

GAS WELDING

This chapter discusses equipment and materials used in gas welding. Information is provided on the operation and maintenance of oxyacetylene and oxy-MAPP equipment. Included are welding techniques and safety precautions associated with gas welding.

Oxyacetylene and oxy-MAPP (methylacetylene-propadiene) welding are two types of gas-welding processes. They require a gas-fueled torch to raise the temperature of two similar pieces of metal to their fusion point that allows them to flow together. A filler rod is used to deposit additional metal. The gas and oxygen are mixed to correct proportions in the torch, and you can adjust the torch to produce various types of flames.

A properly made gas weld is consistent in appearance, showing a uniform deposit of weld metal. Complete fusion of the sidewalls is necessary to form a good joint. Some of the factors you must consider when making a gas weld are as follows: edge preparation, spacing and alignment of the parts, temperature control (before, during, and after the welding process), size of the torch tip, size and type of the filler rod, flame adjustment, and rod and torch manipulation. In some cases, fluxes are needed to remove oxides and slag from the molten metal and to protect the puddle from atmospheric contamination.

When you join sections of plate by gas welding, the edges of the plate at the joint are uniformly melted by the heat from the torch. When welding heavier sheets and plates, you have to use filler metals. The edges of the heavier plate are beveled to permit penetration to the base of the joint. Both the filler metal and the base metal are melted, and as they solidify, they form one continuous piece. For welding light sheet metal, filler metal is usually not necessary. The edges of light sheet metal are flanged at the joint so they flow together to form one solid piece when you melt them.

OXYGEN WELDING EQUIPMENT

An oxygen welding outfit is basically the same as an oxygen cutting outfit with the exception of the torch. The welding outfit usually consists of a cylinder of acetylene or MAPP gas, a cylinder of oxygen, two regulators, two lengths of hose with fittings, and a

welding torch with tips (fig. 5-1). An oxygen welding outfit also is called a welding rig.

In addition to the basic equipment mentioned, you also use the same auxiliary equipment that was discussed in chapter 4. This equipment consists of tip cleaners, cylinder trucks, clamps, and holding jigs. Safety apparel, which includes goggles, hand shields, gloves, leather aprons, sleeves and leggings, is essential and should be worn as required. Information on safety apparel is contained in chapter 3.

Oxygen welding equipment, like cutting equipment, may be stationary or portable. A portable oxygen outfit, as shown in figure 5-2, is an advantage when it becomes necessary to move the equipment.

To perform your welding duties, you must be able to set up the welding equipment and make the adjustments required to perform the welding operation. Thus it is important that you understand the purpose and function of the basic pieces of equipment that make up the welding outfit. The gases, cylinders, regulators, hoses, and safety equipment are covered in chapter 4. If you have any questions, you should review chapter 4 before continuing.

WELDING TORCHES

The oxygen welding torch mixes oxygen and fuel gas in the proper proportions and controls the amount of the mixture burned at the welding tip. Torches have two needle valves: one for adjusting the oxygen flow and the other for adjusting the fuel gas flow. Other basic parts include a handle (body), two tubes (one for oxygen and another for fuel), a mixing head, and a tip. On some models the tubes are silver-brazed to the head and the rear end forgings, which are, in turn, fitted into the handle. Welding tips are made from a special copper alloy and are available in different sizes to handle a wide range of uses and plate thicknesses.

Two general types of welding torches are used:

- Low pressure
- Medium pressure

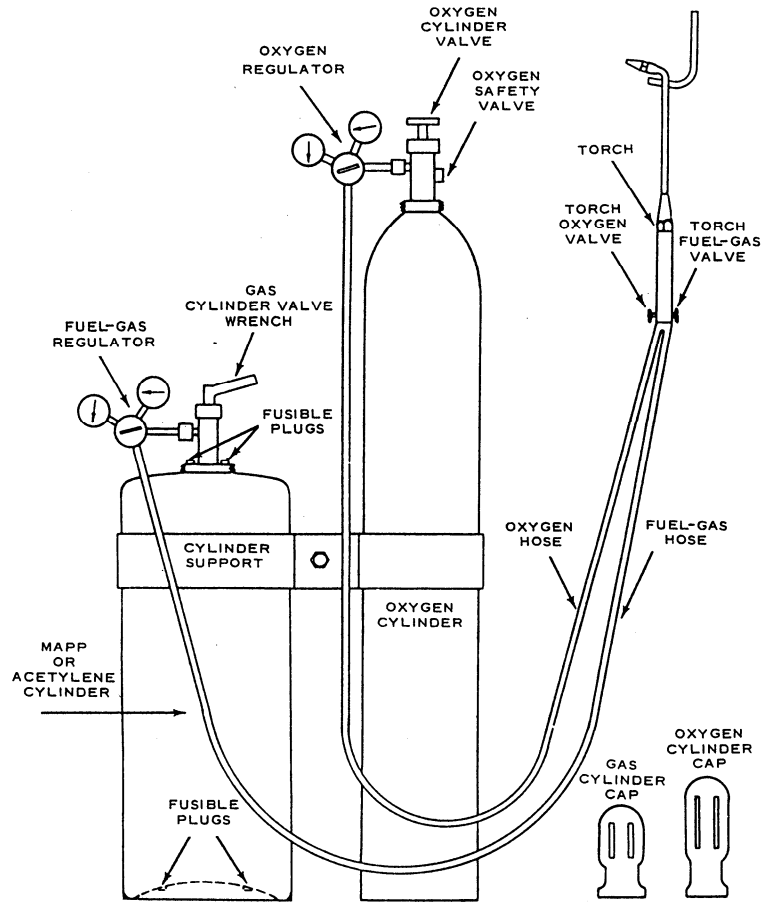


Figure 5-1.—An oxygas welding outfit.

The low-pressure torch is also known as an injector torch. The fuel-gas pressure is 1 psi (pound per square inch) or less. The oxygen pressure ranges between 10 to 40 pounds, depending on the size of the torch tip. A jet of relatively high-pressure oxygen produces the suction necessary to draw the fuel gas into the mixing head. The welding tips may or may not have separate injectors in the tip. Atypical mixing head for the low-pressure (or injector) torch is shown in figure 5-3.

Medium-pressure torches are often called balanced-pressure or equal-pressure torches because the fuel gas and the oxygen pressure are kept equal. Operating pressures vary, depending on the type of tip used.

DANGER

If acetylene is used as the fuel gas, the pressure must never be allowed to exceed 15 psi because acetylene becomes very dangerous at 15 psi and self-explosive at 29.4 psi.

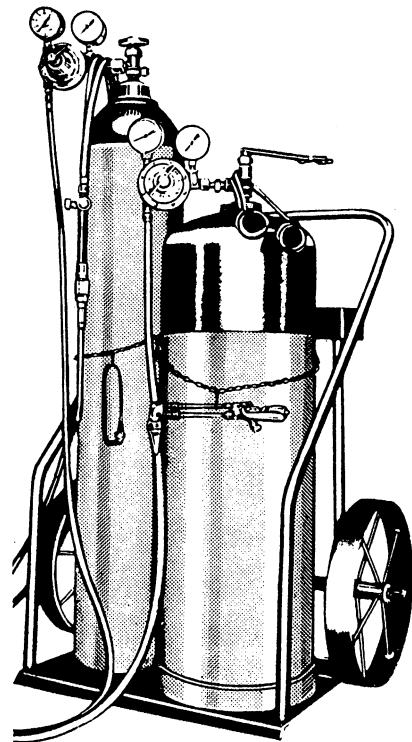


Figure 5-2.—A portable oxygas welding and cutting outfit,

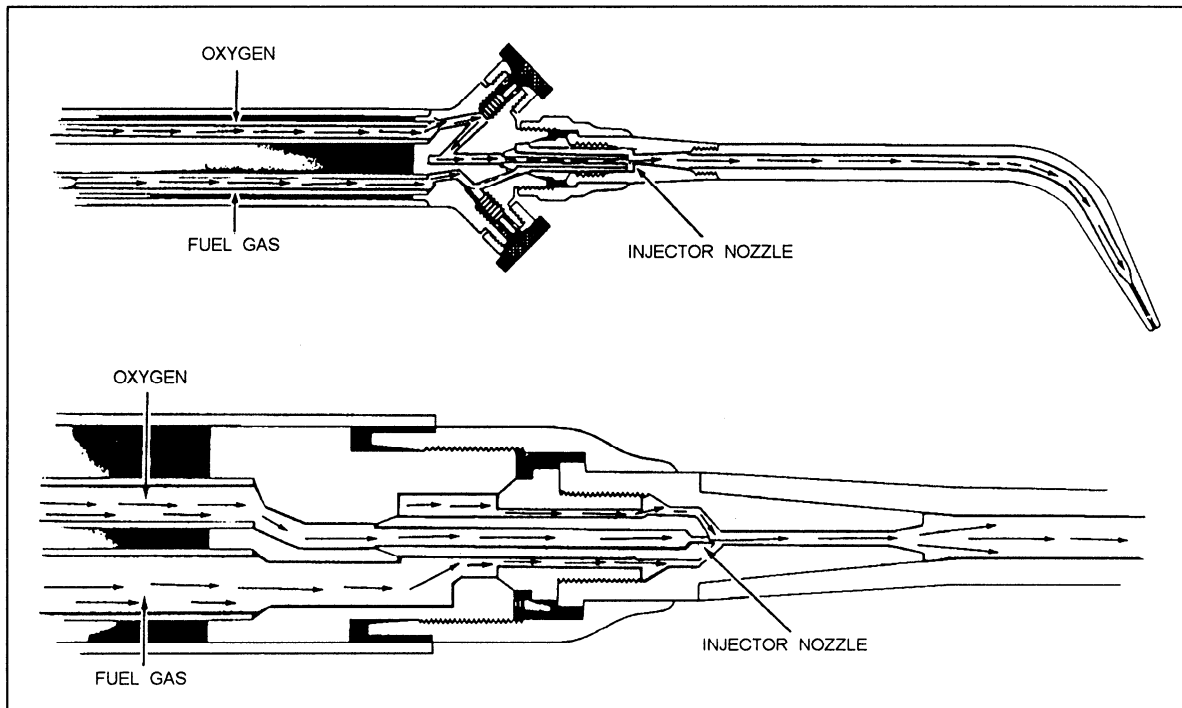


Figure 5-3.—Mixing head for the low-pressure torch.

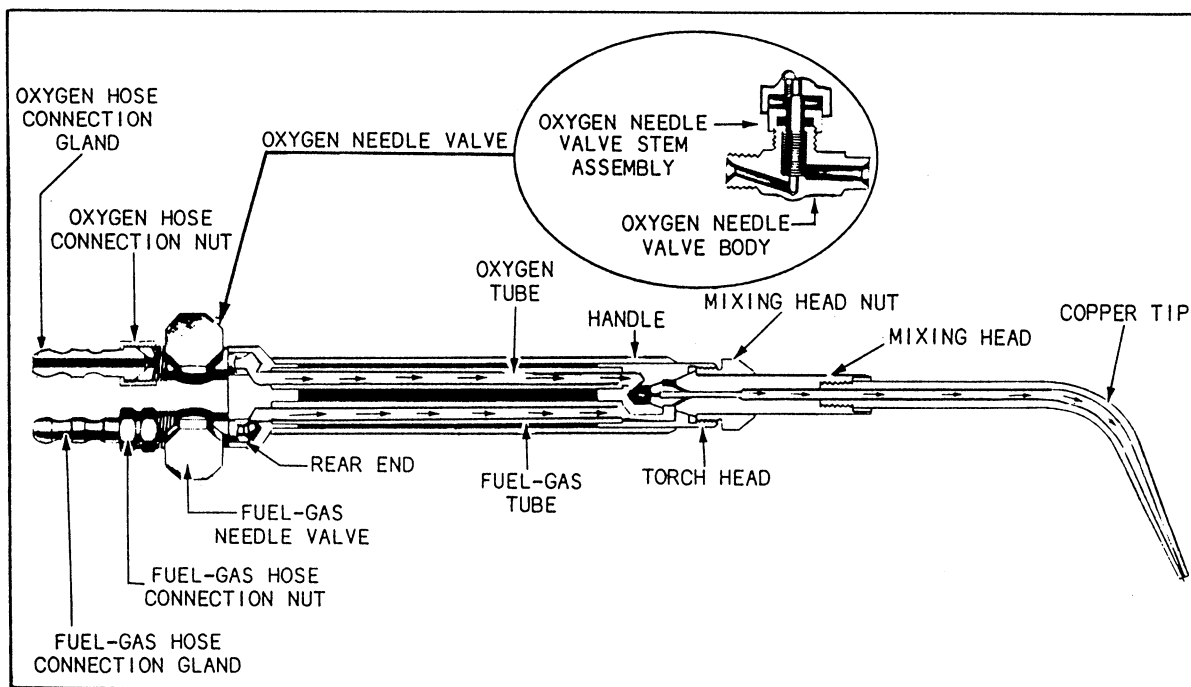


Figure 5-4.—Equal-pressure welding torch.

A typical equal-pressure welding torch, also called a general-purpose torch, is shown in figure 5-4. The medium-pressure torch is easier to adjust than the low-pressure torch and, since equal gas pressures are used, you are less likely to get a flashback. (Flashbacks are covered in chapter 4.)

Welding TIPS and MIXERS are designed in several ways, depending on the manufacturer. Some torch designs have a separate mixing head or mixer for each tip size. Other designs have only one mixer for several tip sizes. Tips come in various types; some are one-piece hard-copper tips and others are two-piece tips that

include an extension tube to make the connection between the tip and the mixing head. When used with an extension tube, removable tips are made of hard copper, brass, or bronze. Tip sizes are designated by numbers, and each manufacturer has his own arrangement for classifying them. Tip sizes differ in the diameter of the hole.

FILLER RODS

The term *filler rod* refers to a filler metal used in gas welding, brazing, and certain electric welding processes in which the filler metal is not a part of the electrical circuit. The only function of the filler rod is to supply filler metal to the joint. Filler rod comes in wire or rod form that is often referred to as “welding rod.”

As a rule, filler rods are uncoated except for a thin film resulting from the manufacturing process. Filler rods for welding steel are often copper-coated to protect them from corrosion during storage. Most rods are furnished in 36-inch lengths and a wide variety of diameters, ranging from 1/32 to 3/8 inch. Rods for welding cast iron vary from 12 to 24 inches in length and are frequently square, rather than round. You determine the rod diameter for a given job by the thickness of the metal you are joining.

Except for rod diameter, you select the filler rod based on the specifications of the metals being joined. These specifications may be federal, military, or Navy specifications. This means that they apply to all federal agencies, the Military Establishment, or the Navy, respectively. Filler metals are presently covered by one or more of these three types of specifications. Eventually, all Navy specifications will be rewritten as military (MIL) specifications. For that reason, some of the specifications for welding materials presented in this section may subsequently be published as military, rather than Navy specifications.

Many different types of rods are manufactured for welding ferrous and nonferrous metals. In general, welding shops stock only a few basic types that are suitable for use in all welding positions. These basic types are known as general-purpose rods.

OPERATION AND MAINTENANCE OF OXYGEN EQUIPMENT

This section discusses basic procedures involved in setting up oxygen equipment, lighting off, adjusting the flame, and securing the equipment. Information also is provided on the maintenance of oxygen welding equipment.

SELECTING THE WELDING TORCH TIP SIZE

Welding torch tip size is designated by a number stamped on the tip. The tip size is determined by the size of the orifice. There is no standard system of numbering welding torch tip sizes; each manufacturer has his own numbering system. In this manual, the tip size is given in the number drill orifice size. Number drills consist of a series of 80 drills, number 1 through 80. The diameter of a number 1 drill is 0.2280 of an inch and the diameter of a number 80 drill is 0.0135 of an inch.

NOTE: As the drill size number increases, the size of the drill decreases.

Once you become familiar with the use of a specific manufacturer's torch and numbering system, it becomes unnecessary to refer to orifice number drill size. The orifice size determines the amount of fuel gas and oxygen fed to the flame; therefore, it determines the amount of heat produced by the torch. The larger the orifice, the greater the amount of heat generated.

If the torch tip orifice is too small, not enough heat will be available to bring the metal to its fusion temperature. If the torch tip is too large, poor welds result from the following: the weld is made too fast, control of the welding rod melting is difficult, and the appearance and quality of the weld is unsatisfactory.

For practice purposes, using an equal-pressure torch, the welding rod sizes and the tip sizes shown in table 5-1 should give satisfactory results.

EQUIPMENT SETUP

Setting up the oxygen equipment and preparing for welding is identical to setting up for oxygen cutting (chapter 4) except for the selection of the torch tip. Select the correct tip and mixing head (depending on torch manufacturer), and connect them to the torch body. Tighten the assembly by hand, and then adjust to the proper angle. After the desired adjustment has been made, tighten the tip. On some types of equipment, the tip is tightened with a wrench, while on other types, only hand tightening is required.

TORCH LIGHTING AND FLAME ADJUSTMENT

When lighting the torch and adjusting the flame, you should always follow the manufacturer's directions for the particular model of torch being used. This is necessary because the procedure varies somewhat with

Table 5-1.—Welding Rod Sizes and Tip Sizes Used to Weld Various Thicknesses of Metal

Metal Thickness	Diameter Welding Rod *	Tip Drill Size	Pressures Oxygen-Fuel Gas	
1/16	1/16-3/32	60-69	4	4
1/8	3/32-1/8	54-57	5	5
1/4	5/32-3/16	44-52	8	8
3/8	3/16-1/4	40-50	9	9

* Sizes listed in this table are approximate and will give satisfactory results. The size of the piece welded will govern the choice. When welding small pieces, use the smaller tip and welding rod. When welding larger pieces, use the larger size tip and welding rod.

different types of torches and, in some cases, even with different models made by the same manufacturer.

After lighting the torch, you adjust the flame according to the type of metal being welded. In-depth coverage of the different types of flames is covered in chapter 4.

The carburizing flame is best used for welding high-carbon steels, for hardfacing, and for welding non-ferrous alloys, such as Monel. A neutral flame is the correct flame to use for welding most metals. When steel is welded with this flame, the puddle of molten metal is quiet and clear, and the metal flows without boiling, foaming, or sparking. The welding flame should always be adjusted to neutral before either the oxidizing or carburizing flame mixture is set.

The oxidizing flame has a limited use and is harmful to many metals. When applied to steel, the oxidizing flame causes the molten metal to foam and produce sparks. The major use of the flame is that of the slightly oxidizing flame used to braze steel and cast iron. A stronger oxidizing flame is used for fusion welding brass and bronze. You determine the amount of excess oxygen to use by watching the molten metal.

MAINTAINING THE EQUIPMENT

For welding equipment to operate at peak efficiency and give useful service, you must perform the proper maintenance and upkeep on it. Your responsibilities involve the maintenance and care of oxygas welding equipment. You will not be required to make major repairs to welding equipment; but when major repairs are needed, it is your responsibility to see that the equipment is removed from service and turned in for repair. This section briefs you on some of the common

types of maintenance duties that you will be required to perform,

Torch Gas Leaks

At times the needle valves may fail to shut off when hand tightened in the usual manner. When this happens, do not use a wrench to tighten the valve stem. Instead, open the valve and try to blow the foreign matter off the valve seat, using the working gas pressure in the hose. If this fails, it will be necessary to remove the stem assembly and wipe the seat clean. Reassemble the valve and try closing it tightly by hand several times. If these measures fail to stop the leak, you should have the parts replaced or the valve body reseated. These repairs should be made only by qualified personnel.

When there is leakage around the torch valve stem, you should tighten the packing nut or repack it if necessary. For repacking, you should use only the packing recommended by the manufacturer of the torch. **DO NOT USE ANY OIL.** If the valve stem is bent or badly worn, replace it with a new stem.

Before you use a new torch for the first time, it is a good idea to check the packing nut on the valves to make sure it is tight. The reason is that some manufacturers ship torches with these nuts loose.

Leaks in the mixing-head seat of the torch causes oxygen and fuel-gas leaks between the inlet orifices leading to the mixing head. This problem causes improper gas mixing and results in flashbacks. The problem can be corrected by having the seat in the torch head reamed and by truing the mixing-head seat. Usually, you must send the equipment to the manufacturer for these repairs.

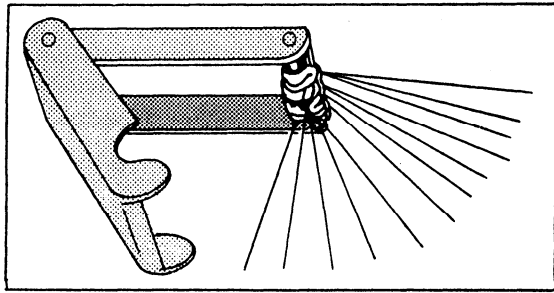


Figure 5-5.—Welding tip orifice cleaner.

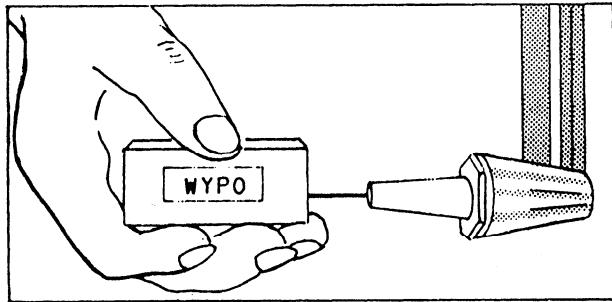


Figure 5-6.—A welding tip cleaner in use.

Welding Torch Tips

Welding tips are subject to considerable abuse and you must keep the orifice smooth and clean if the tip is to perform satisfactorily. When cleaning a welding tip, you must be careful and ensure you do not enlarge or scar the orifice. Carbon deposits and slag must be removed regularly to ensure good performance.

Avoid dropping a tip because the seat that seals the joint may be damaged. Also, the flame end of the tip also may receive damage if it is allowed to come in contact with the welding work, bench, or firebricks. This damage roughens the end of the tip and causes the flame to burn with a "fishtail."

Special welding tip cleaners have been developed to remove the carbon or slag from the tip orifice. The cleaner consists of a series of broachlike wires that correspond in diameter to the diameter of the tip orifices (fig. 5-5). These wires are packaged in a holder, which makes their use safe and convenient. Figure 5-6 shows a tip cleaner in use. Some welders prefer to use a number drill the size of the tip orifice to clean welding tip orifices. A number drill must be used carefully so the orifice is not enlarged, bell-mouthed, reamed out of round, or otherwise deformed.

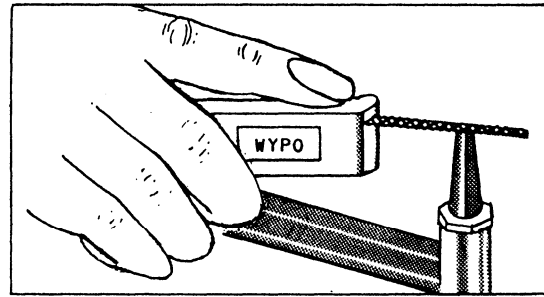


Figure 5-7.—Reconditioning the orifice end of a torch tip.

The flame end of the tip must be clean and smooth. The surface must be at right angles to the centerline of the tip orifice to ensure a proper shaped flame. A 4-inch mill file or the file in the tip cleaner can be used to recondition the surface, as shown in figure 5-7.

Recondition the tip if it becomes rough and pitted or the orifice is bell-mouthed. An easy method to use involves placing a piece of emery cloth, grit side up, on a flat surface; hold the tip perpendicular to the emery cloth, and rub the tip back and forth just enough to true the surface and to bring the orifice back to its original diameter.

Regulator Leaks

With regulators, gas leakage between the regulator seat and nozzle is the most common type of trouble. You often hear this problem referred to as *regulator creep*. This problem can be detected by the gradual rise in pressure on the working-pressure gauge without moving the adjusting screw. Frequently, this trouble is caused by worn or cracked seats. It also can be caused by foreign matter lodged between the seat and the nozzle. It is important that you have leaking regulators repaired at once; otherwise, injury to personnel or equipment damage could result. This is particularly dangerous with fuel-gas regulators because fuel gas at a high pressure in a hose becomes an explosive hazard. To ensure the safety of personnel and equipment, ensure that regulators with such leaks are removed from service and turned in for repair.

OXYGEN WELDING TECHNIQUES

Oxygen welding may be done using either the forehand or the backhand method. Each of these techniques has special advantages and you should become skillful with both. The deciding factor that determines whether a technique is considered forehand or backhand is the relative position of the torch and rod during welding, not

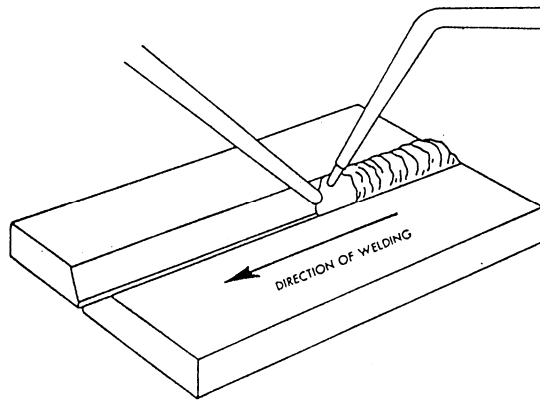


Figure 5-8.—Forehand welding.

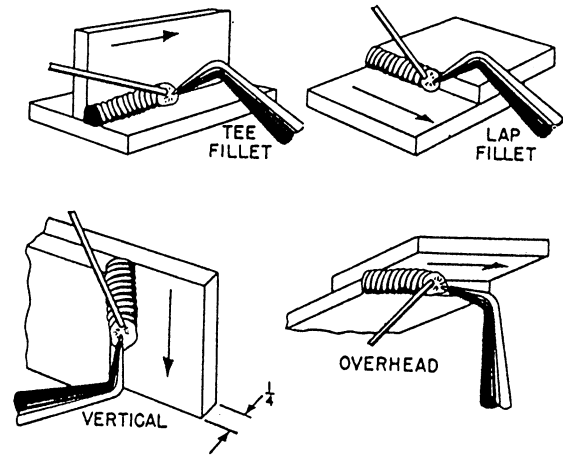


Figure 5-9.—Backhand welding.

the direction of welding. The best method to use depends upon the type of joint, joint position, and the need for heat control on the parts to be welded.

FOREHAND WELDING

Forehand welding (fig. 5-8) is often called Puddle or Ripple Welding. In this method of welding, the rod is kept ahead of the flame in the direction in which the weld is being made. You point the flame in the direction of travel and hold the tip at an angle of about 45 degrees to the working surfaces. This flame position preheats the edges you are welding just ahead of the molten puddle. Move the rod in the same direction as the tip, and by moving the torch tip and the welding rod back and forth in opposite, semicircular paths, you can distribute the heat evenly. As the flame passes the welding rod, it melts a short length of the rod and adds it to the puddle. The motion of the torch distributes the molten metal evenly to both edges of the joint and to the molten puddle.

The forehand method is used in all positions for welding sheet and light plate up to 1/8 of an inch thick. This method is ideal because it permits better control of a small puddle and results in a smoother weld. The forehand technique is not recommended for welding heavy plate due to its lack of base metal penetration.

BACKHAND WELDING

In backhand welding (fig. 5-9), the torch tip precedes the rod in the direction of welding and the flame points back at the molten puddle and completed weld. The welding tip should make an angle of about 60 degrees with the plates or joint being welded. The end of the welding rod is placed between the torch tip and the molten puddle.

Less motion is used in the backhand method than in the forehand method. If you use a straight welding rod, you should rotate it so the end rolls from side to side and melts off evenly. You might have to bend the rod when working in confined spaces. If you do, it becomes difficult to roll a bent rod, and to compensate, you have to move the rod and torch back and forth at a rather rapid rate. When making a large weld, you should move the rod so it makes complete circles in the molten puddle. The torch is moved back and forth across the weld while it is advanced slowly and uniformly in the direction of the welding.

The backhand method is best for welding material more than 1/8 of an inch thick. You can use a narrower vee at the joint than is possible in forehand welding. An included angle of 60 degrees is a sufficient angle of bevel to get a good joint. The backhand method requires less welding rod or puddling as the forehand method.

By using the backhand technique on heavier material, you can increase your welding speed, better your control of the larger puddle, and have more complete fusion at the weld root. If you use a slightly reducing flame with the backhand technique, a smaller amount of base metal is melted while welding the joint. When you are welding steel with a backhand technique and a slightly reducing flame, the absorption of carbon by a thin surface layer of metal reduces the melting point of the steel. This speeds up the welding operation. This technique is also used in surfacing with chromium-cobalt alloys.

MULTILAYER WELDING is used in order to avoid carrying too large a puddle of molten metal when welding thick plate and pipe. Large puddles are difficult to control. Concentrate on getting a good weld at the bottom of the vee in the first pass. Then, in the next

layers, concentrate on getting good fusion with the sides of the vee and the previous layer. The final layer is easily controlled to get a smooth surface. This method of welding has an added advantage in that it refines the previous layer as the succeeding layer is made. In effect, it heat-treats the weld metal by allowing one layer to cool to a black heat before it is reheated. This improves the ductility of the weld metal. If this added quality is desired in the last layer, an additional or succeeding layer is deposited and then machined off.

JOINT EDGE PREPARATION

Sheet metal is easily melted and does not require special edge preparation. In welding operations involving plate, joint edge preparation and proper spacing between edges are important factors. The thickness of the plates determines the amount of edge preparation required. The faces of square edges can be butted together and welded. You can use this type of joint on plate up to 3/16 of an inch thick. For plate 3/16 to 1/4 of an inch thick, a slight root opening between the parts is necessary to get complete penetration. Plate more than 1/4 of an inch thick requires beveled edges and a root opening of 1/16 of an inch. For oxygas welding on plate more than 1/4 of an inch thick, bevel the edges at an angle of 30 degrees to 45 degrees, making the groove included angle from 60 degrees to 90 degrees. You can prepare the edges by flame cutting, shearing, flame grooving, machining, chipping, or grinding. In any case, the edge surfaces should be free of oxides, scale, dirt, grease, or other foreign matter.

Plate from 3/8 to 1/2 of an inch thick can be welded from one side only, but thicker sections should be welded by preparing the edges on both sides. Generally, butt joints prepared on both sides permit easier welding, produce less distortion, and ensure better weld qualities.

Heavy steel plate is rarely welded with oxygas unless other types of welding equipment are not available. The welding of heavy plate is just not cost effective because of the amount of gas consumed and time used to complete a weld. If at all possible, use a form of electric arc welding because the joint can be welded faster, cheaper, and there is less heat distortion.

OXYGAS WELDING OF FERROUS METALS

Low-carbon steel, low-alloy steel, cast steel, and wrought iron are easily welded by the oxygas process. A flux is not necessary with these metals because their oxides melt at a lower temperature than the base metal.

During the welding process, you should enclose the molten puddle with the flame envelope to ensure the molten metal does not contact the air. If the metal is exposed to the air, it will oxidize rapidly. You also should avoid overheating the metal.

The proper flame adjustment is required to make a good weld. Adjust the flame to a neutral or slightly reducing (carburizing) flame. Do not use an oxidizing flame. Manipulate the torch and rod so the tip of the oxygas cone is about 1/16 to 1/8 of an inch from the surface of the metal. Melt the end of the filler rod in the puddle, not with the flame. The welding of low-carbon steels and cast steels presents no special problems other than the selection of the proper filler rod. Low-alloy steels usually require prewelding and postwelding heat treatment. This heat treatment relieves the stresses developed during the welding phase and produces the desired physical properties of the metal.

As the carbon content of a steel increases, welding becomes more difficult. Steels whose carbon content is within the 0.3-percent to 0.5-percent range are welded with a slightly carburizing flame. These low-carbon steels require postwelding heat treatment to develop their best physical properties.

High-carbon steel and tool steel require a slightly different technique. While protecting the parts from drafts, slowly preheat them to about 1000°F. Complete the weld as rapidly as possible using a carburizing flame and no flux. Do not manipulate either rod or torch and add the filler metal in small amounts, as it is needed. You should use a smaller flame and lower gas pressure than that used for low-carbon steel. This is to ensure you do not overheat the steel. You must heat-treat high-carbon steels and tool steels after welding to develop the physical properties required.

The procedure for oxygas welding of WROUGHT IRON is the same as that for low-carbon or mild steel; however, you should keep several points in mind. Wrought iron contains a slag that was incorporated in it during the manufacturing stage. This slag gives the surface of the molten puddle a greasy appearance. Do not confuse this greasy appearance with the appearance of actual fusion. Continue heating until the sidewalls of the joint break down into the puddle. Best results with wrought iron are obtained when the filler metal (usually mild steel) and base metal are mixed in the molten puddle with a minimum of agitation.

Oxygas welding of CAST IRON is not difficult, but does require a modification of the procedure used with steel. For material that does not exceed 3/16 of an inch

in thickness, you do not need to make a V-groove. Metal that is between 3/16 of an inch and 3/8 of an inch should have a single V-butt joint with an included angle of 60 degrees. For metal over 3/8 of an inch, use a double V-butt joint with 60-degree included angles.

Before you begin welding, preheat the entire weldment to a temperature between 750°F and 900°F. The welding should be done with a neutral flame using the backhand method. Use a cast-iron filler metal and the appropriate flux. The flux is necessary, but use it sparingly as needed. Add filler metal by directing the inner cone of the flame against the rod instead of dipping the tip of the rod into the puddle. The filler metal should be deposited in layers not exceeding 1/8 of an inch thick. Upon completion of the weld, you must stress relieve the weldment by heating it to a temperature between 1100°F and 1150°F and then cool it slowly. Oxygas welding cast iron gives a good color match and good machinability; however, if color match is not essential, a cast-iron repair can be made more easily and economically by braze welding.

Oxygas welding can be used with some CHROMIUM-NICKEL STEELS (STAINLESS STEELS). As a rule, oxygas welding is used only for light sheet; heavier pieces of these steels are usually joined by one of the electric arc welding processes. On material 20 gauge (0.040 of an inch) or less in thickness, a flange equal to the thickness of the metal is turned up and the weld is made without filler metal. Before welding, you should clean the joint surfaces of the metal with sandpaper or other abrasives and then apply a stainless steel flux. The torch tip used for welding stainless steel is usually one or two sizes smaller than the tip used to weld mild steel of the same thickness. Adjust the torch so you have a carburizing flame, as seen through your goggles, with an excess fuel-gas feather extending about 1/16 of an inch beyond the tip of the inner cone. Hold the torch so the flame makes an angle of 80 degrees to the surface of the sheet. The tip of the cone should almost, but not quite touch the molten metal. Make the weld in one pass, using a forehand technique. Do not puddle or retrace the weld. A uniform speed of welding is essential. If it is necessary to stop the welding process or reweld a section, wait until the entire weld has cooled.

OXYGAS WELDING OF NONFERROUS METALS

Although brazing and braze welding are used extensively to make joints in nonferrous metals, there are many situations in which oxygas welding is just as suitable. The joint designs are the same for nonferrous

metals as for ferrous metals in most cases. Oxygas welding of nonferrous metals usually requires mechanical cleaning of the surfaces before welding and the use of flux during welding. Filler metals must be suitable for the base metal being welded. A separate section on aluminum and aluminum alloys is included as part of this chapter since you may need more detailed instructions in welding these materials.

Copper

Pure copper can be welded using the oxygas torch. Where high-joint strength is required you should use DEOXIDIZED copper (copper that contains no oxygen). A neutral flame is used and flux is required when welding copper alloys. Because of the high thermal conductivity of copper, you should preheat the joint area to a temperature ranging between 500°F to 800°F and use a larger size torch tip for welding. The larger size tip supplies more heat to the joint and thus makes it possible to maintain the required temperature at the joint. After welding is completed, cool the part slowly. Other than the extra volume of heat required, the technique for welding copper is the same as for steel.

Copper-Zinc Alloy (Brasses)

Copper-zinc alloys (brasses) can be welded using the same methods as deoxidized copper; however, a silicon-copper rod is used for welding brasses. The rods are usually flux-coated so the use of additional flux is not required. Preheat temperatures for these metals range between 200°F to 300°F.

Copper-Silicon Alloy (Silicon Bronze)

Copper-silicon alloy (silicon bronze) requires a different oxygas welding technique from that used for copper and copper-zinc. You weld this material with a slightly oxidizing flame and use a flux having a high boric acid content. Add filler metal of the same composition as the base metal; as the weld progresses, dip the tip of the rod under the viscous film that covers the puddle. Keep the puddle small so the weld solidifies quickly. A word of caution: when welding copper-zinc, you should safeguard against zinc poisoning by either doing all the welding outdoors or by wearing a respirator or by both, depending on the situation.

Copper-Nickel Alloy

Oxygas welding of copper-nickel alloys requires surface preparation and preheating. The flux used for

this welding is a thin paste and is applied by brush to all parts of the joint and to the welding rod. Adjust the torch to give a slightly carburizing flame; the tip of the inner cone should just touch the base metal. Do not melt the base metal any more than necessary to ensure good fusion. Keep the end of the filler rod within the protective envelope of the flame, adding the filler metal without disturbing the molten pool of weld metal. If possible, run the weld from one end of the joint to the other without stopping. After you complete the weld, cool the part slowly and remove the remaining traces of flux with warm water.

Nickel and High-Nickel Alloys

Oxygas welding of nickel and high-nickel alloys is similar to that for copper-nickel alloys. Good mechanical cleaning of the joint surfaces is essential. The joint designs are basically the same as steel of equivalent thickness. The included angle for V-butt welds is approximately 75 degrees. You may weld plain nickel without a flux, but high-nickel alloys require a special boron-free and borax-free flux. The flux is in the form of a thin paste and should be applied with a small brush. You should flux both sides of the seam, the top and bottom, and the filler rod. Adjust the torch to give a very slightly carburizing flame; the tip selected should be the same size or one size larger than for steel of the same thickness. The flame should be soft and the tip of the cone kept in contact with the molten pool. Use a rod suitable for the base metal, and always keep the rod well within the protective envelope of the flame. After the weld is completed, postheat the part and cool it slowly. Then remove the flux with warm water.

Lead

Oxygas welding of lead requires special tools and special techniques. Although you do not require a flux, you must ensure that the metal in the joint area is scrupulously clean. You may accomplish this by shaving the joint surfaces with a scraper and wire brushing them to remove oxides and foreign matter. In the flat-welding position, a square butt joint is satisfactory. In other positions, a lap joint is used almost exclusively. When you use a lap joint, the edges should overlap each other from 1/2 of an inch to 2 inches, depending upon the thickness of the lead.

To weld lead, use a special, lightweight, fingertip torch, with tips ranging from 68 to 78 in drill size. Adjust your torch to a neutral flame with the gas pressure ranging from 1 1/2 psig to 5 psig, depending on the

thickness of the lead. The length of the flame varies from about 1 1/2 inches to 4 inches, depending upon the gas pressures used. When you are welding in the horizontal and flat positions, a soft, bushy flame is most desirable. But, when you are welding in the vertical and overhead positions, better results are obtained with a more pointed flame.

For oxygas welding of lead, you should ensure that the filler metal has the same composition as the base metal. The molten puddle is controlled and distributed by manipulating the torch so the flame moves in a semicircular or V-shaped pattern. Each tiny segment of the weld is made separately, and the torch is flicked away at the completion of each semicircular or V-shaped movement. Joints are made in thin layers. Filler metal is not added during the first pass, but it is added on subsequent passes.

When welding lead or lead alloys, you should wear a respirator of a type approved for protection against lead fumes.

WARNING

LEAD FUMES ARE POISONOUS.

Aluminum and Aluminum Alloys

When assigned to work with nonferrous metals, you can expect jobs that involve the welding of aluminum and aluminum alloys. Pure aluminum has a specific gravity of 2.70 and a melting point of 1210°F. Pure aluminum is soft and seldom used in its pure form because it is not hard or strong enough for structural purposes; however, the strength of aluminum can be improved by the addition of other elements to form aluminum alloys.

Aluminum alloys are usually 90-percent pure. When elements, such as silicon, magnesium, copper, nickel, and manganese, are added to aluminum, an alloy stronger than mild steel results; whereas pure aluminum is only about one fourth as strong as steel.

A considerable number of aluminum alloys are available. You may use some of the aluminum alloys in sheet form to make and repair lockers, shelves, boxes, trays, and other containers. You also may have to repair chairs, tables, and other items of furniture that are made of aluminum alloys.

Oxygas welding of aluminum alloys is usually confined to materials from 0.031 of an inch to 0.125 of an inch in thickness. Also, thicker material can be welded

by the oxygas process if necessary; however, thinner material is usually spot or seam welded.

MELTING CHARACTERISTICS.— Before attempting to weld aluminum alloy for the first time, you should become familiar with how the metal reacts when under the welding flame.

A good example of how aluminum reacts when heated can be seen if you place a small piece of sheet aluminum on a welding table and heat it with a neutral flame. Hold the flame perpendicular to the surface of the sheet and bring the tip of the inner cone almost in contact with the metal. Observe that almost without warning the metal suddenly melts and runs away, leaving a hole in the sheet. Now repeat the operation with the torch held at an angle of about 30 degrees to the plane of the surface. With a little practice, you will be able to melt the surface metal without forming a hole. Now try moving the flame slowly along the surface of the sheet, melting a small puddle. Observe how quickly the puddle solidifies when the flame is removed. Continue this practice until you are able to control the melting. When you have mastered this, proceed by practicing actual welding. Start with simple flanged and notched butt joints that do not require a welding rod. Next, you should try using a welding rod with thin sheet and then with castings.

WELDING RODS.— Two types of welding rods available for gas welding aluminum alloys are the 1100 and 4043 rods. The 1100 rod is used when maximum resistance to corrosion and high ductility are of primary importance. The 1100 rod is used for welding 1100 and 3003 type aluminum alloys only. The 4043 rod is used for greater strength and minimizes the tendency for cracking. It also is used for all other wrought aluminum alloys and castings.

WELDING FLUXES.— The use of the proper flux in welding aluminum is extremely important. Aluminum welding flux is designed to remove the aluminum oxide by chemically combining with it. In gas welding, the oxide forms rapidly in the molten metal. It must be removed or a defective weld will result. To ensure proper distribution, you should paint flux on the welding rod and the surface to be welded.

Aluminum flux is usually in powder form and is prepared for use by mixing with water to form a paste. The paste should be kept in an aluminum, glass, or earthenware container because steel or copper containers tend to contaminate the mixture.

It is essential that plenty of flux be applied to the edges of flanged joints because no filler rod is used in

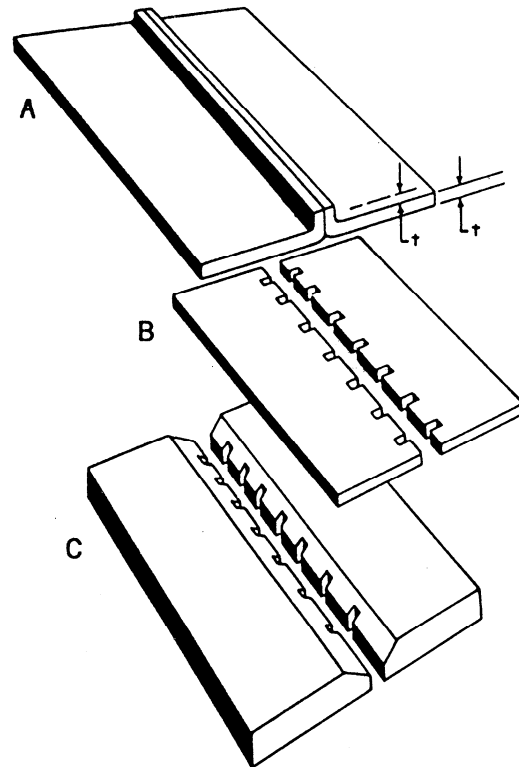


Figure 5-10.—Edge preparation for gas-welding aluminum.

these joints. In all cases, the flux should be applied to both the bottom and top sides of the sheet in the area of the weld. After you finish welding, it is important that you remove all traces of flux. You can do this by using a brush and hot water. If aluminum flux is left on the weld, it will corrode the metal.

WELDING PREPARATION.— The thickness of the aluminum determines the method of edge preparation. On material up to 0.062 of an inch, the edges should be formed to a 90-degree flange. The height of the flange should be about the same height, or a little higher, as the thickness of the material (fig. 5-10, view A). The only requirement for the flanges is that their edges be straight and square. If desired, material up to 0.125 of an inch can be welded with a flange joint. No filler rod is necessary if you flange the edges.

Unbeveled butt welds can be made on thicknesses from 0.062 of an inch to 0.188 of an inch; but in these applications, it is necessary to notch the edges with a saw or cold chisel in a manner similar to that shown in view B of figure 5-10. Edge notching is recommended in aluminum welding because it aids in getting full penetration and prevents local distortion. All butt welds made in material over 0.125 of an inch thick are usually notched in some manner.

In welding aluminum more than 0.188 of an inch thick, bevel the edges and notch them, as shown in view C of figure 5-10. The included angle of bevel maybe from 90 to 120 degrees.

After you have prepared the edges of the pieces properly, you should then clean the surfaces to be welded. If heavy oxide is present on the metal surface, you may have to use a stainless-steel wire brush to remove it. Dirt, grease, or oil can be removed by wiping the weld area with a solvent-soaked rag.

Aluminum plate 1/4 of an inch thick or greater should be preheated to a temperature ranging between 500°F to 700°F. This aids in avoiding heat stresses. Preheating also reduces fuel and oxygen requirements for the actual welding. It is important that the preheating temperature does exceed 700°F. If the temperature does go above 700°F, the alloy maybe severely weakened. High temperatures also could cause large aluminum parts to collapse under their own weight. Thin material should be warmed with the torch before welding. This slight preheat helps to prevent cracks.

WELDING TECHNIQUES.— After preparing and fluxing the pieces for welding, you should pass the flame, in small circles, over the starting point until the flux melts. Keep the inner cone of the flame off the flux to avoid burning it. If the inner cone of the flame should burn the flux, it will be necessary to clean the joint and apply new flux. Next, scrape the rod over the surface at about 3- or 4-second intervals, permitting the rod to come clear of the flame each time. If you leave the rod in the flame too long, it melts before the parent metal does. The scraping action indicates when you can start welding without overheating the metal. Maintain this cycle throughout the course of welding except for allowing the rod to remain under the flame long enough to melt the amount of metal needed. With practice, the movement of the rod can be easily mastered.

Forehand welding is usually preferred for welding aluminum alloys because the flame points away from the completed weld, and this preheats the edges to be welded that prevents too rapid melting. Hold the torch at a low angle when you are welding thin material. For thicknesses 0.188 of an inch and above, you should increase the angle of the torch to a near vertical position. Changing the angle of the torch according to the thickness of the metal minimizes the possibility of burning through the sheet during welding.

When welding aluminum alloys up to 0.188 of an inch thick, you have little need to impart any motion to the torch other than moving it forward. On flanged

material, care must be taken to break the oxide film as the flange melts down. This may be done by stirring the melted flange with a puddling rod. A puddling rod is essentially a paddle flattened and shaped from a 1/4-inch stainless steel welding rod.

With aluminum alloys above 0.188 of an inch in thickness, you should give the torch a more uniform lateral motion to distribute the weld metal over the entire width of the weld. A slight back-and-forth motion assists the flux in its removal of oxides. Dip the filler rod in the weld puddle with a forward motion.

The angle of the torch is directly related to the welding speed. Instead of lifting the flame from time to time to avoid melting holes in the metal, you will find it advantageous to hold the torch at a flatter angle to the work. The welding speed should be increased as the edge of the sheet is approached. The inner cone of the flame should never be permitted to come in contact with the molten metal, but should be held about 1/8 of an inch away from the metal.

In the vertical position, the torch is given an up-and-down motion, rather than a rotating one. In the overhead position, a slight back-and-forth motion is used the same as in flat welding.

Heat-treatable alloys should be held in a jig for welding, whenever possible. This helps to eliminate the possibility of cracking. The likelihood of cracking can also be reduced by the use of a 4043 filler rod. This rod has a lower melting range than the alloy being joined which permits the base metal to solidify before the weld puddle freezes. As the weld is the last area to solidify, all of the contraction strains are in the weld bead, rather than throughout the base metal. You may reduce weld cracking by tack welding the parts while they are in the jig and then loosening the clamps before completing the seam.

As soon as the weld is completed and the work has had time to cool, you should thoroughly wash the weld. This can be done by vigorously scrubbing it with a stiff brush while hot water runs over it until all traces of the flux are removed. This is important, because if any flux is left on the weld, it can corrode the metal. If hot water is not available, you may use a diluted solution of 10 percent sulfuric acid. The acid solution should then be washed off with cold, fresh water after using.

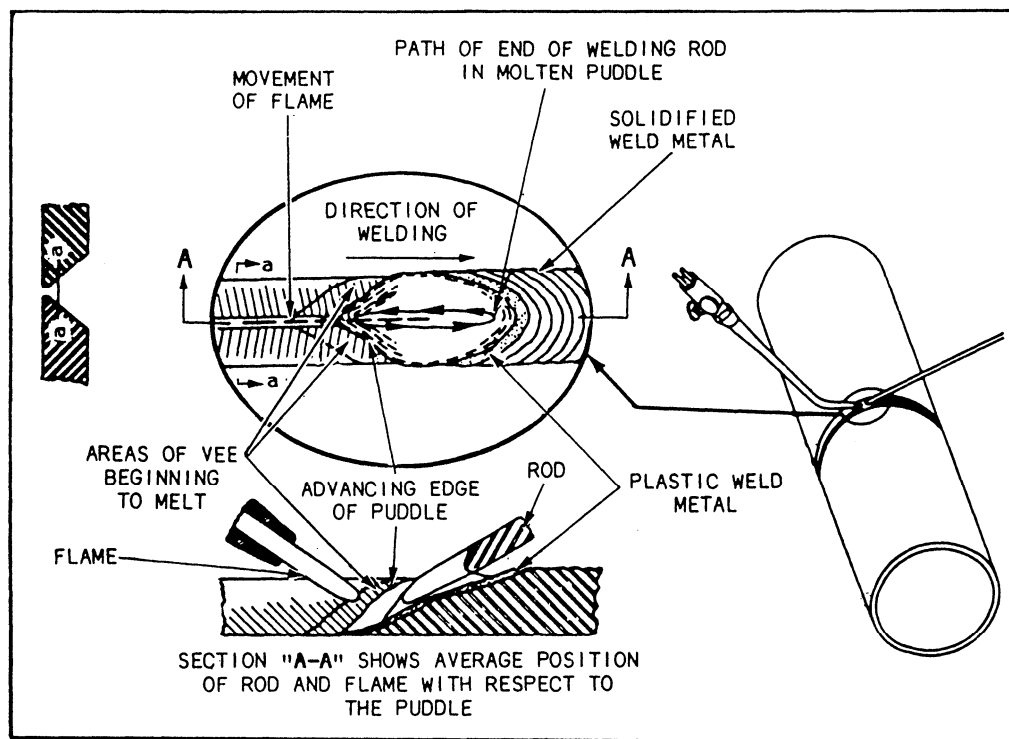


Figure 5-11.—Welding operation with backhand technique.

FUSION WELDING PIPE

In oxygas welding of pipe, many tests have proved that fusion welded pipe joints, when properly made, are as strong as the pipe itself.

For success in oxygas welding of pipe, three essential requirements must be met: there must be a convenient source of controlled heat available to produce rapid localized melting of the metal, the oxides present on the surface or edges of the joints must be removed, and a metal-to-metal union between the edges or surfaces to be joined must be made by means of molten metal.

One method used for welding steel and wrought iron pipe is known as *FUSION WELDING*. This method involves melting the pipe metal and adding metal from a rod of similar composition. The welding operation performed at the top of a joint in a horizontal pipe is shown diagrammatically in figure 5-11. This shows the BACKHAND welding technique. The rod and flame are moved alternately toward and away from each other, as shown in figure 5-12. Full strength oxygas welds can be made in any welding position.

The cohesiveness of the molten metal, the pressure of the flame, the support of the weld metal already deposited, and the manipulation of the rod all combine

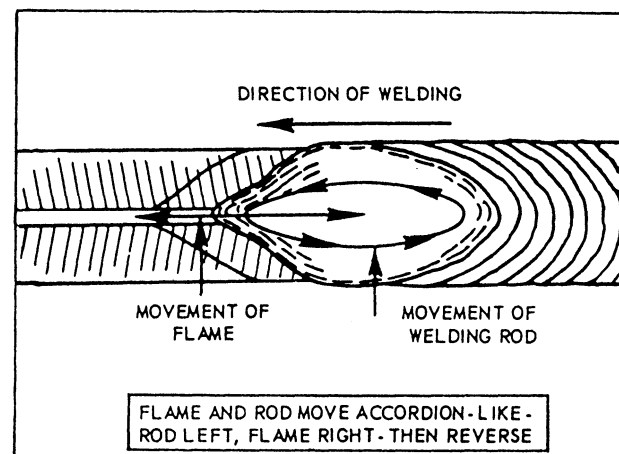


Figure 5-12.—Flame and rod motion with backhand technique.

to keep the molten metal in the puddle from running or falling.

The soundness and strength of welds depend on the quality of the welding rod used. If you have any doubt about the quality of the rods or are not sure of the type to use, then it would be to your advantage to contact the manufacturer or one of his distributors. If the rod is supplied through the federal stock system, supply personnel should be able to look up the information based on the federal stock number of the rod.

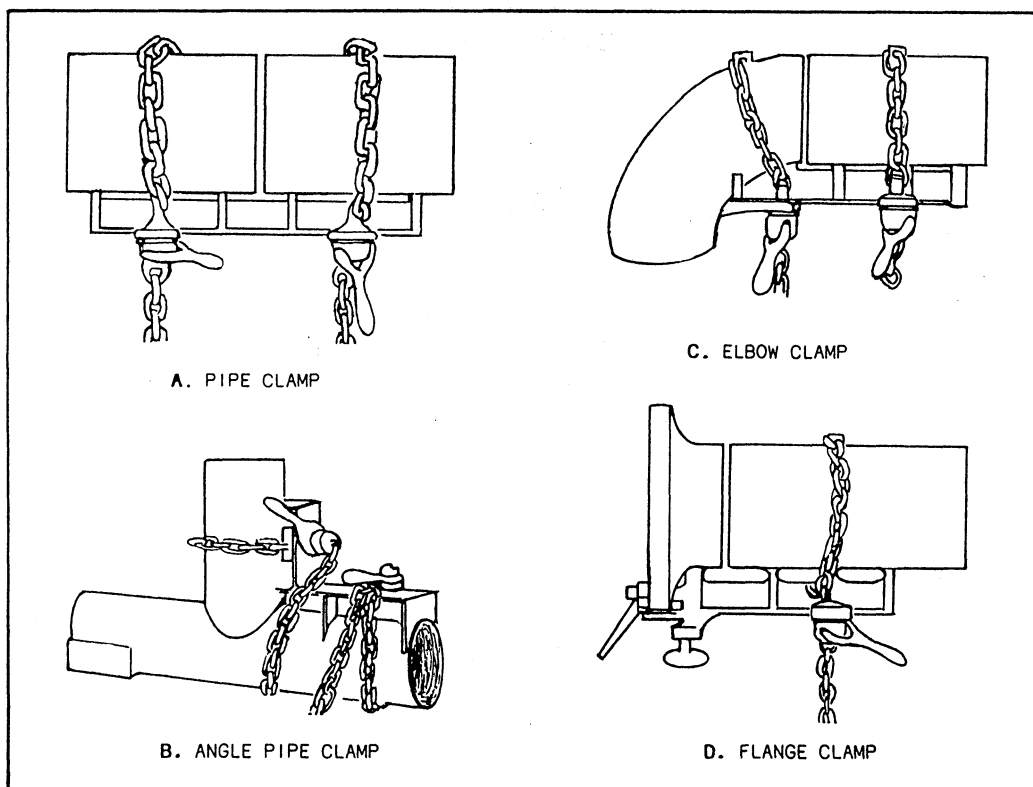


Figure 5-13.—Chain clamps quickly align pipe fittings of any description.

The Linde Company has a method of fusion welding that is remarkably fast and produces welds of high quality. Anyone can use this process for welding pipe if they adhere to the following conditions:

1. Use an excess fuel-gas flame.
2. Use a welding rod containing deoxidizing agents.
3. Use the backhand welding technique.

The following is a brief explanation of the previously mentioned conditions:

1. **EXCESS FUEL-GAS FLAME.** The base metal surface, as it reaches white heat, absorbs carbon from the excess fuel-gas flame. The absorption of carbon lowers the melting point of steel, thereby the surface melts faster and speeds up the welding action.

2. **SPECIAL WELDING ROD.** The deoxidizing agents in the recommended rod eliminates the impurities and prevents excess oxidation of carbon. Were it not for this action, considerable carbon, the most valuable strengthening element of steel, would be lost.

Thus, even in high-carbon, high-strength pipe, the weld metal is as strong as, or stronger than the pipe material.

3. **BACKHAND TECHNIQUE.** This technique produces faster melting of the base metal surfaces. Also, a smaller bevel can be used which results in a savings of 20 to 30 percent in welding time, rods, and gases.

One of the most valuable tools you can use when welding pipe is the pipe clamp. Pipe clamps hold the pipe in perfect alignment until tack welds are placed. They are quick opening and you can move or attach a clamp quickly.

Figure 5-13 shows four different types of chain clamps that are used for pipe welding. If these clamps are not available, you can fabricate your own by welding two C-clamps to a piece of heavy angle iron. A piece of 3/8-inch angle iron that is 4 inches by 4 inches by 12 inches is usually suitable. When working with small-diameter pipe, you can lay it in a piece of channel iron to obtain true alignment for butt welding. When the pipe you are working on has a large diameter, you can use a wide flange beam for alignment purposes.