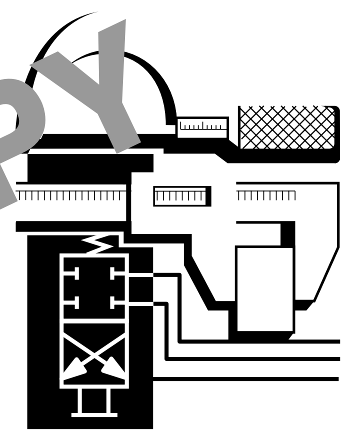
Oxyfuel Operations
Joining, Cutting, and Surfacing

Table of Contents

OXYFUEL OPERATIONS

Lesson One

Welding Ferrous Metals



TPC Training Systems

41801

Lesson

1 Welding Ferrous Metals

TOPICS

Fusion Welding with an Oxyfuel Flame
Other Uses for the Oxyfuel Flame
Fluxes
Flame Characteristics
Temperature Control in Weldments
Welding Common Mild Steels
Welding Stainless Steel
Welding Cast Iron and Wrought Iron

OBJECTIVES

After studying this Lesson, you should be able to…

- Explain how oxyfuel welding joins metals and how it differs from arc welding.
- Explain how braze welding and torch brazing are different from oxyfuel welding and from each other.
- Discuss the purposes for using flux and characteristics that make a flux suitable for an application.
- Compare the appearance and general uses of the carburizing flame, neutral flame, and oxidizing flame.
- Explain why preheating and postheating are used.
- List important considerations in welding common mild steels, stainless steel, and cast and wrought iron.

KEY TECHNICAL TERMS

Oxyfuel welding 1.01 manual fusion process in which welds are made with a very hot gas flame

Filler metal deposition rate 1.06 amount of filler metal melted into a joint in a specific time; usually measured in pounds per hour

Braze welding 1.10 joining process in which only the filler metal is melted—the base metal is heated but not melted

Torch brazing 1.11 joining process in which the filler metal is distributed by capillary action between the close-fitting surfaces of a joint

Flux 1.13 fusible material applied to dissolve oxides and promote the flow of filler metal into the base metal

Carburizing flame 1.20 flame produced by a gas mixture containing more fuel gas than oxygen

Reducing flame 1.22 flame produced by a gas mixture containing more fuel gas than oxygen but more oxygen than the carburizing flame

Neutral flame 1.23 flame produced by a gas mixture containing equal parts of oxygen and fuel gas

The oxyfuel welding process is commonly used in both maintenance and production work because the equipment is relatively inexpensive, easy to operate, and readily made portable. The oxyfuel flame can be used in fusion welding, braze welding, cutting, and heating operations. In maintenance welding, iron and steel are fabricated or repaired by the oxyfuel welding process. Because some metals require special treatment when welded, it is important to understand both the regular and special techniques for working with these metals.

This Lesson explains how an oxyfuel flame is used in fusion welding and other applications. It discusses the use of fluxes, compares flame characteristics, and describes methods of controlling temperature in weldments. In addition, it presents useful information about fusion welding mild steels, stainless steel, cast iron, and wrought iron.

Fusion Welding with an Oxyfuel Flame

1.01 *Oxyfuel welding* is a manual fusion welding process similar to arc welding. In oxyfuel welding, however, welds are made with a very hot gas flame instead of with the heat from an electric arc. The metal surfaces to be joined are melted by the flame so they merge or mingle and, after cooling, form a strongly bonded joint. The joint designs for oxyfuel welding are the same as those used in arc welding.

1.02 Oxygen and acetylene are the gases most commonly used for oxyfuel fusion welding because they produce a hotter flame than other gas mixtures. The oxyacetylene flame has a maximum temperature of about 6300°F (about 3480°C). (Unless otherwise stated, all Fahrenheit and Celsius temperatures are approximate and rounded to a multiple of 5°.) Other gases are sometimes used, although none provides the amount of carbon dioxide shielding to protect the molten weld puddle as acetylene does. For these reasons, the oxyacetylene flame remains the most popular for fusion joining. Storage and handling procedures are basically the same regardless of the gas used, but the adjustments and skill required can differ. Other than the torch tip, the equipment is usually the same for all gases. When changing from one gas to another, make sure the tip can be used safely with the new gas.

1.03 The typical oxyfuel welding outfit consists of a cylinder of oxygen, a cylinder of fuel gas, two separate regulators for controlling gas flow (one for oxygen and one for fuel gas), hoses, and a welding torch. At the torch, oxygen and the fuel gas are mixed and then emitted through the torch tip. All of this equipment is easily made portable by mounting it on a hand truck or special trailer. Because the oxyfuel welding outfit does not require external power, it can be used in field applications where there is no electric power.

1.04 A typical oxyfuel welding work area is shown in Fig. 1-1. For some welding tasks, firebricks are placed under workpieces to protect the surface of the worktable from heat or damage. Torch tips are made in various sizes for many kinds of welding tasks. The torch is ignited with a spark lighter.

WARNING

You can be severely burned if you attempt to light a torch with matches, a cigarette lighter, or burning paper. Always use a spark lighter to light a torch.

Fig. 1-1. Typical oxyfuel welding station

1.05 Several styles and sizes of clamps are used for joint fitup. Pans are placed under the workbench for scrap and waste metal. The quenching can is partly filled with water for quenching and cooling small welded parts so they can be handled safely and easily.

1.06 With practice, you can learn to control the size, shape, and appearance of a weld. The rate of heat input from the oxyfuel flame is controlled by the speed with which the torch is moved and the distance between the torch tip and the base metal. The *filler metal deposition* rate is controlled by coordinating the manipulation of the torch with the motion of dipping the filler rod into the molten weld puddle. The ability to control these welding variables makes oxyfuel welding especially suited for joining thin sheet metal, small pipes, and thin-walled tubes. Oxyfuel welding also produces an acceptable weld on heavy or thick metal sections, but arc welding is more economical.

1.07 Most ferrous and nonferrous metals can be oxyacetylene welded. However, it is important to adjust the mixture of oxygen and fuel gas carefully to obtain appropriate flame characteristics for the particular metal. Flame characteristics include temperature, heat intensity, and chemical activity. For welding with oxyacetylene, for example, a neutral flame (equal parts of oxygen and acetylene) supplies the proper heat intensity and flame atmosphere for the fusion welding of, cast iron, carbon steel, and other iron alloys. Other oxyacetylene flame adjustments are described later in this Lesson.

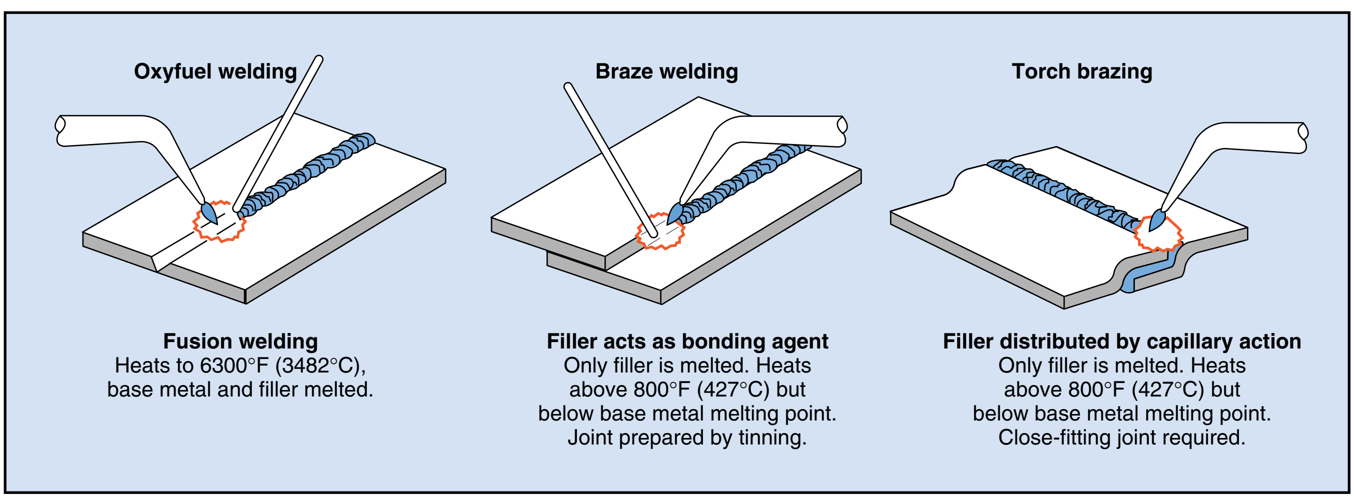
1.08 Alloys of aluminum, copper, nickel, and zinc can also be fusion welded with oxyacetylene. Nearly all oxyfuel fusion welding of steel is done with oxyacetylene. The other oxyfuel gas combinations are used for the fusion welding of metals that have lower melting points than steel—for example, aluminum, lead, magnesium, silicon bronze, zinc, and other nonferrous alloys. The oxyfuel welding process is not suitable for joining certain metals including molybdenum, titanium, tungsten, and zirconium. Because these metals have very high melting points, they are normally joined by one of the arc welding processes.

Other Uses for the Oxyfuel Flame

1.09 Oxyfuel welding equipment is used for other jobs besides fusion welding. It can also be used for braze welding and torch brazing, which are slightly different processes, as shown in Fig. 1-2. Other flame uses include some forms of soldering, preheating and postheating, and flame cutting. Sometimes the terms fusion welding, braze welding, and torch brazing are confused. The following paragraphs explain the differences between these processes.

1.10 *Braze welding* is not a fusion welding process because only the filler metal is melted. The base metal is heated but not melted. Filler metal deposited in the joint acts as a bonding agent. The joint designs for braze welding are the same as those for fusion welding, but braze welding requires an extra step. First the joint surfaces must be mechanically cleaned, heated, chemically cleaned by the flux, and

Fig. 1-2. Three important uses of a gas flame



sometimes *tinned* (coated) with a thin film of filler metal. Because the braze welding filler metal is usually an alloy of copper and zinc, the process is sometimes called bronze welding.

1.11 Like braze welding, *torch brazing* is a metal joining process in which the base metal is heated but not melted. However, in torch brazing the filler metal is distributed by capillary action between the close-fitting surfaces of a joint. Because this action requires small openings or narrow clearances, special joint design and careful fitup are very important. The main difference between brazing and braze welding is that brazing works by means of capillary action and has special joint requirements. The metal joining process known as silver brazing was once called "silver soldering." However, it is not soldering, but brazing with a silver alloy filler metal.

1.12 Other means of brazing include furnace brazing, induction brazing, dip brazing, flow brazing, and even arc brazing. Torch brazing is the most popular method for maintenance and repair brazing because the equipment is portable and easy to operate. The other kinds of brazing are more commonly used in production line applications.

Fluxes

1.13 To weld some metals, a flux is needed to produce a sound joint. In welding, the term *flux* refers to a fusible (easily melted) material applied before welding to dissolve oxides and chemically clean the surface to prevent other undesirable inclusions that could interfere with weld quality. Fluxes are also used in many soldering and brazing operations. Table 1-1 on the following page lists American Welding Society (AWS) classifications of some common brazing fluxes.

1.14 Fluxes promote the flow of the filler metal onto the metals being joined. They also act as cleaning agents to dissolve oxides, release trapped gases and slag, and help clean the metal for welding. However, the joint surfaces should always be cleaned by chipping, grinding, or wire brushing before flux is applied.

1.15 Fluxes are made in paste, powder, and liquid form. Powders can be poured or sprinkled on the base metal, or the filler rod can be heated and dipped into the powder. Liquid and paste fluxes can be brushed onto the filler rod and the base metal. These methods of application are illustrated in Fig. 1-3 on page 9. In shielded metal arc welding (SMAW), the flux is incorporated in a cellulose or mineral coating around the electrode wire core.

1.16 Fluxes are not normally required for oxyfuel welding of steel. However, they are generally necessary for welding cast iron, stainless steels, and most nonferrous metals because the oxides of these metals have higher melting points than the metals themselves. Thus, the oxides remain solid even when the base metal has melted and become fluid. As solids, the oxides interfere with the proper distribution of molten metal in the weld puddle. Fluxes help dissolve and dispose of the oxides on or in the base metal.

1.17 No single flux material is satisfactory for every application. The choice of flux depends mainly on the properties of the base metal and filler metal. In welding gray cast iron, for example, a suitable flux may contain boric acid, soda ash, and small amounts of ammonium sulfate, sodium chloride, or powdered iron. The flux for oxyfuel welding of high-silicon cast iron pipe, however, is likely to be a compound of lime and sodium bisulfate.

1.18 Although there is no one best flux for all applications, a suitable flux has these characteristics:

- melts readily and is chemically active at the melting point of filler metal
- remains stable and does not vaporize rapidly at welding temperatures
- dissolves and disperses oxides
- adheres to hot metal surfaces—does not run or blow away
- does not cause glare or excess smoke that obscures the welding process
- is easy to apply and easy to remove after welding is completed.

Flame Characteristics

1.19 Correct adjustment of the oxyacetylene flame is very important in welding operations. Changing the

Table 1-1. General classifications for commercial brazing fluxes*

AWS brazing flux type no.	Metal combinations for which various fluxes are suitable: Base metals	Metal combinations for which various fluxes are suitable: Filler metals	Effective temperature range of flux, °F	Major constituents of flux	Physical form	Methods of Application†
1 2	Aluminum and aluminum alloys Magnesium alloys	BAlSi BMg	700-1190 900-1200	Fluorides, chlorides Fluorides, chlorides	Powder Powder	1, 2, 3, 4 3, 4
3A	Copper and copper-base alloys (except those with aluminum); iron base alloys; cast iron; carbon and alloy steel; nickel and nickel base alloys; stainless steels; precious metals (gold, silver, palladium, etc.)‡	BCuP BAg	1050-1600	Boric acid, borates, fluorides, fluoborate wetting agent	Powder Paste Liquid	1, 2, 3
3B	Copper and copper-base alloys (except those with aluminum); iron base alloys; cast iron; carbon and alloy steel; nickel and nickel base alloys; stainless steels; precious metals (gold, silver, palladium, etc.)	BCu BCuP BAg BAu RBCuZn BNi	1350-2100	Boric acid, borates, fluorides, fluoborate, wetting agent	Powder Paste Liquid	1, 2, 3
4	Aluminum-bronze; aluminum-brass§	BAg, BCuZn, BCuP	1050-1[illegible]	Bora[illegible] [illegible]s, [illegible]hlori[illegible]	Powder Paste	1, 2, 3
5	Copper and copper-base alloys (except those with aluminum); nickel and nickel-base alloys; Stainless steels; carbon and alloy steels; cast iron and miscellaneous iron-bas[illegible]ys; precious metals (ex[illegible] go[illegible] and silver)	BCu, BC[illegible] BAg[illegible]-19) [illegible]Au, [illegible]	[illegible]40[illegible]20[illegible]	[illegible]ax, boric acid borates	Powder Paste Liquid	1, 2, 3

* This table provides a guide for class[illegible]ation of most commercial prop[illegible] [illegible]es. For [illegible]ditional data consult AWS specification for brazing filler metal A5.8; consult also [illegible]VS Brazing Manual.

† 1—Sprinkle dry powder on joint; 2—dip heated filler met[illegible]od in p[illegible]der [illegible] paste; 3—mix to paste consistency with water, alcohol, monochlorobenzene, etc.; 4—molten flux bath.

‡ Some type 3A fluxes are specifically recom[illegible]nded for bas[illegible] listed under type 4.

§ In some cases type 1 flux may be used on ba[illegible] [illegible]listed under type 4.

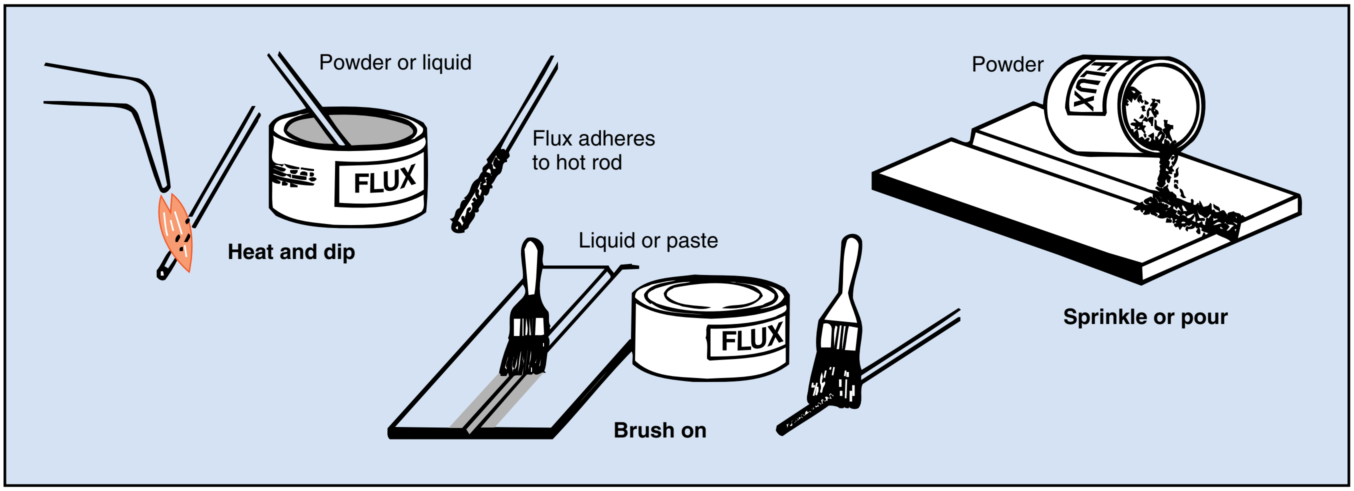
gas mixture ratio changes the flame characteristics. Gas working pressures are set at the regulators. Flame adjustments are made at the torch needle control valves. The three kinds of oxyacetylene flame are the carburizing or reducing flame, the neutral flame, and the oxidizing flame, all illustrated in Fig. 1-4.

1.20 When a torch is ignited, only the acetylene control valve is opened. Acetylene burning in air produces a long, yellow, sooty flame. Opening the oxygen control valve produces a *carburizing flame*. This flame has three distinct sections: a sharply pointed blue-white inner cone, a feathery white intermediate cone, and a large blue outer flame envelope about 3 to 4 in. (7.5 to 10 cm) long.

1.21 The carburizing flame temperature at the tip of the inner cone is about 5300°F (about 2925°C), which is a lower temperature than that of the other flames. This flame is used for hard-surfacing applications and for welding high-carbon steels and some nonferrous alloys. For these applications, the intermediate cone of the carburizing flame should be about three to four times as long as the inner cone.

1.22 The *reducing flame* is a variation of the carburizing flame. It is produced by increasing the amount of oxygen in the flame. The intermediate cone of a reducing flame is about one-quarter to one-half the length of the inner cone of the flame. This flame has an inner cone tip temperature of about 5450°F

Fig. 1-3. Methods of applying flux



(about 3010°C), which is just slightly hotter than the normal carburizing flame. The slight excess of acetylene compared to oxygen in the reducing flame helps prevent oxidation in the weld puddle during welding applications with low-alloy steel filler rods.

1.23 The *neutral flame* is used more often than any other kind. It is produced by a gas mixture that contains equal amounts of oxygen and acetylene. The inner cone of the neutral flame is brilliant white, and there is no intermediate cone. The inner cone size varies slightly depending on gas working pressures and tip size, but is usually between 1/4 and 3/8 in. (6 and 10 mm) long. Neutral flame temperatures range from as high as 6000°F (3315°C) at the tip of the inner cone down to about 2400°F (1315°C) near the end of the outer envelope.

1.24 It is more difficult to produce the *oxidizing flame* than the other flames. This flame results from burning a gas mixture containing more oxygen than acetylene. The inner cone is smallest of all the flames, and it begins to neck down (become narrower) very close to the torch tip. With twice as much oxygen as acetylene in the flame, temperature at the tip of the inner cone exceeds 6000°F (3315°C). The exact ratio of oxygen and acetylene varies from application to application. Sometimes the proper mixture ratio must be determined by making test welds or by trial and error.

1.25 Because the oxidizing flame is the hottest of all flames, it has limited use and is even harmful to some metals. For example, the high temperature and quantity of oxygen can cause steel to burn and foam, producing many sparks. Examples of common uses for the oxidizing flame are welding and torch brazing of copper, brass, and bronze alloys. The oxidizing flame produces a film or oxide slag on these

Fig. 1-4. Oxyacetylene flame variations

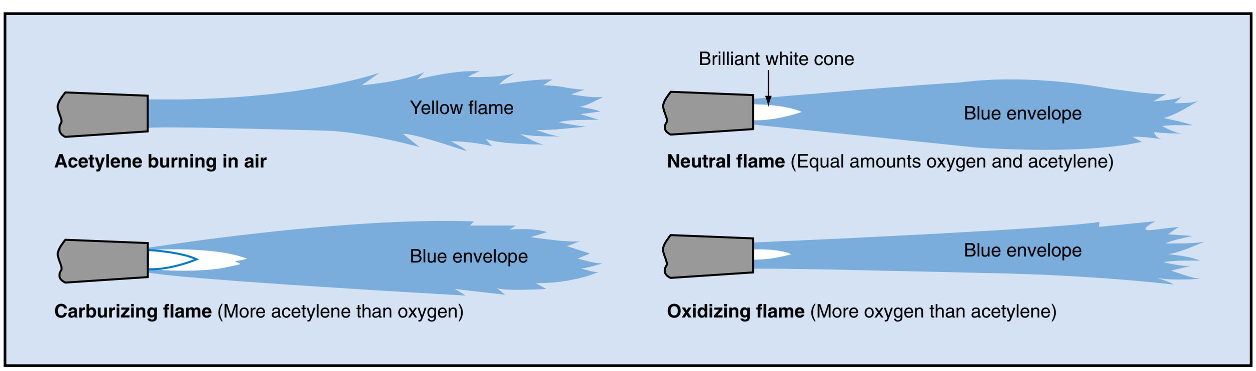


Fig. 1-5. Preheating helps relieve heat stresses

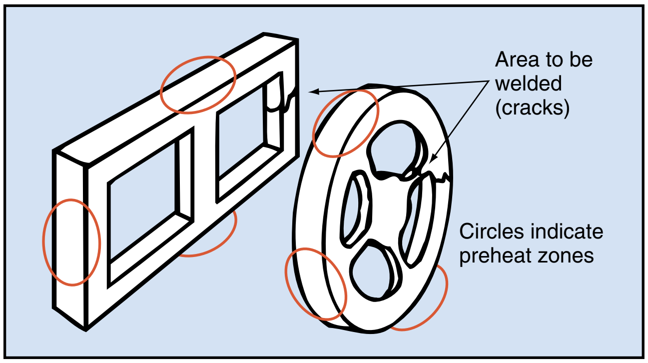
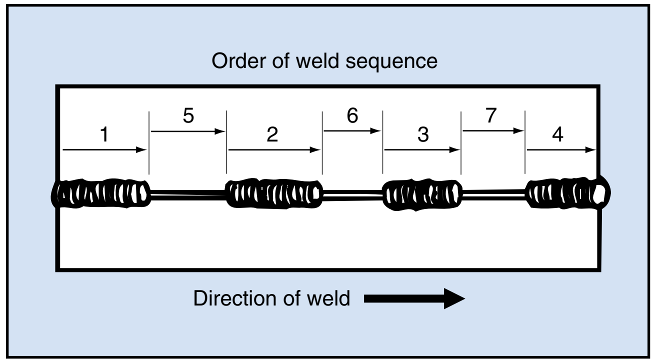


Fig. 1-6. Backstep weld



metals that helps shield the work and reduces the rate of cooling.

Temperature Control in Weldments

1.26 The careful control of temperature before, during, and after welding is often critical. Preheating and postheating treatments are specified for many welds on many kinds of metals. Controlling the base metal temperature between weld passes is important in all multipass welds. Welded joints can be made in many metals without additional heating if the joint is not restricted. Two exceptions, however, are high-carbon steel and cast iron.

1.27 *Preheating* is the application of heat to the base metal before welding. It helps prepare the base metal for the extreme heat to which it is exposed during fusion welding. When this treatment is required, the temperature and duration (hold time) of preheating are specified on the welding drawings. Preheating is not required for all welds.

1.28 The preheat temperature and the hold time are determined by the composition, shape, and thickness of the metal. For some alloys, welding is more successful without preheating. Because of the many variations in preheat requirements, it is essential to follow welding specifications precisely for each job.

1.29 Preheating can be done with oxyacetylene torches, gasoline or diesel fuel oil burners, ovens, or electric furnaces. A gas flame is often used for heating areas in large pieces for which the use of an oven or furnace is not practical. It is then important to study the shape of the pieces to be welded to determine where heat should be applied to relieve stresses. Figure 1-5 shows preheat areas for two workpieces.

1.30 *Postheating* is used primarily for relieving stresses in the metal after it has been welded. The postheat temperature, hold time, and cooling rate differ from job to job. In general, slow cooling is essential for relieving shrinkage stress. If the metal is cooled too rapidly, new stresses develop and thus defeat the purpose of earlier preheating.

1.31 Requirements for stress relieving are determined by the composition of the metal, the thickness of the metals to be joined, and the final use and complexity of the weldment. In some cases, stress relieving may be specified for a partly welded joint. Welded joints that will be subjected to high pressure usually require stress relief.

1.32 Another way to control temperature is to deposit the weld in a backstep sequence. The *backstep weld* is started as a skip weld, as shown in Fig. 1-6. It is completed by later filling the gaps between the first series of welds—that is, by welding in areas 5, 6, and 7. The work is cleaned before another series of welds is begun.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of your Book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. Oxyfuel welding forms a bonded joint by means of a(n) ________ instead of an arc as in arc welding.	1-1. VERY HOT GAS FLAME Ref: 1.01
1-2. The gases you will probably use most often in oxyfuel welding are ________ and________.	1-2. OXYGEN, ACETYLENE Ref: 1.02
1-3. Always use a(n) ________ to light a gas torch.	1-3. SPARK LIGHTER Ref: Warning following 1.04
1-4. In braze welding, the ________ metal is heated but not melted, but the ________ metal is melted.	1-4. BASE; FILLER Ref: 1.10
1-5. A main reason for using fluxes in welding is to dissolve ________.	1-5. OXIDES Ref: 1.13
1-6. Because it is the hottest of all flames, the ________ flame can damage some metals.	1-6. OXIDIZING Ref: 1.25
1-7. Which two ferrous metals always require preheating, postheating, or both?	1-7. HIGH-CARBON STEEL, CAST IRON Ref: 1.26
1-8. You can control temperature in welding jobs by preheating, postheating, or using ________ welds.	1-8. BACKSTEP Ref: 1.32

Welding Common Mild Steels

1.33 Low-carbon steel, low-alloy steel (steel with small amounts of other alloying elements), and steel castings are easily welded by the oxyfuel process. Normally a flux is not necessary with these metals because their oxides melt at a lower temperature than the base metal. However, the molten weld puddle must be kept covered by the envelope of the flame throughout the welding process. The molten metal oxidizes rapidly if air is allowed to contact the weld puddle.

1.34 When welding mild steel, avoid excess heat. Use either the forehand or the backhand technique, depending on metal thickness. Adjust the torch for a neutral or slightly carburizing flame. Do not use an oxidizing flame. Hold the torch so the tip of the inner cone is about 1/16 to 1/8 in. (1.5 to 3 mm) above the surface of the steel, as shown in Fig. 1-7. Melt the end of the filler rod by dipping it in the weld puddle, not by directing the flame at it.

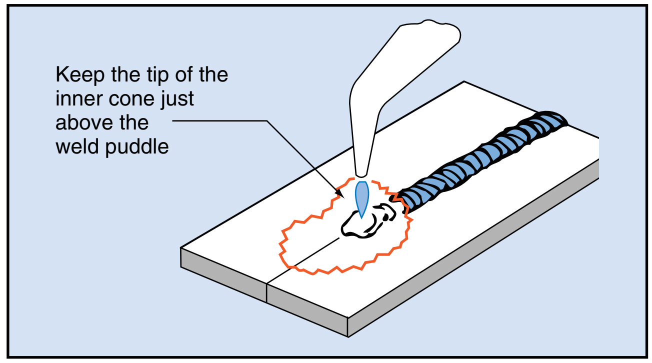
1.35 The welding of low-carbon steels and cast steels presents no special problems if the correct filler rod has been selected. In general, this means using a rod whose alloy composition matches or nearly matches that of the base metal. Low-alloy steels often require preheating and postheating to relieve stresses developed during welding and to aid in obtaining the required physical properties.

1.36 The greater the carbon content of steel, the more difficult it is to weld. Because medium-carbon steels contain 0.3 to 0.6% carbon, they should be welded with a slightly carburizing flame. The medium-carbon steels often require postheating to develop the best physical properties. Otherwise, the technique is the same as that for welding the mild (low-carbon or low-alloy) steels.

1.37 A slightly different technique is required for high-carbon and tool steels. The parts should be preheated slowly to about 1000°F (540°C). Usually a carburizing flame (more acetylene than oxygen) is recommended, and no flux is required. The weld should be completed as quickly as possible, with minimum side-to-side manipulation of the torch.

1.38 Because it is important to avoid overheating high-carbon steels, a smaller flame with lower gas pressures than those used for low-carbon steels is often recommended. High-carbon or tool steel weldments usually require postheat treatment to obtain or restore desired physical properties—for example, strength or hardness.

Fig. 1-7. Correct flame position



Welding Stainless Steel

1.39 Oxyfuel welding of *stainless steel* (various steel alloys containing chromium) is generally limited to sheets or pieces less than 1/16 in. (1.5 mm) thick. Heavier stainless steel pieces are joined by the gas tungsten arc welding (GTAW) or gas metal arc welding (GMAW) process because of the superior results possible.

1.40 Stainless steels are particularly difficult to weld because they tend to warp and distort when subjected to high welding heat. Warping and distortion can be minimized by means of a skip sequence or backstep welding technique, carefully planned fitup, and rigid clamping. Sometimes chill plates are used to help conduct heat away from the joint area. Postheating can also eliminate some of the heat-effect problems.

1.41 The surface of stainless steels is coated with chromium oxide. This coating must be removed by grinding, chipping, or wire brushing before flux is applied. To brush clean, always use a brush made of stainless steel wire rather than carbon steel because tiny particles from a carbon steel brush can contaminate the weld. Coat the joint surfaces with a stainless steel flux immediately after cleaning.

1.42 A common flux for gas welding stainless steel consists of zinc chloride and water with small amounts of hydrochloric acid and potassium dichromate. Stainless steel filler rods are made in many

Fig. 1-8. Joint without filler metal

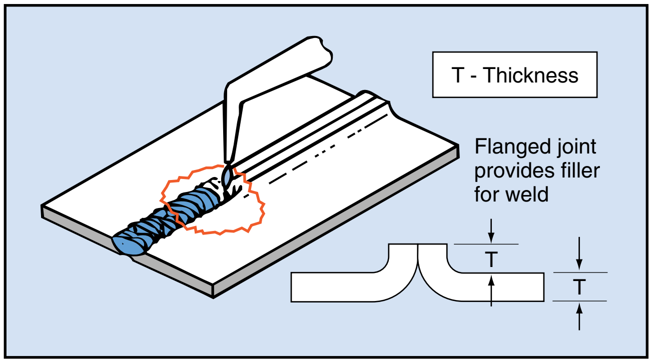
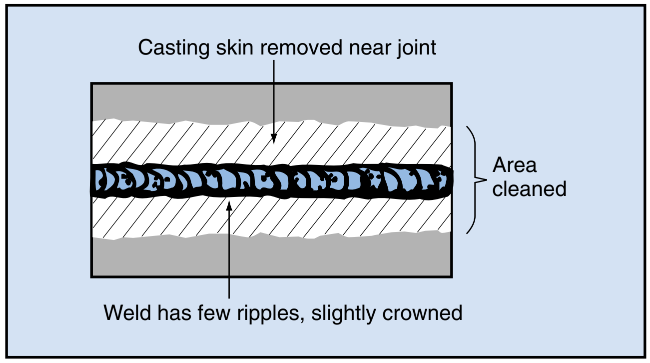


Fig. 1-9. Cast iron joint properly prepared and welded



different alloy compositions so that you can closely match the filler metal with the stainless steel to be welded.

1.43 Stainless steel sheets up to about 3/32 in. (2.5 mm) thick can sometimes be welded without a filler rod. When the part design and weld requirements permit, the edges of a joint can be turned up to form a flange, as shown in Fig. 1-8. As the flange melts, it provides filler metal for the joint. Although the flange method is frequently used on stainless steel joints, it can also be used for making joints without filler rods in thin sections of other metals.

1.44 Normally a smaller torch tip is used for welding stainless steel than for welding carbon steel of the same thickness. The flame is adjusted so it is slightly carburizing with the intermediate cone extending about 1/16 in. (2 mm) beyond the tip of the inner cone. The torch is held at about a 45° angle, with the inner cone tip just above the base metal (weld puddle) surface, and advanced with uniform speed without retracing or backtracking in the weld. If you stop welding for any reason, clean the weld and allow it to cool before you resume.

1.45 It is often helpful if the work is inclined slightly so the weld can be made in a downhill direction. By tilting the joint, you cause some of the flux to flow down ahead of the weld puddle, thus helping to protect the base metal and the heat-affected zone.

1.46 The following are extremely important in producing satisfactory welds:

- Move the torch across the work at a uniform rate of speed.
- Avoid excess heat.

A small weld puddle will form in the stainless steel. Filler rod is fed in and melted in the puddle as necessary. Keep the end of the filler rod in or near the puddle. If you withdraw the rod from the protective heat of the flame envelope, oxides that could contaminate the weld will form on the rod. To stop welding, slowly raise the torch away from the work, thus allowing the weld to cool slightly while the flame still protects it from the atmosphere.

Welding Cast Iron and Wrought Iron

1.47 Oxyacetylene welding of *cast iron* (sometimes called *gray iron*) is not difficult, but the procedure is slightly different from welding mild steel. The following are very important in producing acceptable cast iron welds:

- joint edge preparation (cleaning and grooving)
- preheating
- a suitable flux
- postheating.

For thin pieces up to about 3/16 in. (5 mm) thick, square butt joints without spacing may be suitable. In pieces more than 1/4 in. (6 mm) thick, grooving and a 1/16 in. (1.5 mm) root opening are generally recommended.

1.48 Thoroughly clean all cast iron joint surfaces by grinding and filing and remove all surface oil, grease, paint, and dirt. Chip or grind an expanded area around the joint, as shown in Fig. 1-9. Brush away all loose bits of metal from the grinding or filing operation. If possible, gradually preheat the entire casting to a dull red color, about 1000°F (about 540°C). You can use a flame-proof insulating blanket that covers all but the joint area to help retain the heat. Apply flux sparingly to the joint surfaces and to the filler rod.

1.49 Using a neutral flame, keep the inner cone between 1/8 and 1/4 in. (3 and 6 mm) above the base metal. Dip the end of the filler rod into the weld puddle and keep it there throughout the weld. Adjust the speed of travel so the weld deposit builds up slightly above the surrounding metal. Advance the weld puddle when you see the sides of the joint edges melting into the weld puddle.

1.50 If gas bubbles or white spots appear in the puddle, apply more flux and skim the impurities off the puddle with the end of the rod. Deposit filler metal in layers about 1/8 in. (3 mm) thick with each weld pass. Clean the joint thoroughly between the passes of a multipass weld, maintaining the casting temperature at or above 900°F (480°C) throughout the welding operation.

1.51 Postheating treatment is usually necessary to prevent the casting from cracking as it cools. If possible, the casting should be placed in an oven or furnace and gradually heated to about 1200°F (about 650°C). It should be postheated at this temperature for approximately one hour per inch (2.5 cm) of casting thickness, followed by controlled cooling at the rate of 50°F (10°C) per hour until it has cooled to 500°F (260°C). Then postheating can be stopped and the casting can be allowed to cool in air. Preheat and postheat treatments are especially important for complex cast iron castings—for example, a spoked flywheel or a ribbed framework.

1.52 The procedure for oxyfuel welding of *wrought iron* is similar to that for low-carbon or mild steel. However, wrought iron contains an iron silicate slag that is incorporated during its manufacture. This slag gives the surface of the molten puddle a greasy appearance. Do not confuse this greasy appearance with the shiny weld puddle appearance normally associated with actual fusion—continue heating until the side walls of the joint break down into the puddle. Preheating and postheating are not necessary.

1.53 For best results when welding wrought iron, allow the filler metal (usually mild steel) and base metal to mix in the molten puddle with as little agitation as possible. Avoid high gas working pressures and aim for smooth torch travel with minimum side-to-side movement. In multilayer welding, deposit layers about 1/8 in. (3 mm) thick the full length of the joint. Clean the weld thoroughly between passes by wire brushing.

1-9. When welding mild steel, adjust the torch for a neutral or slightly ________ flame.	1-9. CARBURIZING Ref: 1.34
1-10. The greater the ________ content of steel, the more difficult it is to weld.	1-10. CARBON Ref: 1.36
1-11. What two kinds of steel usually require both preheat and postheat treatments?	1-11. HIGH-CARBON; TOOL Ref: 1.37, 1.38
1-12. Stainless steel can be joined using oxy-fuel welding if the pieces are less than ________ in. (mm) thick.	1-12. 1/16 in. (1.5 mm) Ref: 1.39
1-13. For two workpieces of the same size, which metal usually requires the larger torch tip—stainless steel or carbon steel?	1-13. CARBON STEEL Ref: 1.44
1-14. It is good practice to preheat cast iron to a(n) ________ color, about ________°F.	1-14. DULL RED; 1000 (540°C) Ref: 1.48
1-15. Cast iron should be postheated at about 1200°F (650°C) for approximately ________ per 1 in. (2.5 cm) of casting thickness.	1-15. ONE HOUR Ref: 1.51
1-16. The filler metal for wrought iron is usually ________ steel.	1-16. MILD Ref: 1.53

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. Of all gas mixtures used in oxyfuel fusion welding, oxyacetylene is used most often because it

- ☐ a. is easiest to manipulate
- ☐ b. is most economical
- ☐ c. produces the cleanest flame
- ☐ d. produces the hottest flame

1-2. The rate of heat input from the gas flame is controlled by the speed with which the torch is moved and the

- ☐ a. characteristics of the base metal
- ☐ b. distance between the torch tip and the base metal
- ☐ c. distance between the torch tip and the cylinders
- ☐ d. length of the hoses

1-3. Because the process depends on capillary action, special joint design and careful fitup are especially important in

- ☐ a. braze welding
- ☐ b. oxyfuel welding
- ☐ c. soldering
- ☐ d. torch brazing

1-4. The need for using a flux for oxyfuel welding a ferrous metal depends on the

- ☐ a. characteristics of the flame
- ☐ b. extent of preweld cleaning
- ☐ c. temperature at which the metal oxides melt
- ☐ d. thickness of the metal

1-5. A flame that has a brilliant white inner cone and no intermediate cone is referred to as a(n) ________ flame.

- ☐ a. carburizing
- ☐ b. neutral
- ☐ c. reducing
- ☐ d. oxidizing

1-6. An oxidizing flame is commonly used to weld

- ☐ a. copper, brass, and bronze alloys
- ☐ b. mild steels
- ☐ c. molybdenum and titanium
- ☐ d. thick stainless steel

1-7. The main reason for postheat treatment is to

- ☐ a. cool the metal rapidly
- ☐ b. prepare the metal for postweld cleaning
- ☐ c. relieve stresses in the metal
- ☐ d. weld areas missed previously

1-8. Good practice in oxyfuel welding common mild steels includes

- ☐ a. adjusting for an oxidizing flame
- ☐ b. covering the weld puddle with the flame
- ☐ c. melting the filler rod with the flame tip
- ☐ d. using a stainless steel flux

1-9. Good practice in oxyfuel welding stainless steel includes

- ☐ a. adjusting for maximum heat
- ☐ b. cleaning with a carbon steel brush
- ☐ c. keeping the filler rod in or near the weld puddle
- ☐ d. using a neutral flame

1-10. Good practice in welding cast iron and wrought iron includes

- ☐ a. cooling in air on firebrick
- ☐ b. using a neutral flame
- ☐ c. using less flux if white spots appear in the weld puddle
- ☐ d. using maximum gas working pressure

SUMMARY

Oxyfuel welding is a fusion process in which welds are made with a very hot flame. Because oxyacetylene produces a hotter flame than other gases, it is the gas mixture used most often. Usually different gases require different torch tips, but the methods remain the same. Oxyfuel fusion welding equipment is also used for braze welding, which is not a fusion process because only the filler metal is melted, and torch brazing, in which the filler metal is distributed by capillary action.

Fluxes are used for some oxyfuel welds to dissolve oxides and promote the flow of filler metal. Fluxes for oxyfuel welding are made in powder, paste, and liquid form. The choice of flux depends on the characteristics of the application.

Both the carburizing flame and the reducing flame consist of more acetylene than oxygen, but the reducing flame contains a slightly greater percentage of oxygen than the carburizing flame. The neutral flame, which contains equal amounts of oxygen and acetylene, is the flame used for most oxyfuel welding jobs. The oxidizing flame consists of more oxygen than acetylene and is the hottest kind of flame. Preheat and postheat treatments and wander welds are ways of controlling temperature in welds to help avoid or eliminate metal stresses caused by temperature changes.

Common mild steels are welded with a neutral or slightly carburizing flame and usually without a flux. High-carbon and tool steels should be preheated. The filler rod is dipped in the weld puddle. A smaller torch tip is used for welding stainless steel, which requires special precleaning and a stainless steel flux. Only thin stainless steel is joined by the oxyfuel welding process. Both preheating and postheating are usually needed for welding cast iron, but not for wrought iron. Cast iron weldments are subject to gas bubbles in the weld puddle, and the slag in wrought iron causes a greasy appearance that looks like a weld puddle.

Answers to Self-Check Quiz

1-1. d. Produces the hottest flame. Ref: 1.02

1-2. b. Distance between the torch tip and the base metal. Ref: 1.06

1-3. d. Torch brazing. Ref: 1.11

1-4. c. Temperature at which the metal oxides melt. Ref: 1.16

1-5. b. Neutral. Ref: 1.23

1-6. a. Copper, brass, and bronze alloys. Ref: 1.25

1-7. c. Relieve stresses in the metal. Ref: 1.30

1-8. b. Covering the weld puddle with the flame. Ref: 1.33

1-9. c. Keeping the filler rod in or near the weld puddle. Ref: 1.46

1-10. b. Using a neutral flame. Ref: 1.49

Contributions from the following sources are appreciated:

Figure 1-1. Singer Safety Company