be touched to the joint and the filler should be fed into the joint. More heat should be applied to the piece of which the filler should be pulled. Once cooled, it should be examined for quality.

Teaching Strategy: Use VM–D through VM–G. Assign LS–A.

Review/Summary. Use the student learning objectives to summarize the lesson. Have students explain the content associated with each objective. Student responses can be used in determining which objectives need to be reviewed or taught from a different angle.

Application. Use the included visual master(s) and lab sheet(s) to apply the information presented in the lesson.

- **Evaluation.** Evaluation should focus on student achievement of the objectives for the lesson. Various techniques can be used, such as student performance, on the application activities. A sample written test is provided.

■ **Answers to Sample Test:**

Part One: Matching

1. c
2. f
3. a
4. e
5. b
6. d

Part Two: Completion

1. downhand, horizontal, vertical, overhead
2. Oxygen
3. neutral, oxidizing, carburizing
4. Acetylene
5. butt, fillet (T)
6. carburizing flame

Part Three: Short Answer

1. Fusion—The base metal is melted, and there is mixing of the base metal with the rod. Braze—The base metal is not melted. There is no mixing of the base metal with the rod; it can be done faster; and there is less expansion and contraction.
2. Standing—It is held like a hammer or a fishing pole. Sitting—It is held like a pencil.
3. Flux cleans the metal, removes and prevents tarnish and corrosion, promotes the wetting process, and aids in capillary action.

Fuel Gas Welding (FGW) Processes and Techniques

► Part One: Matching

Instructions: Match the term with the correct definition.

- | | |
|----------------|--------------|
| a. acetylene | d. flashback |
| b. blowpipe | e. oxygen |
| c. carburizing | f. regulator |

- _____ 1. A flame caused by an excessive amount of acetylene with a long, bluish outer flame
- _____ 2. A device used to vary line pressure on a tank
- _____ 3. A fuel gas made of carbon and hydrogen that is produced from the chemical reaction between calcium carbide and water
- _____ 4. A tasteless, colorless, odorless gas that is slightly heavier than air and is nonflammable
- _____ 5. A mixing chamber
- _____ 6. A fire inside the blowpipe

► Part Two: Completion

Instructions: Provide the word or words to complete the following statements.

- 1. The common welding positions are _____, _____, _____, and _____.
- 2. _____ is a tasteless, colorless, odorless gas that is slightly heavier than air and is nonflammable.



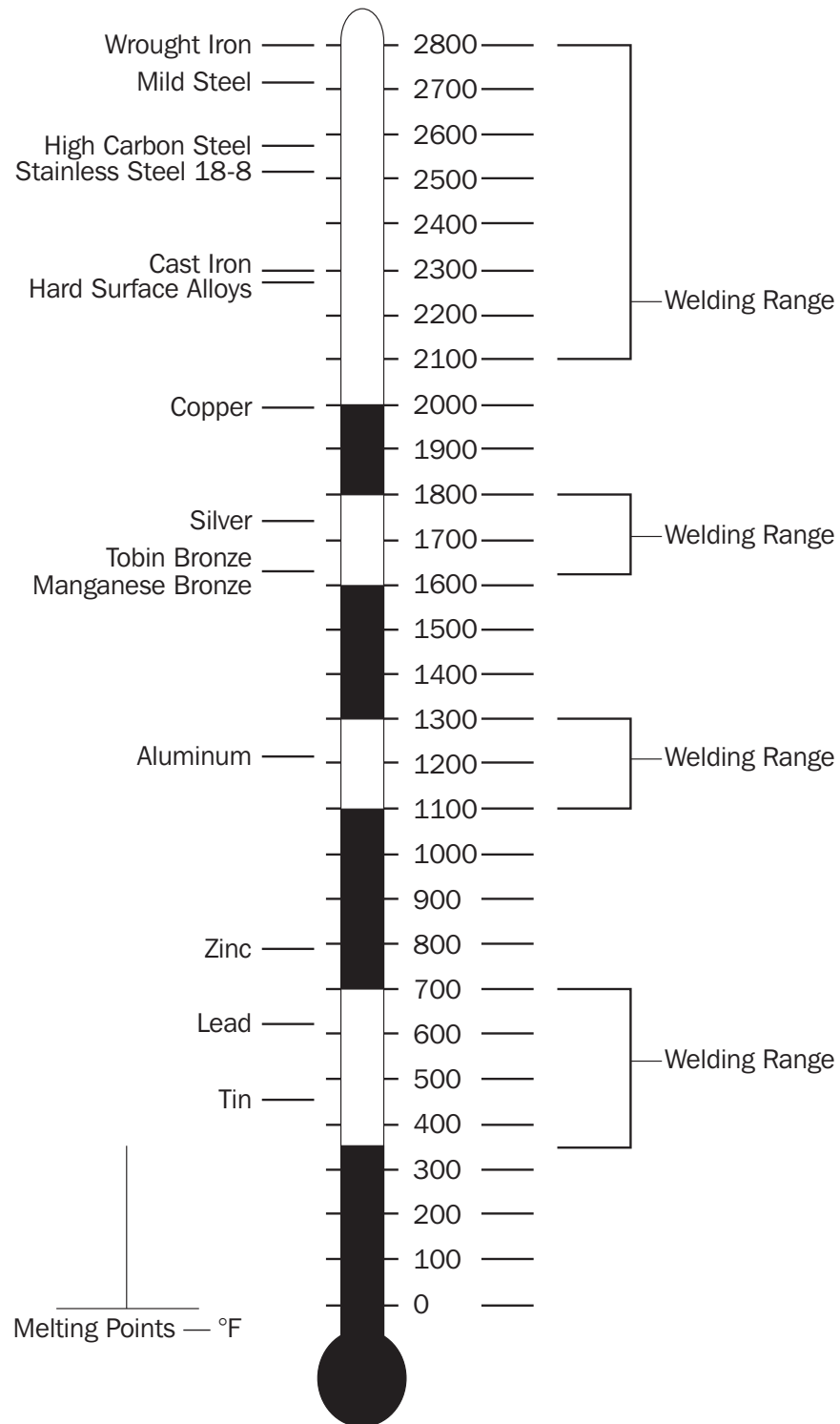
3. The three types of oxyacetylene welding flames are _____, _____, and _____.
4. _____ is a fuel gas made of carbon and hydrogen and is produced from the chemical reaction between calcium carbide and water.
5. The two most common types of welds are _____ and _____.
6. The _____ is caused by an excessive amount of acetylene and has a long, bluish outer flame.

► **Part Three: Short Answer**

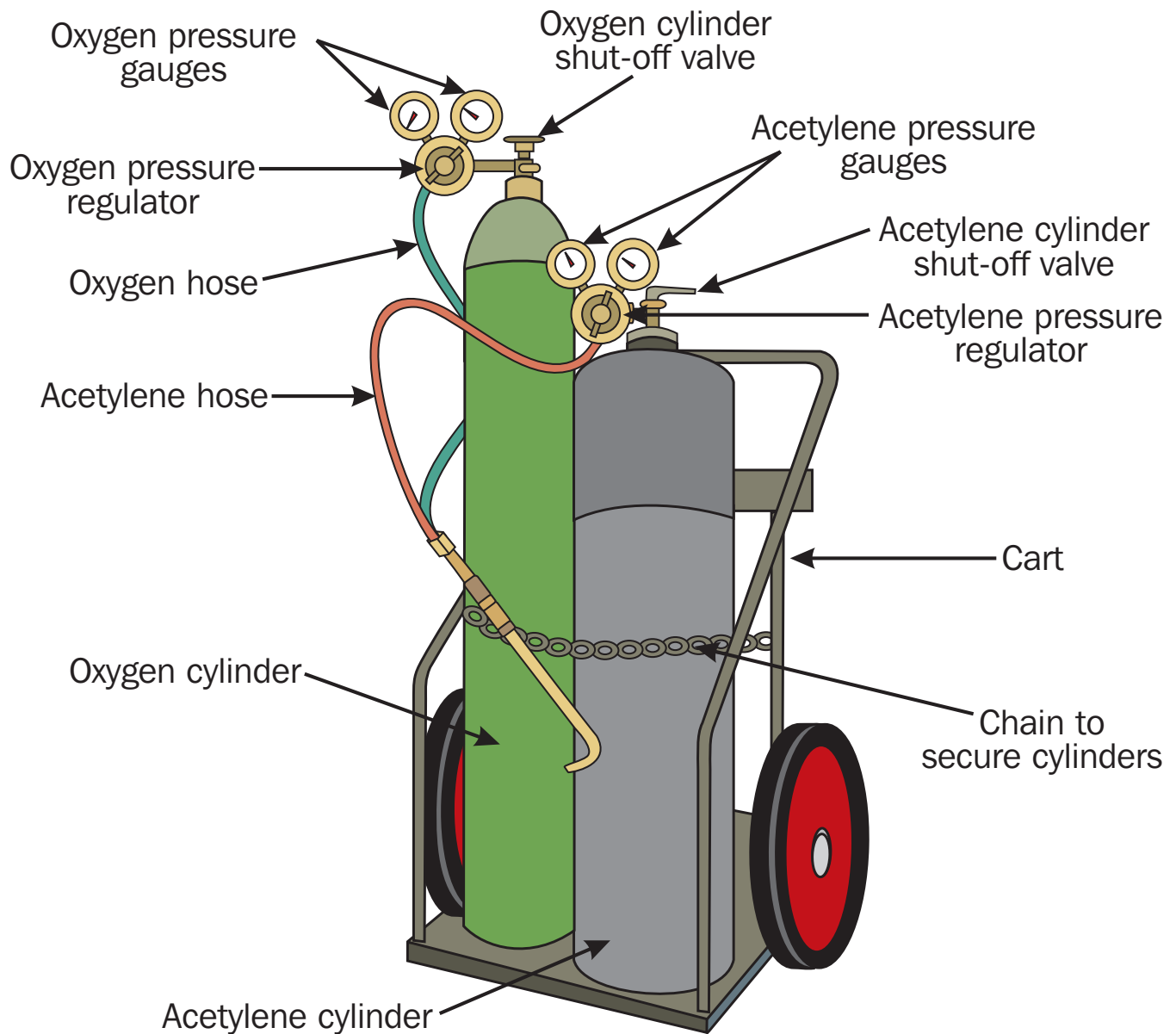
Instructions: Answer the following.

1. What are the differences between fusion welding and braze welding?
2. Discuss how the blowpipe is held when standing and when sitting.
3. Why is flux needed when brazing?

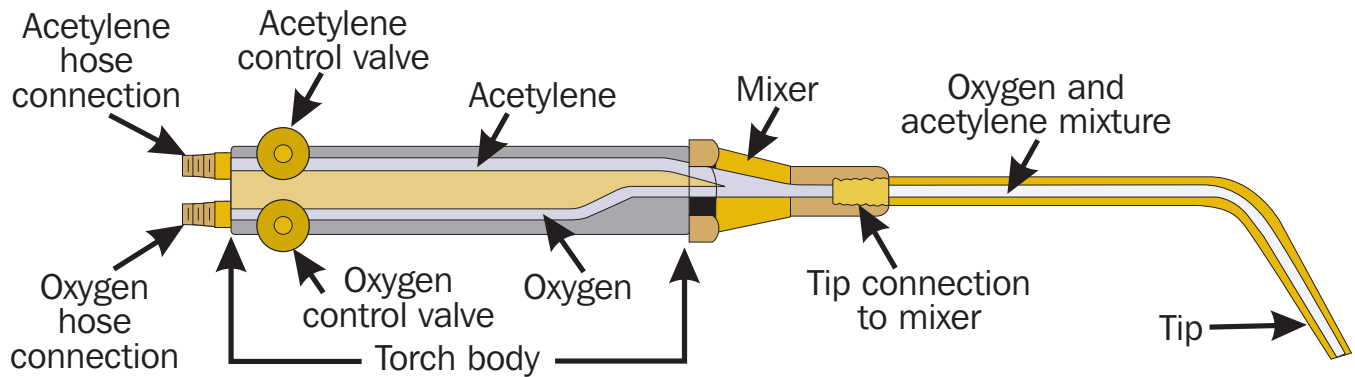
TEMPERATURE DATA



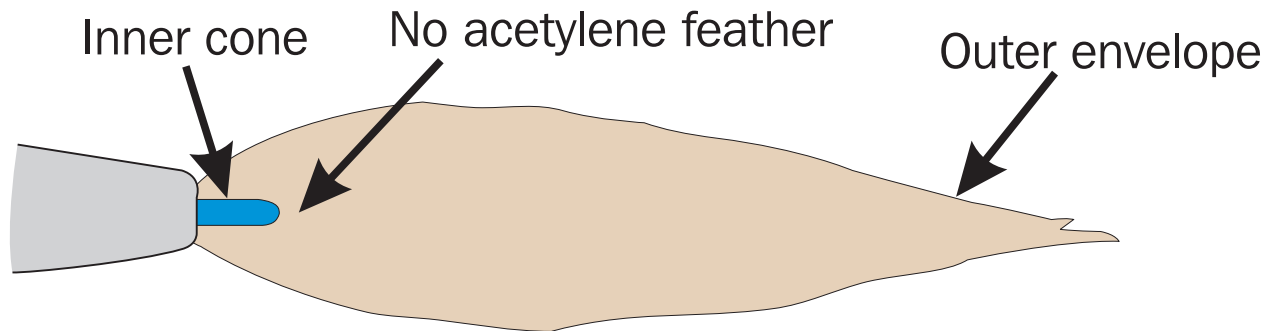
MAJOR PARTS OF AN OXYACETYLENE WELDING AND CUTTING OUTFIT



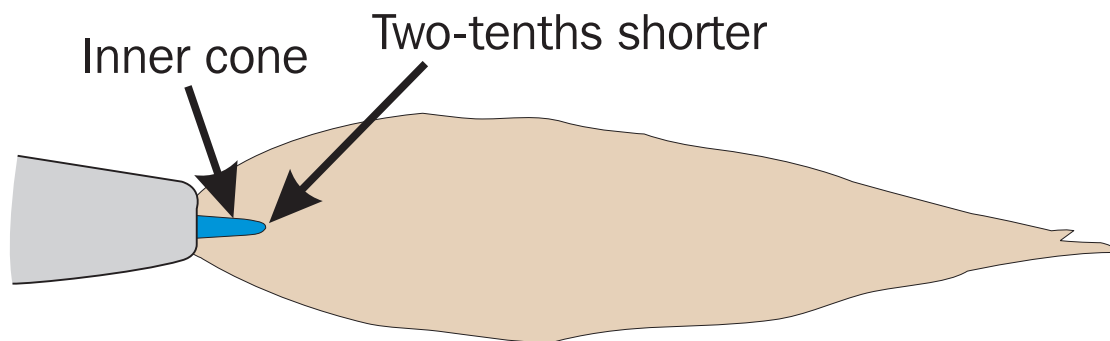
BLOWPIPE DETAIL



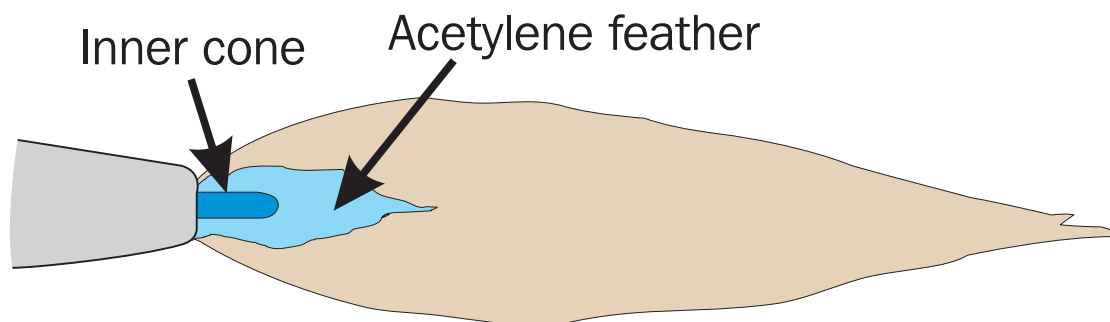
FLAMES



Neutral Flame

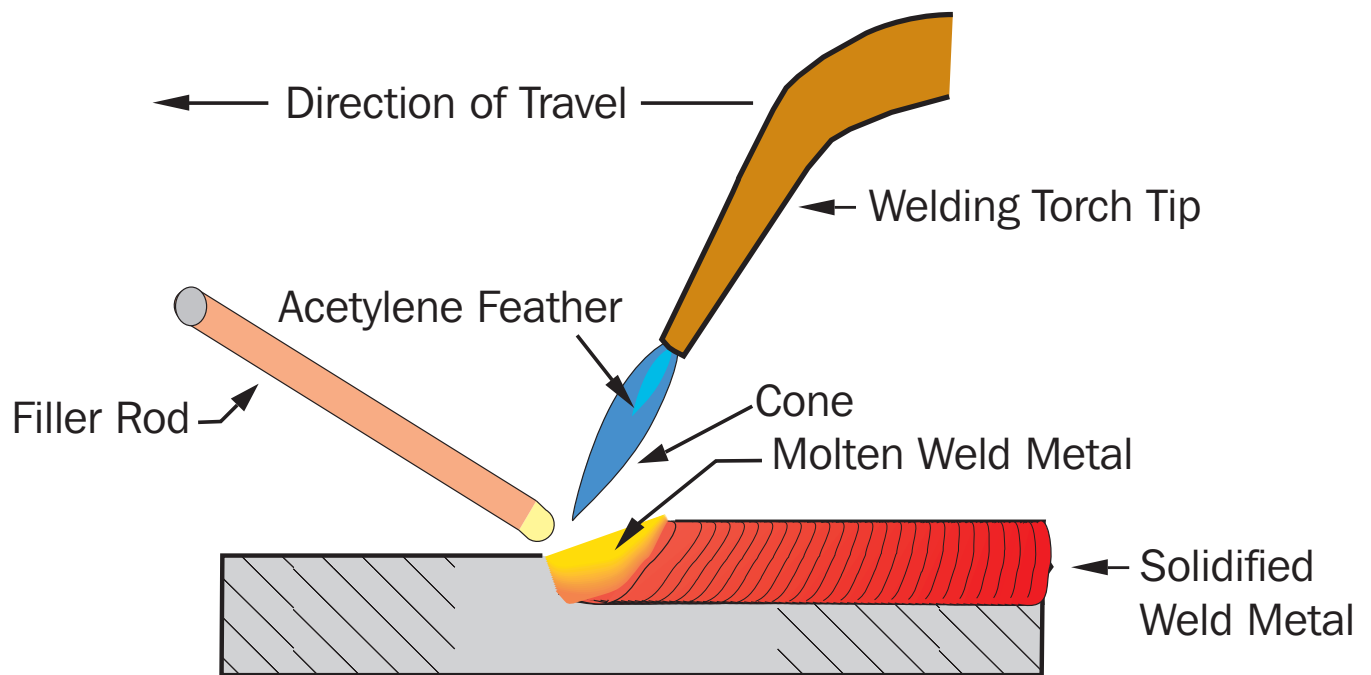


Oxidizing Flame

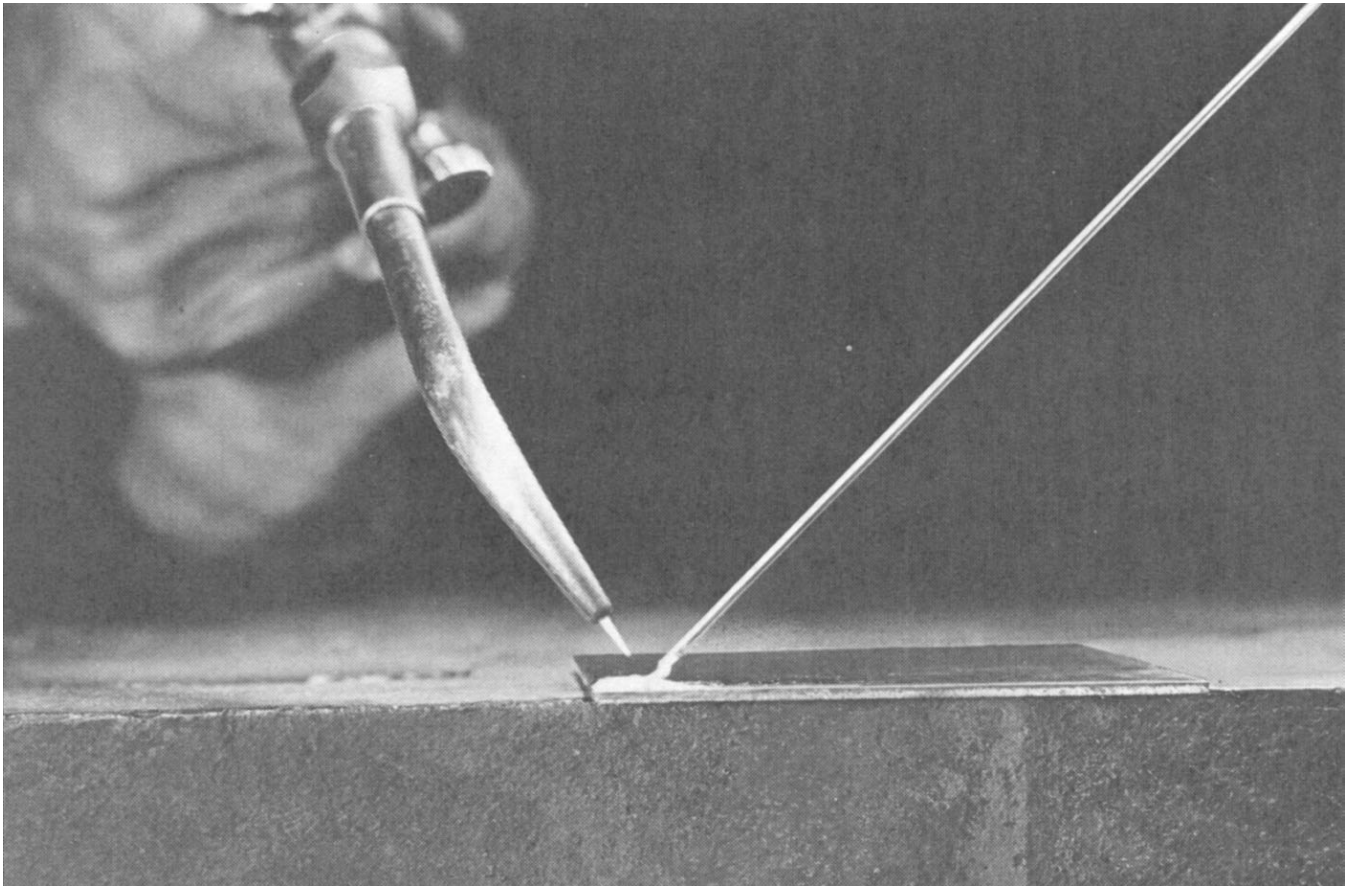


Carburizing Flame

OXYACETYLENE WELDING STRUCTURE

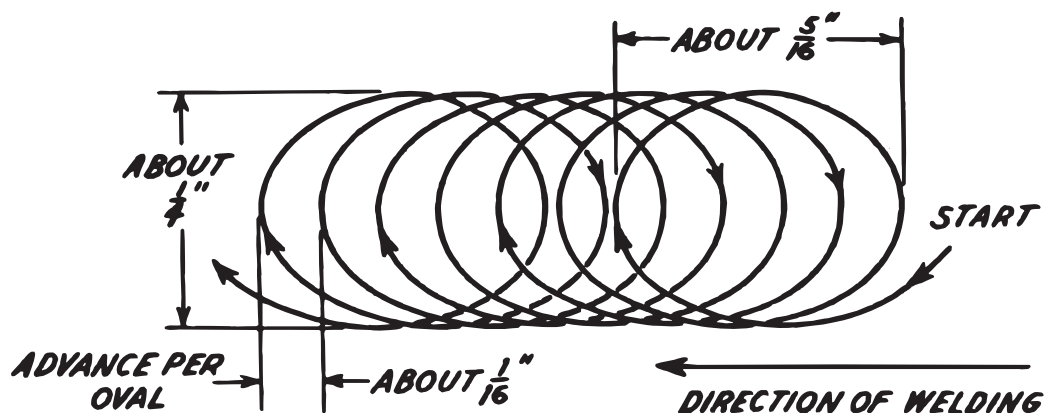


OXYACETYLENE WELDING POSITION

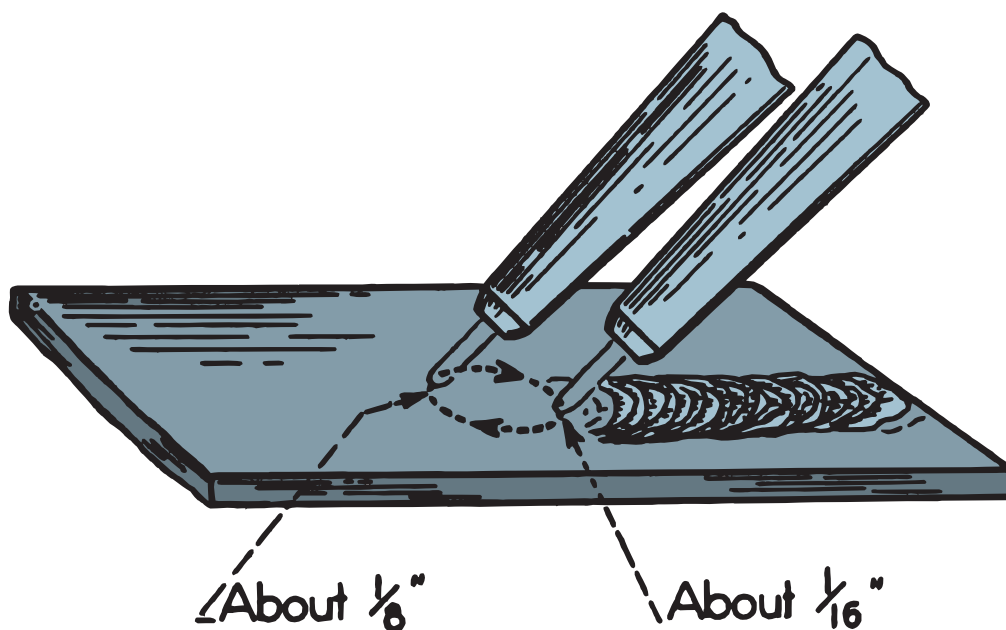


**The correct position of a blowpipe and rod
when the rod is lowered.**

OXYACETYLENE WELDING MOTIONS



The blowpipe motion frequently used.



This view of the blowpipe motion shows how the flame is lifted at the front edge of the circle.

Gas Welding Exercises

Purpose

The purpose of this activity is to perform gas welding exercises.

Objective

Demonstrate gas welding techniques.

Materials

- ◆ fuel gas welding equipment
- ◆ welding safety equipment
- ◆ steel
- ◆ lab sheet copies (one for each exercise)

Procedure

Complete the following lab exercises in the order shown. A lab sheet should accompany each exercise. Before moving to the next exercise, gain instructor approval and directions.

- | | | |
|----------------------|------------------------|-------------------------|
| #1 Fusion melt strip | #5 Fusion tee (fillet) | #9 Brazing tee (fillet) |
| #2 Fusion bead | #6 Brazing bead | #10 Brazing tin can lid |
| #3 Fusion butt | #7 Brazing butt | #11 Brazing tin can |
| #4 Fusion lap | #8 Brazing lap | |

1. Lab exercise no. and type of weld: _____
2. Welding position: _____
3. Type and size of rod used: _____



4. Type and thickness of base metal: _____

5. Current setting: _____ Flowmeter setting: _____

6. SCORECARD:

a. General appearance (smooth, uniform ripples)	5	4	3	2	1	0
b. Width (uniform)	5	4	3	2	1	0
c. Height (uniform)	5	4	3	2	1	0
d. Penetration	5	4	3	2	1	0
e. Starting	5	4	3	2	1	0
f. Stopping	5	4	3	2	1	0
g. Safety procedures followed	5	4	3	2	1	0
h. Other	5	4	3	2	1	0
i. TOTAL POINTS EARNED _____						

7. Comments:

8. Grading Scale	36 to 40	A- to A+
	32 to 35	B- to B+
	28 to 31	C- to C+
	24 to 27	D- to D+
	1 to 23	F
	0	0