CHAPTER 6

SOLDERING, BRAZING, BRAZE WELDING, AND WEARFACING

The information presented in chapter 5 covered the joining of metal parts by the process of fusion welding. In this chapter, procedures that do not require fusion are addressed. These procedures are as follows: soldering, brazing, braze welding, and wearfacing. These procedures allow the joining of dissimilar metals and produce high-strength joints. Additionally, they have the important advantages of not affecting the heat treatment or warping the original metal as much as conventional welding.

SOLDERING

Soldering is a method of using a filler metal (commonly known as solder) for joining two metals without heating them to their melting points. Soldering is valuable to the Steelworker because it is a simple and fast means for joining sheet metal, making electrical connections, and sealing seams against leakage. Additionally, it is used to join iron, nickel, lead, tin, copper, zinc, aluminum, and many other alloys.

Soldering is not classified as a welding or brazing process, because the melting temperature of solder is below 800°F. Welding and brazing usually take place above 800°F. The one exception is lead welding that occurs at 621°F. Do not confuse the process of SILVER SOLDERING with soldering, for this process is actually a form of brazing, because the temperature used is above 800°F.

This chapter describes the following: equipment and materials required for soldering, the basic methods used to make soldered joints, and the special techniques required to solder aluminum alloys.

EQUIPMENT

Soldering requires very little equipment. For most soldering jobs, you only need a heat source, a soldering copper or iron, solder, and flux.

Sources of Heat

The sources of heat used for soldering vary according to the method used and the equipment available. Welding torches, blow-torches, forges, and furnaces are some of the sources of heat used. Normally, these heating devices are used to heat the soldering coppers that supply the heat to the metal surfaces and thus melt the solder. Sometimes, the heating devices are used to heat the metal directly. When this is done, you must be careful to prevent heat damage to the metal and the surrounding material.

SOLDERING COPPERS.— A soldering copper (usually called a soldering iron) consists of a forged copper head and an iron rod with a handle. (See fig. 6-1.)

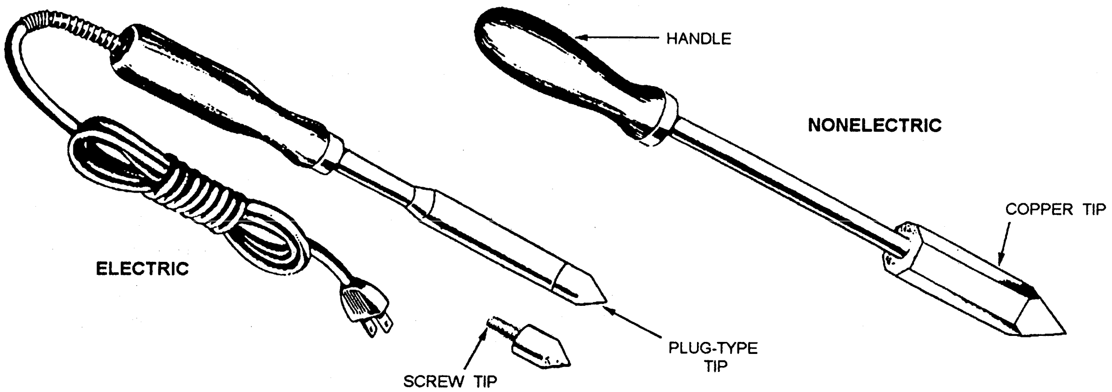

Figure 6-1.—Soldering irons.

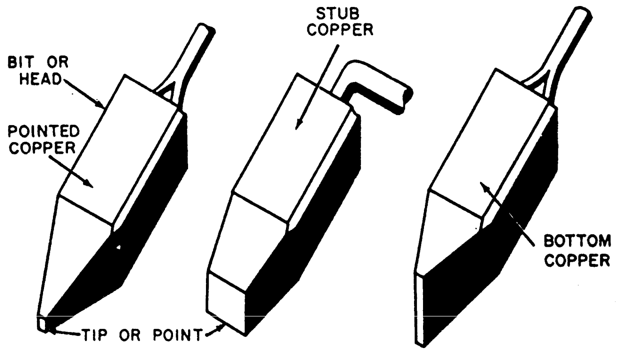

Figure 6-2.—Soldering copper heads.

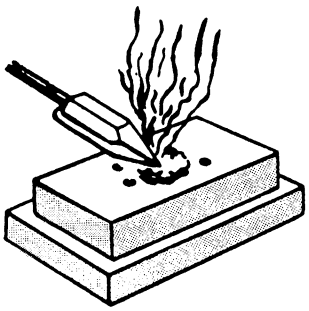

Figure 6-4.—Tinning a copper (solder placed on cake of sal ammoniac).

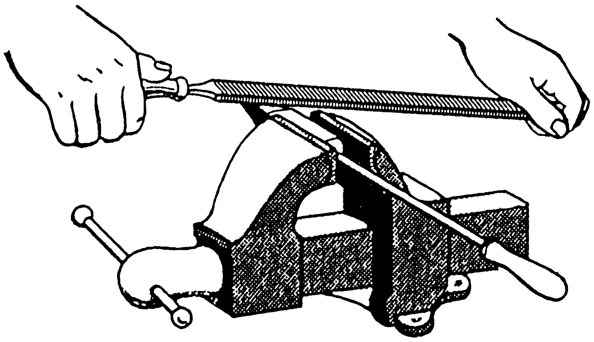

Figure 6-3.—Filing a soldering copper.

The handle, which may be wood or fiber, is either forced or screwed onto the rod.

Soldering heads are available in various shapes. Figure 6-2 shows three of the more commonly used types. The pointed copper is for general soldering work The stub copper is used for soldering flat seams that need a considerable amount of heat. The bottom copper is used for soldering seams that are hard to reach, such as those found in pails, pans, trays, and other similar objects.

Nonelectrical coppers are supplied in pairs. This is done so one copper can be used as the other is being heated. The size designation of coppers refers to the weight (in pounds) of TWO copperheads; thus a reference to a pair of 4-pound coppers means that each copper head weighs 2 pounds. Pairs of coppers are usually supplied in 1-pound, 1 1/2-pound, 3-pound, 4-pound, and 6-pound sizes. Heavy coppers are designed for soldering heavy gauge metals, and light coppers are for thinner metals. Using the incorrect size of copper usually results in either poorly soldered joints or overheating.

Filing and Tinning Coppers.— New soldering coppers must be tinned (coated with solder) before use. Also, coppers must be filed and retinned after overheating or for any other reason that caused the loss of their solder coating. The procedure for filing and tinning a copper is as follows:

1. Heat the copper to a cherry red.

2. Clamp the copper in a vise, as shown in figure 6-3.

3. File the copper with a single-cut bastard file. Bear down on the forward stroke, and release pressure on the return stroke. Do not rock the file. Continue filing the tapered sides of the copper until they are bright and smooth.

CAUTION

Remember that the copper is hot! Do not touch it with your bare hands.

4. Smooth off the point of the copper and smooth off any sharp edges.

5. Reheat the copper until it is hot enough to melt the solder.

6. Rub each filed side of the copper back and forth across a cake of sal ammoniac, as shown in figure 6-4.

7. Apply solder to the copper until it is tinned. You may rub the solder directly onto the copper, or place it on the cake of sal ammoniac. Do not push the iron into the cake of sal ammoniac, because this can split the cake.

When sal ammoniac is not available, use powdered rosin instead. In this instance, place the powdered rosin on top of a brick. Rub the copper back and forth to pick up the rosin and then place the solder directly onto the copper. (See fig. 6-5.)

Commercially prepared soldering salts are also used in tinning soldering coppers. These salts are available in

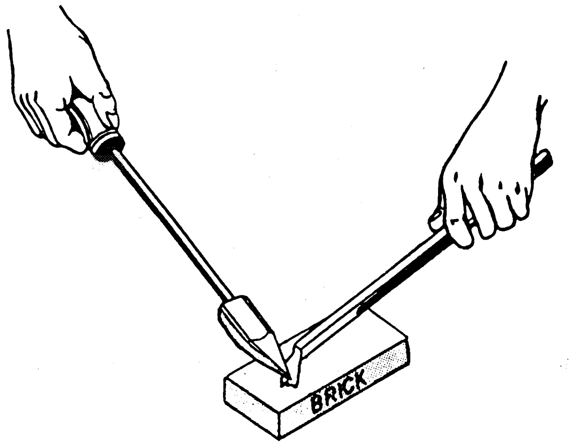

Figure 6-5.—Tinning a copper (solder placed directly on copper).

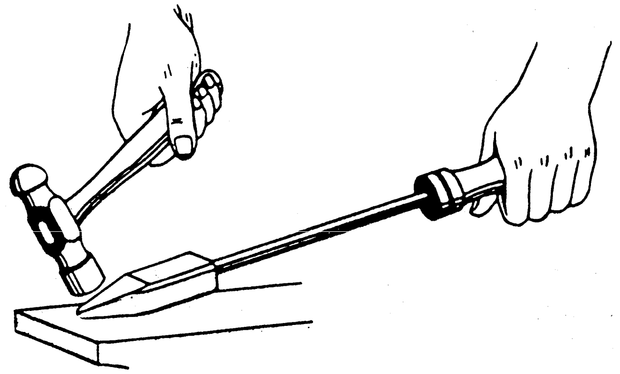

Figure 6-6.—Forging a soldering copper.

powder form. Dissolve the powder in water according to the directions and dip the soldering copper into the solution and then apply the solder.

Forging Soldering Coppers.— Soldering coppers may be reshaped by forging when they become blunt or otherwise deformed. The procedure for forging a copper is as follows:

1. File the copper to remove all old tinning and to smooth the surfaces.

2. Heat the copper to a bright red.

3. Hold the copper on an anvil and forge it to the required shape by striking it with a hammer. (See fig. 6-6.) As you reshape the copper, a hollow will appear at the point. Keep this hollow to a minimum by striking the end of the copper. Do not shape too long a taper or sharp point, because this causes the copper to cool too rapidly. Turn the copper often to produce the necessary squared-off sides and reheat the copper as often as necessary during this part of the forging.

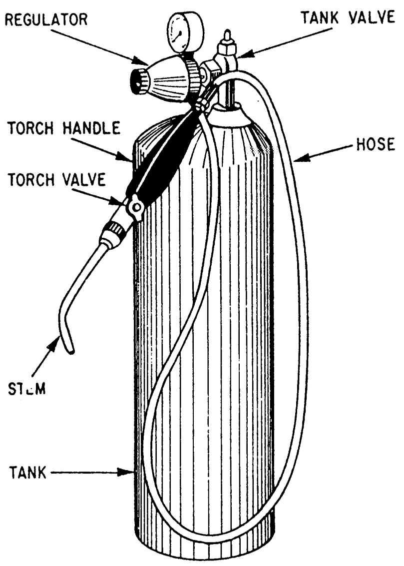

Figure 6-7.—Presto-lite heating unit.

4. Reheat the copper to a bright red, and use a flat-faced hammer to remove as many hollows as possible.

5. File and tin the copper using the previously described procedure.

ELECTRIC SOLDERING COPPERS.— Electric soldering coppers, or soldering irons, as they sometimes are called, are built with internal heating coils. The soldering heads are removable and interchangeable. Tinning is basically the same with the exception that the tip usually does not become cherry red. Forging or reshaping is not necessary, because the heads are easily replaced.

Electric soldering irons are usually used for electrical work or other small jobs. They are especially suited for this type of work, because they do not require auxiliary heating and they can be manufactured as small as a pencil.

GAS TORCHES.— Gas torches can be used in combination with soldering head attachments or as a direct heat source. The Presto-lite heating unit is ideal for soft soldering, because it delivers a small controllable flame. It also may be used effectively to heat soldering coppers. As figure 6-7 shows, this heating unit includes a fuel tank regulator, hose, and torch. It burns acetylene or MAPP gas as fuel in the presence of oxygen. The torch tip (stem) is interchangeable with other tips that come with the unit.

Soft Solder

There are many different types of solder being used by industry. Solders are available in various forms that include bars, wires, ingots, and powders. Wire solders are available with or without a flux core. Because of the many types of solder available, this chapter only covers the solders most commonly used by Steelworkers.

TIN-LEAD SOLDER.— The largest portion of all solders in use is solders of the tin-lead alloy group. They have good corrosion resistance and can be used for joining most metals. Their compatibility with soldering processes, cleaning, and most types of flux is excellent. In describing solders, it is the custom of industry to state the tin content first; for example, a 40/60 solder means to have 40% tin and 60% lead.

Tin-lead alloy melting characteristics depend upon the ratio of tin to lead. The higher the tin content, the lower the melting temperature. Tin also increases the wetting ability and lowers the cracking potential of the solder.

The behavior of tin-lead solder is shown by the diagram in figure 6-8. This diagram shows that 100% lead melts at 621°F and 100% tin melts at 450°F. Solders that contain 19.5% to 97.5% tin remain a solid until they exceed 360°F. The eutectic composition for tin-lead solder is about 63% tin and 37% lead. (“Eutectic” means the point in an alloy system that all the parts melt at the same temperature.) A 63/37 solder becomes completely liquid at 361°F. Other compositions do not. Instead, they remain in the pasty stage until the temperature increases to the melting point of the other alloy. For instance, 50/50 solder has a solid temperature of 361°F and a liquid temperature range of 417°F. The pasty temperature range is 56°F—the difference between the solid and the liquid.

Solders with lower tin content are less expensive and primarily used for sheet metal products and other high-volume solder requirements. High tin solders are extensively used in electrical work. Solders with 60% tin or more are called fine solders and are used in instrument soldering where temperatures are critical.

TIN-ANTIMONY-LEAD SOLDER.— Antimony is added to a tin-lead solder as a substitute for some of the tin. The antimony, up to 6%, increases the strength and mechanical properties of the solder. A word of caution, solders having a high antimony content should not be used on aluminum, zinc, or zinc-coated materials. They form an intermetallic compound of zinc and antimony that causes the solder to become very brittle.

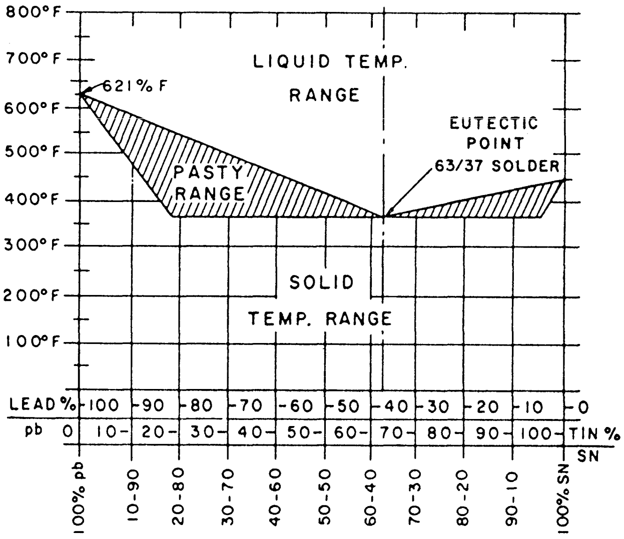

Figure 6-8.—Tin-lead alloy constitutional diagram.

TIN-ZINC SOLDER.— Several tin-zinc solders have come into use for the joining of aluminum alloys. The 91/9 and 60/40 tin-zinc solders are for higher temperature ranges (above 300°F), and the 80/20 and 70/30 tin-zinc alloys are normally used as precoating solders.

LEAD-SILVER SOLDER.— Lead-silver solders are useful where strength at moderately high temperatures is required. The reason lead by itself cannot be used is that it does not normally wet steel, cast iron, or copper and its alloys. Adding silver to lead results in alloys that more readily wet steel and copper. Flow characteristics for straight lead-silver solders are rather poor, and these solders are susceptible to humidity and corrosion during storage. The wetting and flow characteristics can be enhanced as well as an increased resistance to corrosion by introducing a tin content of 1%.

Lead-silver solders require higher soldering temperatures and special fluxing techniques. The use of a zinc-chloride base flux or uncoated metals is recommended, because rosin fluxes decompose rapidly at high temperatures.

TIN-ANTIMONY SOLDER.— Tin-antimony solders are used for refrigeration work or for joining copper to cast-iron joints. The most common one is the 95/5 solder.

TIN-SILVER SOLDER.— Tin-silver solder (96/4) is used for food or beverage containers that must be cadmium and lead-free. It also can be used as a replacement for tin-antimony solder (95/5) for refrigeration work

Table 6-1.—Fluxes Used for Soldering Some Common Metals

Metals	Fluxes
Brass, copper, tin	Rosin
Lead	Tallow, rosin
Iron, steel	Borax sal ammoniac
Stainless steel and other nickel alloys	Phosphenic acid
Galvanized iron	Zinc chloride
Zinc	Zinc chloride
Aluminum	Stearine, special flux

These solders and the procedures for their use are also listed in the *Welding Materials Handbook*, NAVFAC, P-433.

Fluxes

Scale, rust, and oxides form on most metal surfaces when exposed to air, and heating accelerates this formation. Solder will not adhere to or wet the metal unless these pollutants are removed. Fluxes are chemical compounds used to clean and maintain the metal surfaces during the soldering process. They also decrease the surface tension of the solder, making it abetter wetting agent. Fluxes are manufactured in cake, paste, liquid, or powder form and are classified as either noncorrosive or corrosive. Table 6-1 shows the fluxes that are normally used for soldering common metals.

NONCORROSIVE FLUXES.— Noncorrosive fluxes are for soldering electrical connections and for other work that must be free of any trace of corrosive residue. Rosin is the most commonly used noncorrosive flux. In the solid state, rosin is inactive and noncorrosive. When heated, it melts and provides some fluxing action. Rosin is available in powder, paste, or liquid form.

Rosin fluxes frequently leave a brown residue. This residue is nonconductive and sometimes difficult to remove. The removal problem can be reduced by adding a small amount of turpentine to the rosin. Glycerine is added to the rosin to make the flux more effective.

CORROSIVE FLUXES.— Corrosive fluxes have the most effective cleaning action, but any trace of corrosive flux that remains on the work can cause corrosion later. For this reason, corrosive fluxes are not used on electrical connections or other work where corrosion would cause a serious problem.

The most commonly used corrosive fluxes are sal ammoniac (ammonium chloride) and zinc chloride. These fluxes are frequently used in either solution or in paste form. The solvent, if present, evaporates as the work heats, leaving a layer of solid flux on the work. When the metal reaches the soldering temperature, this layer of flux melts, partially decomposes, and liberates hydrochloric acid. The hydrochloric acid dissolves the oxides from the work surfaces and the solder, making them ready for soldering.

Zinc chloride (sometimes called **CUT ACID** or **KILLED ACID)** can be made in the shop as long as safety precautions are followed. To prepare zinc chloride, pour a small amount of muriatic acid (the commercial form of hydrochloric acid) into a glass or acid-resistant container and then add small pieces of zinc. As you add the zinc, the acid boils and bubbles as a result of a chemical reaction that produces zinc chloride and hydrogen gas. Keep adding small pieces of zinc to the mixture until the liquid no longer boils and bubbles. At this point, the reaction is complete and you then dilute the liquid in the container with an equal amount of water. Make only enough as required and strain it before use. If any is leftover, store it in a tightly sealed glass container.

WARNING

> When diluting the acid, you always add the acid to the water. Adding water to acid can result in an explosive reaction, resulting in serious injuries.

Specific precautions must be taken when preparing zinc chloride. Rubber gloves, a full-face visor, and an apron are required. The fumes given off by muriatic acid or by the mixture of muriatic acid and zinc are a health hazard as well as an explosive. Prepare zinc chloride under a ventilation hood, out in the open, or near openings to the outside to reduce inhalation of the fumes or the danger of explosion. It is essential that precautions be taken to prevent flames or sparks from coming in contact with the liberated hydrogen.

Another type of corrosive flux in use is known as **SOLDERING SALTS.** Commercially prepared soldering salts are normally manufactured in a powder form that is water soluble that allows you to mix only the amount needed.

After a corrosive flux has been used for soldering, you should remove as much of the flux residue as possible from the work. Most corrosive fluxes are water soluble; therefore, washing the work with soap and water and then rinsing thoroughly with clear water usually removes the corrosive residue. To lessen damage, you should ensure the work is cleaned immediately after the soldering.

SOLDERING TECHNIQUES

The two soldering methods most often used are soldering with coppers or torch soldering. The considerations that apply to these methods of soldering are as follows:

1. Clean all surfaces of oxides, dirt, grease, and other foreign matter.

2. Use the proper flux for the particular job. Some work requires the use of corrosive fluxes, while other work requires the use of noncorrosive fluxes. Remember, the melting point of the flux must be BELOW the melting point of the solder you are going to use.

3. Heat the surfaces just enough to melt the solder. Solder does not stick to unheated surfaces; however, you should be very careful not to overheat the solder, the soldering coppers, or the surfaces to be joined. Heating solder above the work temperature increases the rate of oxidation and changes the proportions of tin and lead.

4. After making a soldered joint, you should remove as much of the corrosive flux as possible.

Sweat Soldering

Sweat soldering is used when you need to make a joint and not have the solder exposed. You can use this process on electrical and pipe connections. To make a sweated joint, you should clean, flux, and tin each adjoining surface. Hold the pieces firmly together and heat the joint with a soldering copper or a torch until the solder melts and joins the pieces together. Remove the source of heat and keep the parts firmly in position until the solder has completely hardened. Cleaning any residue from the soldered area completes the job.

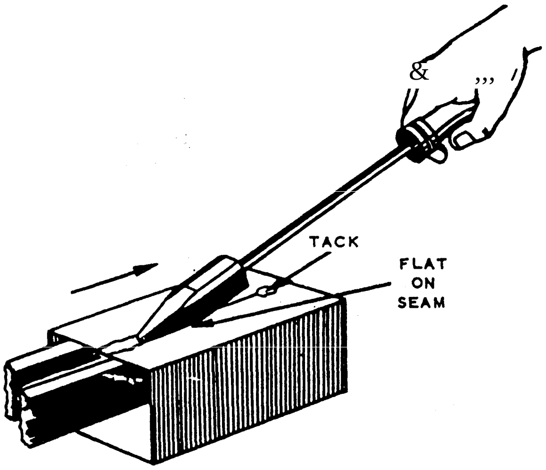

Figure 6-9.—Soldering a seam.

Seam Soldering

Seam soldering involves running a layer of solder along the edges of a joint. Solder seam joints on the inside whenever possible. The best method to use for this process is soldering coppers, because they provide better control of heat and cause less distortion.

Clean and flux the areas to be soldered. If the seam is not already tacked, grooved, riveted, or otherwise held together, tack the pieces so the work stays in position. Position the piece so the seam does not rest directly on the support. This is necessary to prevent loss of heat to the support. After you have firmly fastened the pieces together, solder the seam.

Heat the area by holding the copper against the work. The metal must absorb enough heat from the copper to melt the solder, or the solder will not adhere. Hold the copper so one tapered side of the head is flat against the seam, as shown in figure 6-9. When the solder begins to flow freely into the seam, draw the copper along the seam with a slow, steady motion. Add as much solder as necessary without raising the copper from the work. When the copper becomes cold, you should use the other copper and reheat the first one. Change coppers as often as necessary. Remember, the best soldered seams are made without lifting the copper from the work and without retracing completed work. Allow the joint to cool and the solder to set before

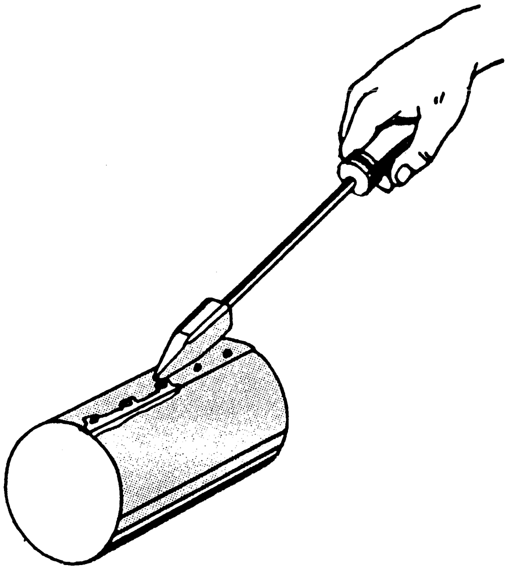

Figure 6-10.—Soldering a riveted seam.

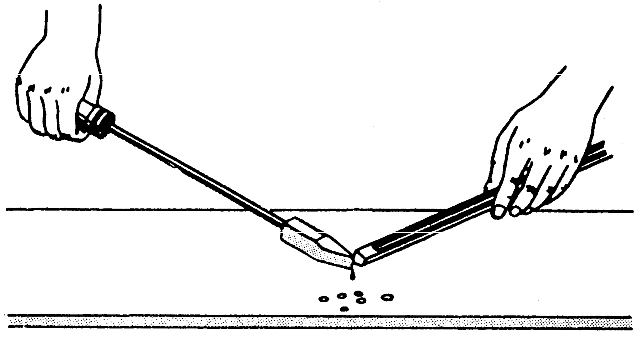

Figure 6-11.—Making solder beads.

moving the joint. When you use a corrosive flux, clean the joint by rinsing it with water and then brushing or wiping it with a clean, damp cloth.

Riveted seams are often soldered to make them watertight. Figure 6-10 shows the procedure for soldering a riveted seam.

Solder beads, or solder shots, are sometimes used for soldering square, rectangular, or cylindrical bottoms. To make the solder beads, hold the solder against a hot copper and allow the beads to drop onto a clean surface, as shown in figure 6-11.

To solder a bottom seam with solder beads, you should first flux the seam before dropping one of the cold beads of solder into the container. Place the hot soldering copper against the seam, as shown in figure 6-12. Hold the copper in one position until the solder starts to flow freely into the seam. Draw the copper slowly along the seam, turning the work as you go. Add more beads as you need them and reheat the copper as necessary.

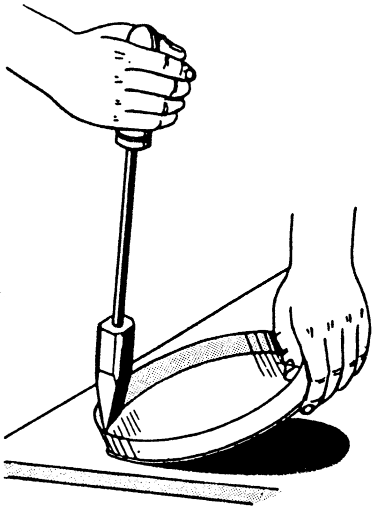

Figure 6-12.—Soldering a bottom seam.

To heat an electric soldering copper, you merely plug it in. Otherwise, the procedure is much the same as that just described. Be very careful not to let an electric soldering copper overheat. Overheating can burn out the electrical element as well as damage the copper and tinning,

Soldering Aluminum Alloys

Soldering aluminum alloys is more difficult than soldering many other metals. The difficulty arises primarily from the layer of oxide that always covers aluminum alloys. The thickness of the layer depends on the type of alloy and the exposure conditions.

Using the proper techniques, many of the aluminum alloys can be successfully soldered. Wrought aluminum alloys are usually easier to solder than cast aluminum alloys. Heat-treated aluminum alloys are extremely difficult to solder, as are aluminum alloys containing more than 1% magnesium.

The solders used for aluminum alloys are usually tin-zinc or tin-cadmium alloys. They are generally called **ALUMINUM SOLDERS.** Most of these solders have higher melting points than the tin-lead solders used for ordinary soldering. Corrosive and noncorrosive fluxes are used for soldering aluminum.

The first step in soldering aluminum is to clean the surfaces and remove the layer of oxide. If a thick layer of oxide is present, you should remove the main part of it mechanically by filing, scraping, sanding, or wire brushing. A thin layer of oxide can often be removed by using a corrosive flux. Remember, remove any residual flux from the joint after the soldering is finished.

After cleaning and fluxing the surfaces, you should tin the surfaces with aluminum solder. Apply flux to the work surfaces and to the solder. You can tin the surfaces with a soldering copper or with a torch. If you use a torch, do not apply heat directly to the work surfaces, to the solder, or to the flux. Instead, play the torch on a nearby part of the work and let the heat conduct through the metal to the work area. Do not use more heat than is necessary to melt the solder and tin the surfaces. Work the aluminum solder well into the surfaces. After tinning the surfaces, the parts may be sweated together.

Another procedure you can use for soldering aluminum alloys is to tin the surfaces with an aluminum solder and then use a regular tin-lead solder to join the tinned surfaces. This procedure can be used when the shape of the parts prevents the use of the sweating method or demands a large amount of solder. When using tin-lead solder with aluminum solder, you do not have to use flux.

After soldering is complete, you should clean the joints with a wire brush, soap and water, or emery cloth. Ensure that you remove all the flux from the joint since any flux left will cause corrosion.

BRAZING

Brazing is the process of joining metal by heating the base metal to a temperature above 800°F and adding a nonferrous filler metal that melts below the base metal. Brazing should not be confused with braze welding, even though these two terms are often interchanged. In brazing, the filler metal is drawn into the joint by capillary action and in braze welding it is distributed by tinning. Brazing is sometimes called hard soldering or silver soldering because the filler metals are either hard solders or silver-based alloys. Both processes require distinct joint designs.

Brazing offers important advantages over other metal-joining processes. It does not affect the heat treatment of the original metal as much as welding does, nor does it warp the metal as much. The primary advantage of brazing is that it allows you to join dissimilar metals.

EQUIPMENT

Brazing requires three basic items. You need a source of heat, filler metals, and flux. In the following paragraphs these items are discussed.

Heating Devices

The source of heat depends on the type and amount of brazing required. If you are doing production work and the pieces are small enough, they can be put into a furnace and brazed all at once. Individual torches can be mounted in groups for assembly line work, or you can use individual oxyacetylene or Mapp-oxygen torches to braze individual items.

Filler Metals

Filler metals used in brazing are nonferrous metals or alloys that have a melting temperature below the adjoining base metal, but above 800°F. Filler metals must have the ability to wet and bond with the base metal, have stability, and not be excessively volatile. The most commonly used filler metals are the silver-based alloys. Brazing filler metal is available in rod, wire, preformed, and powder form.

Brazing filler metals include the following eight groups:

1. Silver-base alloys
2. Aluminum-silicon alloys
3. Copper
4. Copper-zinc (brass) alloys
5. Copper-phosphorus alloys
6. Gold alloys
7. Nickel alloys
8. Magnesium alloys

Fluxes

Brazing processes require the use of a flux. Flux is the substance added to the metal surface to stop the formation of any oxides or similar contaminants that are formed during the brazing process. The flux increases both the flow of the brazing filler metal and its ability to stick to the base metal. It forms a strong joint by bringing the brazing filler metal into immediate contact with the adjoining base metals and permits the filler to penetrate the pores of the metal.

You should carefully select the flux for each brazing operation. Usually the manufacturer's label specifies the type of metal to be brazed with the flux. The following factors must be considered when you are using a flux:

- Base metal or metals used
- Brazing filler metal used
- Source of heat used

Flux is available in powder, liquid, and paste form. One method of applying the flux in powdered form is to dip the heated end of a brazing rod into the container of the powdered flux, allowing the flux to stick to the brazing rod. Another method is to heat the base metal slightly and sprinkle the powdered flux over the joint, allowing the flux to partly melt and stick to the base metal. Sometimes, it is desirable to mix powdered flux with clean water (distilled water) to form a paste.

Flux in either the paste or liquid form can be applied with a brush to the joint. Better results occur when the filler metal is also given a coat.

The most common type of flux used is borax or a mixture of borax with other chemicals. Some of the commercial fluxes contain small amounts of phosphorus and halogen salts of either iodine, bromine, fluorine, chlorine, or astatine. When a prepared flux is not available, a mixture of 12 parts of borax and 1 part boric acid may be used.

WARNING

> Nearly all fluxes give off fumes that may be toxic. Use them only in WELL-VENTILATED spaces.

JOINT DESIGN

In brazing, the filler metal is distributed by capillary action. This requires the joints to have close tolerances and a good fit to produce a strong bond. Brazing has three basic joint designs (fig. 6-13): lap, butt, and scarf. These joints can be found in flat, round, tubular, or irregular shapes.

Lap Joints

The lap joint is one of the strongest and most frequently used joint in brazing, especially in pipe work The primary disadvantage of the lap joint is the increase in thickness of the final product. For maximum strength, the overlap should be at least three times the thickness of the metal. A 0.001-inch to 0.003-inch clearance between the joint members provides the greatest strength with silver-based brazing filler metals. You should take precautions to prevent heat expansion from closing joints that have initial close tolerances.

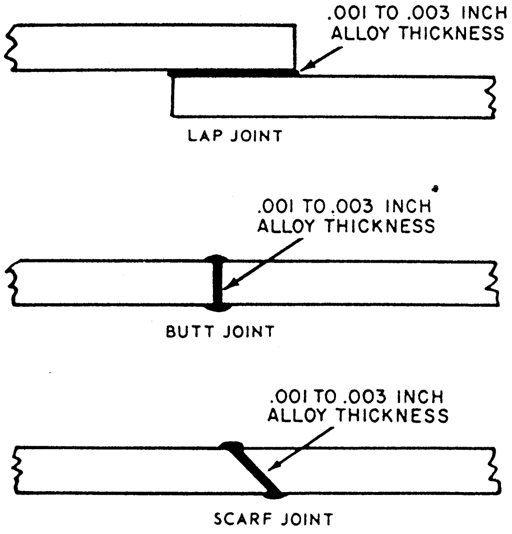

Figure 6-13.—Three types of common joint designs for brazing.

Butt Joints

Butt joints are limited in size to that of the thinnest section so maximum joint strength is impossible. Butt joint strength can be maximized by maintaining a joint clearance of 0.001 to 0.003 of an inch in the finished braze. The edges of the joint must be perfectly square to maintain a uniform clearance between all parts of the joint. Butt joints are usually used where the double thickness of a lap joint is undesirable. When double-metal thickness is objectionable and you need more strength, the scarf joint is a good choice.

Scarf Joints

A scarf joint provides an increased area of bond without increasing the thickness of the joint. The area of bond depends on the scarf angle cut for the joint. Usually, an area of bond two to three times that of a butt joint is desirable. A scarf angle of 30 degrees gives a bond area twice that of a 90-degree butt joint, and an angle of 19 1/2 degrees increases the bond area three times.

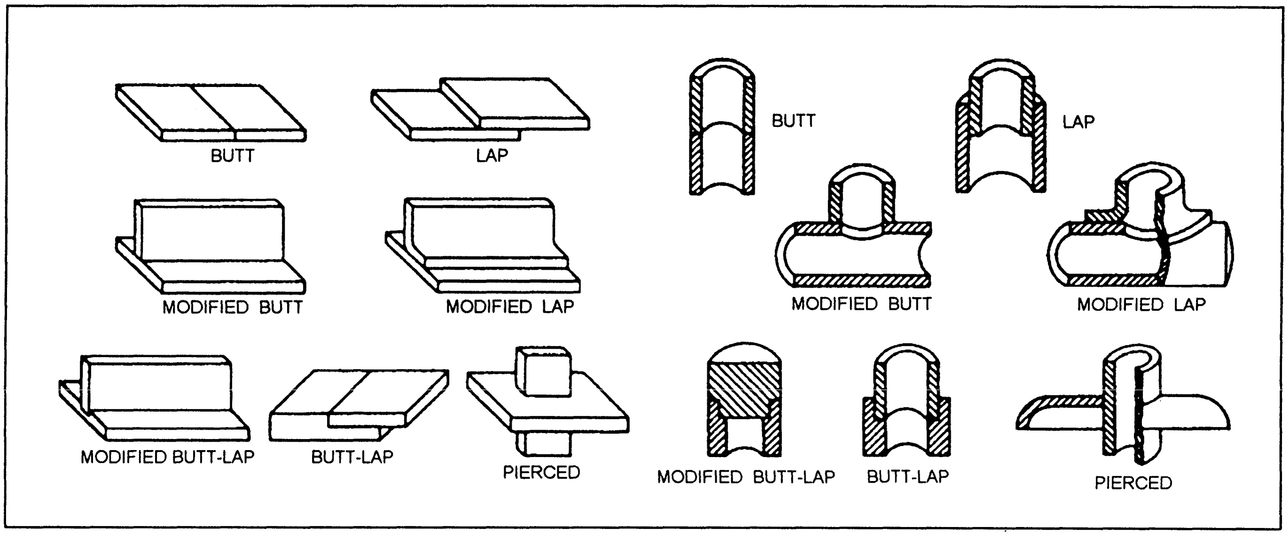

Figure 6-14.—Joints designed to produce good brazing results.

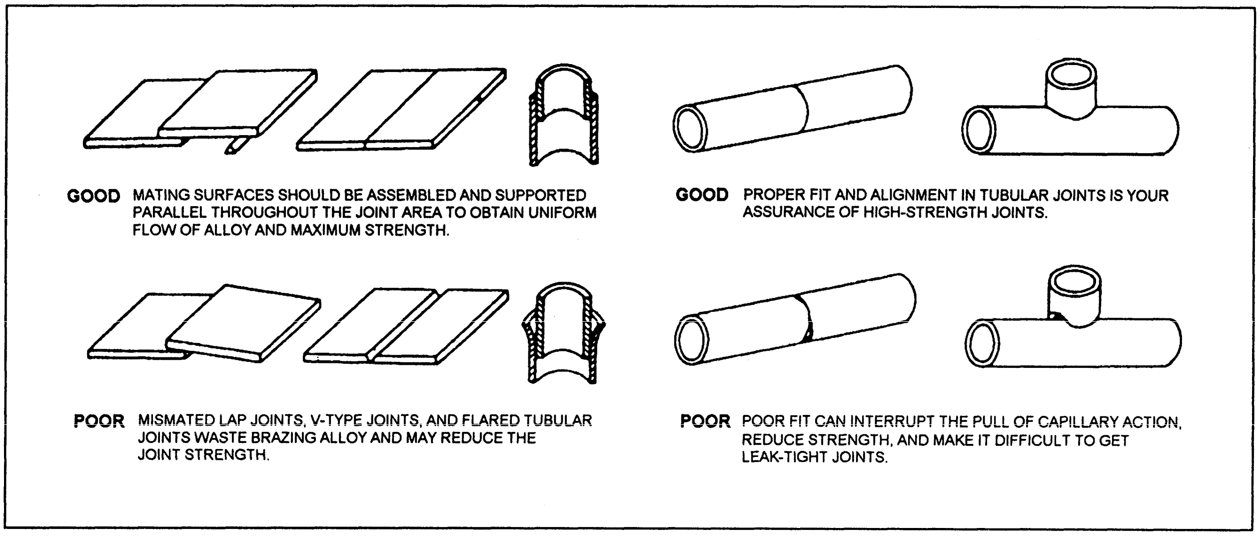

Figure 6-15.—Some well-designed joints that have been prepared for brazing, and some poorly designed joints shown for comparison

Figure 6-14 shows some variations of butt and lap joints designed to produce good brazing results. A comparison of good and bad designed joints is shown in figure 6-15.

BRAZING PROCEDURES

The procedure for brazing is very similar to braze and oxyacetylene welding. The metal needs to be cleaned by either mechanical, chemical, or a combination of both methods to ensure good bonding. The two pieces must befitted properly and supported to prevent voids in the joint or accidental movement during brazing and cooling operations.

Surface Preparation

The surfaces of the metal must be cleaned for capillary action to take place. When necessary, chemically clean the surface by dipping it in acid. Remove the acid by washing the surface with warm water. For mechanical cleaning, you can use steel wool, a file, or abrasive paper. Do not use an emery wheel or emery cloth,

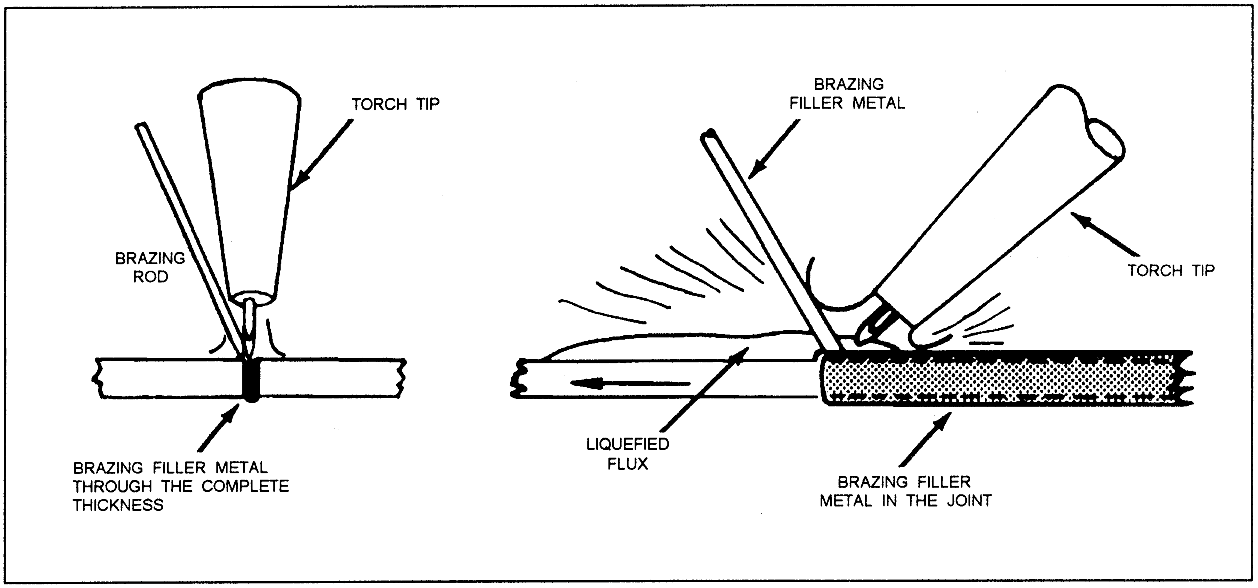

Figure 6-16.—Brazing a butt joint.

because abrasive particles or oil might become embedded in the metal.

Work Support

Mount the work in position on firebricks or other suitable means of support, and if necessary, clamp it. This is important because if the joint moves during the brazing process, the finished bond will be weak and subject to failure.

Fluxing

The method of application varies, depending upon the form of flux being used and the type of metal you are brazing. Refer to the material on fluxes previously described. It is extremely important that the flux is suitable for your job.

Brazing

The next step is to heat the parts to the correct brazing temperature. Adjust the torch flame (oxygas) to a neutral flame because this flame gives the best results under normal conditions. A reducing flame produces an exceptionally neat-looking joint, but strength is sacrificed. An oxidizing flame will produce a strong joint but it has a rough-looking surface.

The best way to determine the temperature of the joint, as you heat it, is by watching the behavior of the flux. The flux first dries out as the moisture (water) boils off at 212°F. Then the flux turns milky in color and starts to bubble at about 600°F. Finally, it turns into a clear liquid at about 1100°F. That is just short of the brazing temperature. The clear appearance of the flux indicates that it is time to start adding the filler metal. The heat of the joint, not the flame, should melt the filler metal. When the temperature and alignment are proper, the filler metal spreads over the metal surface and into the joint by capillary attraction. For good bonding, ensure the filler metal penetrates the complete thickness of the metal. Figure 6-16 shows a good position for the torch and filler metal when brazing a butt joint.

Stop heating as soon as the filler metal has completely covered the surface of the joint, and let the joint cool slowly. Do not remove the supports or clamps or move the joint in any way until the surface is cool and the filler metal has completely solidified.

Finally, clean the joint after it has cooled sufficiently. This can be done with hot water. Be sure to remove all traces of the flux because it can corrode the metal. Excess metal left on the joint can be filed smooth.

The above described procedure is a general one, but it applies to the three major types of brazing: silver, copper alloy, and aluminum. The differences being the base metals joined and the composition of the filler metals.

Table 6-2.—Silver Brazing Filler Metal Alloys

ASTM Spec #B-73-29	Percent				Melts°F	Flows°F	Color
	Silver	Copper	Zinc	Cadmium			
	9	53	38		1450	1565	
1	10	52		.05	1510	1600	Yellow
	*15	80		(5% Phos)	1185	1300	Gray
2	20	45	35	.05	1430	1500	Yellow
3	20	45	30	.05	1430	1500	Yellow
	30	38	32		1370	1410	
	**35	26	21	18	1125	1295	Almost white
	40				1135	1205	Almost white
4	45	30	25		1250	1370	Almost white
	**45	15	16	24	1125	1145	Almost white
5	50	34	16		1280	1425	Almost white
	**50	15.5	16.5	18	1160	1175	Almost white
	**50	15.5	15.5	16 (3% Ni)	1195	1270	White
6	65	20	15		1280	1325	White
7	70	20	10		1335	1390	White
8	80	16	4		1360	1490	White

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*–A special alloy containing phosphorus and used only on nonferrous metals

**–Some special alloys of silver using a fairly high cadmium content

Silver Brazing

Often, you will be called on to do a silver brazing job. Table 6-2 lists different types of silver brazing alloys and their characteristics. A popular way to apply silver brazing metal on a tubing is to use silver alloy rings, as shown in figure 6-17. This is a practical and economical way to add silver alloy when using a production line system. Another method of brazing by using preplaced brazing shims is shown in figure 6-18. The requirements of each job varies; however, through experience you can become capable of selecting the proper procedure to produce quality brazing.

BRAZE WELDING

Braze welding is a procedure used to join two pieces of metal. It is very similar to fusion welding with the exception that the base metal is not melted. The filler metal is distributed onto the metal surfaces by tinning. Braze welding often produces bonds that are comparable to those made by fusion welding without the destruction of the base metal characteristics. Braze welding is also called bronze welding.

Braze welding has many advantages over fusion welding. It allows you to join dissimilar metals, to minimize heat distortion, and to reduce extensive preheating. Another side effect of braze welding is the elimination of stored-up stresses that are often present in fusion welding. This is extremely important in the repair of large castings. The disadvantages are the loss of strength when subjected to high temperatures and the inability to withstand high stresses.

EQUIPMENT

The equipment needed for braze welding is basically identical to the equipment used in brazing. Since braze welding usually requires more heat than brazing, an oxyacetylene or oxy-mapp torch is recommended.

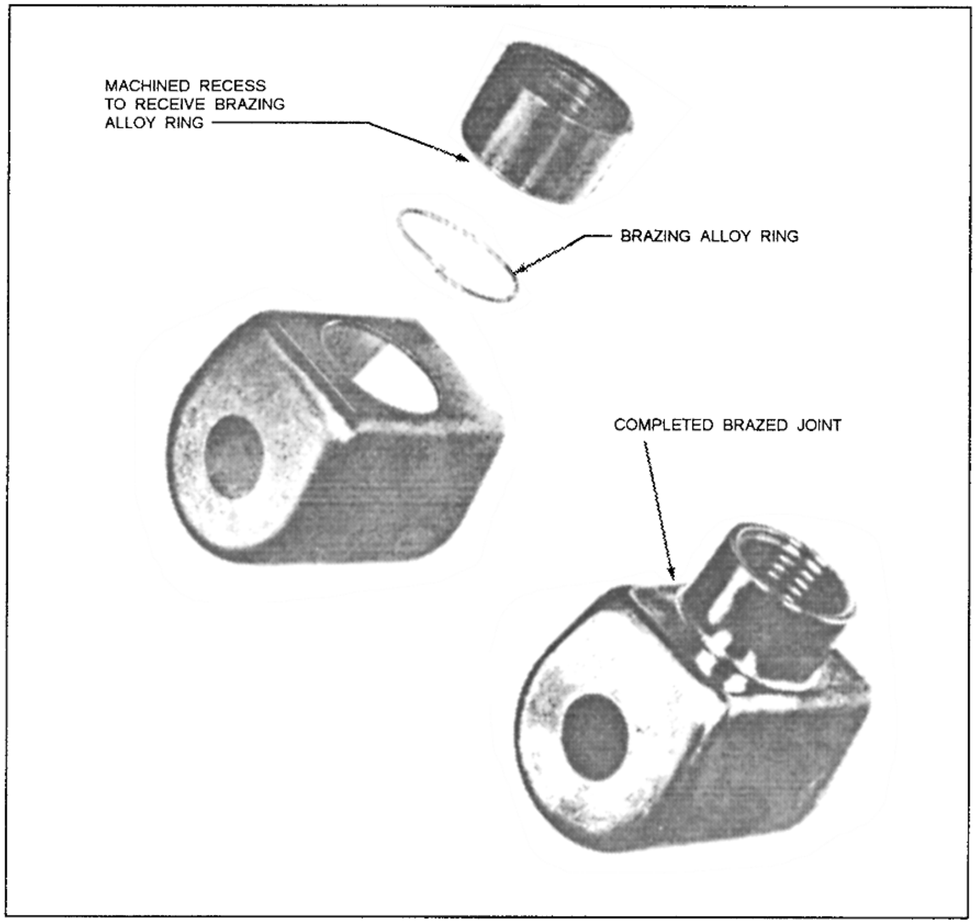

Figure 6-17.—Silver-brazed joints designed to use preplaced silver alloy rings. The alloy forms almost perfect fillets, and no further finishing is necessary.

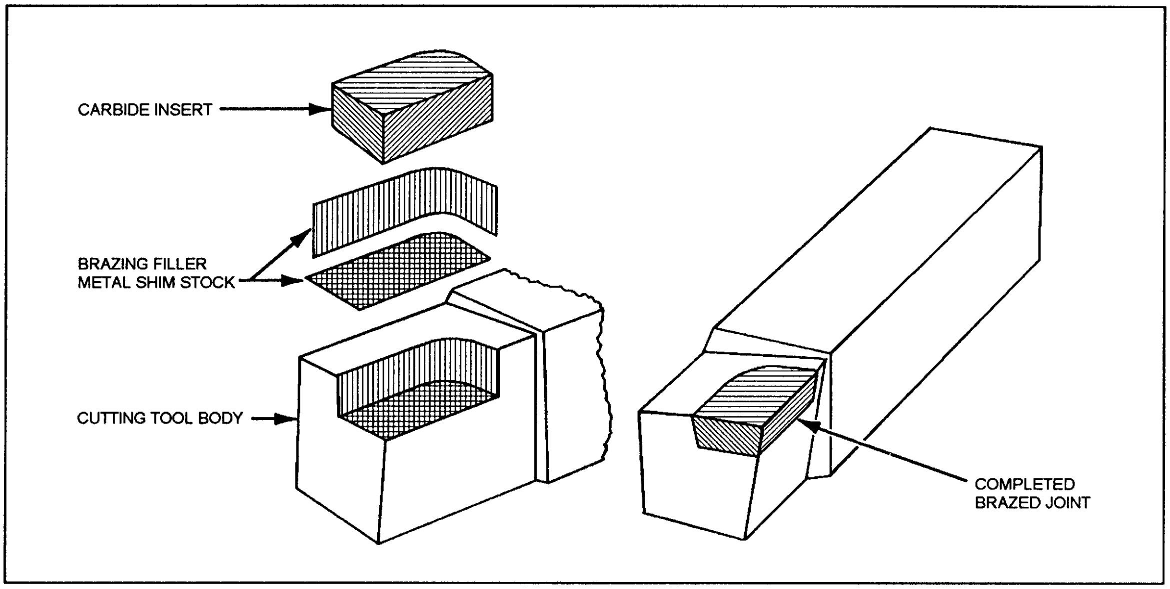

Figure 6-18.—A machining tool bit showing how the carbide insert is brazed to the tool bit body using preplaced brazing filler metal shims.

Table 6-3.—Copper Alloy Brazing Filler Metals

	Copper %	Zinc %	Tin %	Fe %	Mn %	Si %	Ni %	P %	Use	Melting Temp °F	Flow Temp °F
Brass Brazing Alloy	60	40							Copper, Nickel, Alloy, Steel	1650	1660
Naval Brass	60	39.25	.75						Copper, Steel, Nickel Alloys	1630	1650
Tobin Bronze	59	40.5	.50						Steel, Cast Iron	1625	
Manganese Bronze	58.5	39.25	1.0	1.0	.25				Steel	1590	1630
Low Fuming Bronze	57.5 52 50	40.48 48 50	.9	1.0	.03	.09			Cast Iron, Steel	1598 1570 1585	 1595 1610
Nickel Silver	55-65	27-17					18		Steel, Nickel Alloys, Cast Iron		
	48	42					10		Steel, Nickel Alloys	1690	1715
Copper Silicon	98.25				.25	1.5			Steel to Copper	1981	
Phosphor Bronze	98.2		1.5					.3	Copper Alloys	1922	

Filler Metal

The primary elements of a braze welding rod are copper and zinc. These elements improve ductility and high strength. Small amounts of iron, tin, aluminum, manganese, chromium, lead, nickel, and silicon are also added to improve the welding characteristics of the rod. They aid in deoxidizing the weld metal, increasing flow action, and decreasing the chances of fuming. Table 6-3 lists some copper alloy brazing filler metals and their use. The most commonly used are brass brazing alloy and naval brass. The selection of the proper brazing filler metal depends on the types of base metals.

Flux

Proper fluxing is essential in braze welding. If the surface of the metal is not clean, the filler metal will not flow smoothly and evenly over the weld area. Even after mechanical cleaning, certain oxides often remain and interfere with the flow of the filler metal. The use of the correct flux eliminates these oxides.

Flux may be applied directly to the weld area, or it can be applied by dipping the heated end of the rod into the flux. Once the flux sticks to the rod, it then can be transferred to the weld area. A prefluxed braze welding rod is also available, and this eliminates the need to add flux during welding.

BRAZE WELDING PROCEDURES

Edge preparation is essential in braze welding. The edges of the thick parts can be beveled by grinding, machining, or filing. It is not necessary to bevel the thin parts (one-fourth inch or less). The metal must be bright and clean on the underside as well as on the top of the joint. Cleaning with a file, steel wool, or abrasive paper removes most foreign matter such as oil, greases, and oxides. The use of the proper flux completes the process and permits the tinning to occur.

After you prepare the edges, the parts need to be aligned and held in position for the braze welding process. This can be done with clamps, tack welds, or a combination of both. The next step is to preheat the assembly to reduce expansion and contraction of the metals during welding. The method you use depends upon the size of the casting or assembly.

Once preheating is completed, you can start the tinning process. Adjust the flame of the torch to a slightly oxidizing flame and flux the joint. Through experience, you will find that the use of more flux during the tinning process produces stronger welds. Apply heat to the base metal until the metal begins to turn red. Melt some of the brazing rod onto the surface and allow it to spread along the entire joint. You may have to add more filler metal to complete the tinning. Figure 6-19 shows

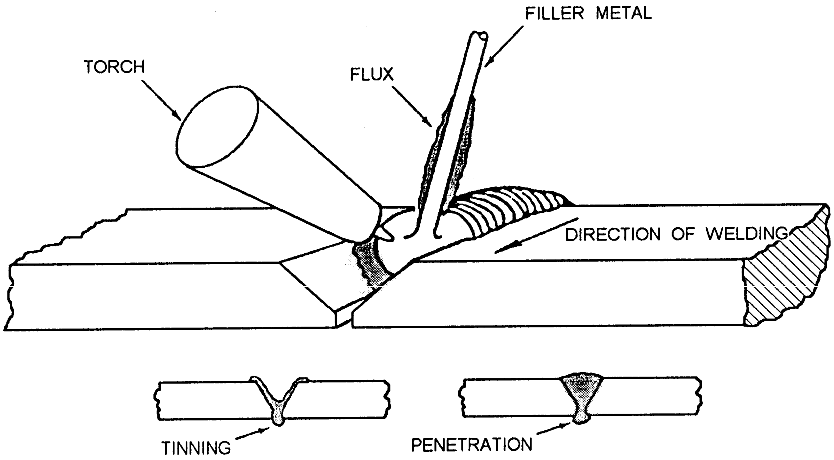

Figure 6-19.—Braze welding cast iron, using the backhand method.

an example of tinning being used with the backhand method of welding.

Temperature control is very important. If the base metal is too hot, the filler metal bubbles or runs around like beads of water on a hot pan. If the filler metal forms little balls and runs off the metal, then the base metal is too cold.

After the base metal is tinned, you can start adding beads of filler metal to the joint. Use a slight circular motion with the torch and run the beads as you would in regular fusion welding. As you progress, keep adding flux to the weld. If the weld requires several passes, be sure that each layer is fused into the previous one.

After you have completed the braze welding operation, heat the area around the joint on both sides for several inches. This ensures an even rate of cooling. When the joint is cold, remove any excess flux or any other particles with a stiff wire brush or steel wool.

WEARFACING

WEARFACING is the process you use to apply an overlay of special ferrous or nonferrous alloy to the surface of new or old parts. The purpose is to increase their resistance to abrasion, impact, corrosion, erosion, or to obtain other properties. Also, wearfacing also can be used to build up undersized parts. It is often called hard-surfacing, resurfacing, surfacing, or hardfacing.

As a Steelworker, there are times when you are required to build up and wear-face metal parts from various types of construction equipment. These parts include the cutting edges of scraper or dozer blades, sprocket gears, and shovel or clamshell teeth. You may even wear-face new blades or shovel teeth before they are put into service for the first time. There are several different methods of wearfacing; however, in this discussion we only cover the oxygas process of wearfacing.

Wearfacing provides a means of maintaining sharp cutting edges and can reduce wear between metal parts. It is an excellent means for reducing maintenance costs and downtime. These and other advantages of wearfacing add up to increased service life and high efficiency of equipment.

Wearfacing with the oxygas flame is, in many respects, similar to braze welding. The wearfacing metals generally consist of high-carbon filler rods, such as high chromium or a Cr-Co-W alloy, but, in some instances, special surfacing alloys are required. In either event, wearfacing is a process in which a layer of metal of one composition is bonded to the surface of a metal of another composition.

The process of hard-surfacing is suitable to all low-carbon alloy and stainless steels as well as Monel and cast iron. It is not intended for aluminum, copper, brass, or bronze, as the melting point of these materials prohibits the use of the hard-surfacing process. It is possible to increase the hardness of aluminum by applying a zinc-aluminum solder to the surface. Copper, brass, and bronze can be improved in their wear ability by the overlay of work-hardening bronze. Carbon and alloy tool steels can be surface-hardened, but they offer difficulties due to the frequent development of shrinkage and strain cracks. If you do surface these materials, they should be in an annealed, and not a hardened condition. When necessary, heat treating and hardening can be accomplished after the surfacing operation. Quench the part in oil, not water.

WEARFACING MATERIALS

A surfacing operation using a copper-base alloy filler metal produces a relatively soft surface. Work-hardening bronzes are soft when applied and give excellent resistance against frictional wear. Other types of alloys are available that produce a surface that is corrosion and wear resistant at high temperatures. Wearfacing materials are produced by many different manufacturers; therefore, be sure that the filler alloys you select for a particular surfacing job meet Navy specifications.

Two types of hard-surfacing materials in general use in the Navy are iron-base alloys and tungsten carbide.

Iron-Base Alloys

These materials contain nickel, chromium, manganese, carbon, and other hardening elements. They are used for a number of applications requiring varying degrees of hardness. A Steelworker frequently works with iron-base alloys when he builds up and resurfaces parts of construction equipment.

Tungsten Carbide

You use this for building up wear-resistant surfaces on steel parts. Tungsten carbide is one of the hardest substances known to man. Tungsten carbide can be applied in the form of inserts or of composite rod. Inserts are not melted but are welded or brazed to the base metal, as shown in figure 6-18. The rod is applied with the same surfacing technique as that used for oxygas welding; a slightly carburizing flame adjustment is necessary.

WEARFACING PROCEDURES

Proper preparation of the metal surfaces is an important part of wearfacing operations. Make sure that scale, rust, and foreign matter are removed from the metal surfaces. You can clean the metal surfaces by grinding, machining, or chipping. The edges of grooves, corners, or recesses should be well rounded to prevent base metal overheating and to provide a good cushion for the wearfacing material.

Weafacing material is applied so it forms a thin layer over the base metal. The thickness of the deposit is usually from one sixteenth to one eighth of an inch and is seldom over one fourth of an inch. It is generally deposited in a single pass. Where wear is extensive, it may become necessary to use a buildup rod before wearfacing. If in doubt as to when to use a buildup rod, you should check with your leading petty officer.

Preheating

Most parts that require wearfacing can be preheated with a neutral welding flame before surfacing. You should use a neutral flame of about 800°F. Do not preheat to a temperature higher than the critical temperature of the metal or to a temperature that can cause the formation of scale.

Application

In general, the torch manipulations and the wearfacing procedures are similar to brazing techniques. However, higher temperatures (about 2200°F) are necessary for wearfacing, and tips of one or two sizes larger than normal are used.

To begin, you heat a small area of the part with a sweeping torch movement until the surface of the base metal takes on a sweating or wet appearance. When the surface of the base metal is in this condition, bring the end of the surfacing alloy into the flame and allow it to melt. Do not stir or puddle the alloy; let it flow. When the surface area has been properly sweated, the alloy flows freely over the surface of the base metal.

Being able to recognize a sweated surface is essential for surfacing. Sweating occurs when you heat the steel with a carburizing flame to a white heat temperature. This carburizes an extremely thin layer of the base metal, approximately 0.001 inch thick. The carburized layer has a lower melting point than the base metal. As a result, it becomes a liquid, while the underlying metal remains a solid. This liquid film provides the medium for flowing the filler metal over the surface of the base metal. The liquid film is similar to and serves the same purpose as a tinned surface in soldering and braze welding.

When you heat steel with a carburizing flame, it first becomes red. As heating continues, the color becomes lighter and lighter until a bright whiteness is attained. At this point, a thin film of liquid, carburized metal appears on the surface. Surfacing alloy added at this time flows over the sweated surface and absorbs the film of carburized metal. This surface condition is not difficult to recognize, but you should make several practice passes before you try wearfacing for the first time.

When you use an oxygas torch for surfacing with chromium cobalt, the torch flame should have an excess fuel-gas feather about three times as long as the inner

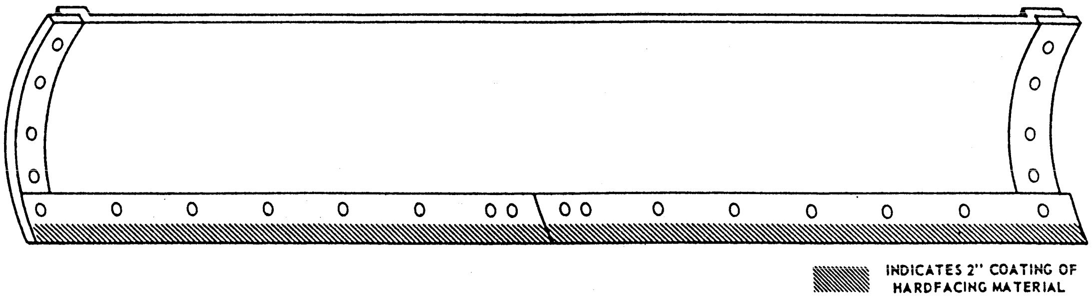

Figure 6-20.—Grader blade with hardfacing material applied to cutting edge.

cone. Unless the excess fuel-gas flame is used, the proper base metal surface condition cannot be developed. Without this condition, the surfacing alloy does not spread over the surface of the part.

Figure 6-20 shows a grader blade with a deposit of hardfacing material applied along the cutting edge. A grader blade is usually wearfaced by the electric arc process. If the electric arc process is not available, you may use the oxygas torch.

Welding Materials Handbook, NAVFAC P-433, is an excellent source of information for wearfacing construction equipment.