

Soldering, Brazing, and Welding



Objectives

This chapter describes the process of making watertight pipe joints using heat and various filler metals.

After studying this chapter, you will be able to:

- Identify the solders, brazing filler materials, and fluxes needed for successfully soldering and brazing copper pipe and fittings.
- Describe and demonstrate the processes for soldering and brazing copper pipe.
- Describe the process for welding plastic pipe and fittings.

Technical Terms

Soldering Capillary attraction
Nonferrous metal Oxidation

Soldering, brazing, welding, and cementing are used to join water supply pipe and fittings that are not threaded. Cementing is used with plastic pipe and does not require the application of heat. Lead wiping is an obsolete process for water supply systems. If lead pipe is encountered in older installations, it should be replaced with materials that meet current plumbing codes.

History Brief

The earliest evidence indicates that soldering began in Mesopotamia about 4000 BC. Soft solder containing tin and lead was developed in Northern Europe approximately 1900 BC by the Celts and Gauls primarily for jewelry, cooking utensils, and tools.

Sweat Soldering

Soldering uses heat and a nonferrous filler metal to form joints between two metallic surfaces. A *nonferrous metal* does not contain iron and is, therefore, nonmagnetic. Soldering is generally used by plumbers to join rigid copper pipe and fittings. The filler metal is distributed evenly between the close-fitting surfaces of the joint by capillary attraction. **Capillary attraction** is the tendency of a liquid to be drawn to the surface of solids in a “soaking” or “spreading” action.

Solders

Public Law 99-339, better known as the Federal Safe Drinking Water Act Amendments of 1986, mandates the use of lead-free solder for potable water supply piping. Therefore, the traditional soft solder composed of 50% tin and

50% lead is no longer permitted for joining copper pipe. Several solder products have been developed in which the lead is replaced with other alloys. Antimony, copper, and silver are among the more commonly used alloys. Solder alloyed with antimony is somewhat more likely to corrode than those containing silver. Silver is, however, more expensive. **Figure 9-1** contains examples of typical solder compositions and the recommended temperature range for effective soldering. The larger the temperature range, the easier the product is to use.

Plumbers generally prefer $\frac{1}{8}$ " solid core solder that is sold in one-pound spools. These solders should be used only where pipe temperatures will not exceed 250°F (121°C). They are generally suited to low-pressure steam applications, as well.

Hard solders are composed of various percentages of copper and zinc alloys. They are used in the brazing of cast iron, iron, steel, brass, and sometimes copper.

Code Note

Lead-free solder and flux or solder and flux containing no more than two-tenths of a percent of lead must be used when making solder joints in potable water supply piping.

Fluxes

Soldering flux performs several functions:

- It protects the surface from oxidation during heating. **Oxidation** is the process of picking up oxygen that produces tarnish and rust in metals.

| Tin (%) | Composition | | | Soldering temperature range (°F) |
|---------|--------------|------------|------------|----------------------------------|
| | Antimony (%) | Copper (%) | Silver (%) | |
| 95 | 5 | | | 430–480 |
| 96 | | 4 | | 430–450 |
| 95.5 | | 4 | .5 | 440–500 |
| 94 | | | 6 | 430–550 |

Figure 9-1. The composition and recommended soldering temperature for lead-free solder.

- It helps the filler metal flow easily into the joint.
- It floats out remaining oxides ahead of the molten solder.
- It increases the wetting action of solder by lowering the surface tension of the molten metal.

Highly corrosive fluxes contain inorganic acids and salts such as zinc chloride, ammonium chloride, sodium chloride, potassium chloride, hydrochloric acid, and hydrofluoric acid.

Less corrosive fluxes contain milder acids such as citric acid, lactic acid, and benzoic acid. Although they are briefly very active at soldering temperatures, their corrosive elements are driven off by the heat. Residue does not remain active and is easily removed after the joint is cool.

Noncorrosive fluxes, the only type suited for plumbing work, are composed of water and white resin dissolved in an organic or benzoic acid. The residue does not cause corrosion. These fluxes are effective on copper, brass, bronze, nickel, and silver. Noncorrosive fluxes are recommended for joining copper pipe and fittings.

The best fluxes for joining copper pipe and fittings are compounds containing mild concentrations of zinc and ammonium chloride. These cleaning agents are mixed with a petroleum base to produce a noncorrosive paste that is easily applied.

Soldering: The process of forming joints between two metallic surfaces by using heat and a nonferrous filler metal.

Nonferrous metal: Metal that does not contain iron and is, therefore, nonmagnetic.

Capillary attraction: The tendency of a liquid to be drawn to the surface of solids in a “soaking” or “spreading” action.

Oxidation: The process of picking up oxygen that produces tarnish and rust in metals.



Sweat Soldering Procedure

Soldering is not difficult. Each operation, however, must be performed carefully for satisfactory results. Carefully study the following procedures before attempting to make a solder joint:

1. Cut the copper pipe with a tubing cutter, **Figure 9-2**.
2. Ream the ends of each pipe to remove metal burrs, **Figure 9-3**.
3. Cleaning is a very important part of making good solder joints. Use a copper cleaning tool, **Figure 9-4**, such as abrasive paper (fine grit), emery cloth, or No. 00 steel wool, to clean the copper pipe ends and the socket or cup of the fitting. Do a thorough job. After the scale and dirt are removed, brush away any loose abrasive particles. Avoid touching the clean metal with your fingers.



A



B

Figure 9-2. A tubing cutter produces a square cut that needs little dressing. A—Standard tubing cutter. B—Small tubing cutter for use in tight spaces. (Wheeler Mfg. Co.)



Figure 9-3. A reamer is used to remove the wire edge or burrs formed on the inside of copper tubing during cutting. (Wheeler Mfg. Co.)



A



B



C

Figure 9-4. These special cleaning tools are used to prepare copper tubing and fittings for soldering. A—Fitting brush. B—Tube brush. C—Abrasive ministrips. (Mill-Rose Co.; Wheeler Mfg. Co.)

4. Immediately apply the proper flux to all pipe and joint areas to be soldered with a clean brush, as shown in **Figure 9-5**. It is important to apply flux soon after the joint is cleaned. Otherwise, the copper begins to oxidize and the oxide inhibits the soldering process.
5. Assemble the fluxed pipes into the fitting. Push and turn until the pipes are bottomed against the inside shoulders of the fitting.
6. Select the proper solid core solder.
7. Light a small, portable propane gas torch to heat the pipe and fitting. Self-igniting torches,



Flux Acid brushes



Figure 9-5. Soldering flux is applied to pipe and joint areas with an acid brush to reduce oxidation during the heating cycle. (Mill-Rose Co.)

8. Direct the heat onto the copper pipe before heating the fitting. This heats the pipe to the correct temperature without overheating the fitting. The pipe generally dissipates more heat than the fitting, and the fitting can be heated very quickly once the pipe has reached the right temperature. Hold the torch so that the inner cone of the flame touches the metal, as in **Figure 9-8**.
9. Slowly touch the end of the solder wire to the joint area to check for proper temperature.



Figure 9-6. Self-igniting torches provide sufficient heating capacity for soldering copper tubing and fittings. (Irwin Industrial Tool Co.)

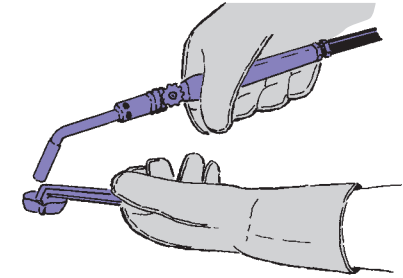


Figure 9-7. When lighting the torch, direct the tip away from you and any flammable material. Use a spark lighter to ignite the fuel gas.

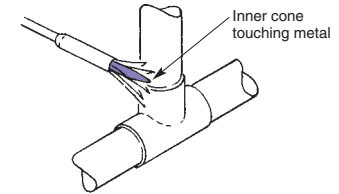


Figure 9-8. The inner cone of the torch flame should touch the metal. This is the hottest part of the flame.

10. The joint may be wiped with a clean damp cloth while hot to remove excess solder and any remains of the flux, as shown in **Figure 9-9**. A damp cloth helps cool the joint.
11. Secure the propane torch and other equipment. Be certain the valve on a propane torch is closed after use. Store the torch in a cool place away from any source of heat.

Code Note

Use a dielectric fitting or brass converter fitting when joining copper and galvanized pipe.



Figure 9-9. To produce a joint that is smooth and neat, wipe with a damp burlap or denim cloth while the joint is still hot.

Brazing

Like soldering, brazing uses a nonferrous filler metal to join base metals. However, brazing is done with temperatures above 800°F (427°C). In brazing, the melting point of the filler metal is below that of the base metals being joined.

In plumbing, brazing is used to join pipe and fittings in saltwater pipelines, oil pipelines, refrigeration systems, vacuum lines, chemical-handling systems, air lines, and low-pressure steam lines. Cast bronze fittings are commonly silver brazed to copper, brass, copper nickel, and steel pipes and tubes. Silver brazing involves the use of filler metal containing silver and bronze, and requires higher temperatures than brazing using brass filler metal.

Braze welding cast iron parts by a metal worker should not be confused with the brazing done on piping. They are different processes. Brazing of pipe is an adhesion process. The metals being joined are heated but not melted.

The joint formed by brazing is superior to that formed by soldering. It is used where mechanical strength and higher pressure-resistant joints are needed. The strength comes from the ability of the brazing alloys or silver braze to flow into the porous grain structure of the pipe and fitting. However, this excellent bond is only possible if:

- The surface is clean.
- The proper flux and filler rod are used.

- The clearance gap between the outside of the pipe and the bore is only 0.003" to 0.004", as shown in **Figure 9-10**.

Brazing Materials

Filler metal for brazing is available in the following different shapes: wires, rods, sheets, and washers. The classifications, each with special uses, include:

- Aluminum-silicon—Used for brazing aluminum and aluminum alloys.
- Copper-phosphorus—Used for joining copper, copper alloys, and other nonferrous metals.
- Silver—Used for joining almost all ferrous and nonferrous metals. The exceptions for use include aluminum and other metals with low melting points.
- Copper and copper-zinc—Suited for joining both ferrous and nonferrous metals. This compound is used in a 50/50 mixture for brazing copper. A 64% copper/36% zinc compound is used for iron and steel.
- Nickel—Used when extreme heat and corrosion resistance is needed. Applications include food and chemical processing equipment, automobiles, cryogenics, and vacuum equipment.

Flux, an important component in the soldering process, is even more necessary in brazing. In addition to protecting the surface

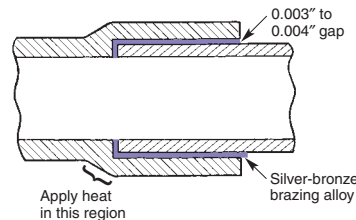


Figure 9-10. A cross-sectional enlargement of the clearance gap between a pipe and a bronze pipe fitting.

from oxidation and aiding the flow of filler metal, brazing flux serves to indicate the temperature of the metal. Without flux it would be almost impossible to know when the base metal reaches the correct temperature. Fluxes are produced in powder, paste, and liquid form. Many different types of flux are commercially available for use with various base metals and filler rods. When brazing copper, it is important to select a flux that is compatible with the filler metal being used. For small jobs, powdered flux is often preferred because it will adhere to a heated brazing rod. Preheat the rod and stick it into the powdered flux. When the base metal is aluminum, brazing must take place at a lower temperature.

Supplying Heat

Brazed copper joints are made at a temperature of 1400°F (760°C) or higher. An oxyacetylene torch, as shown in **Figure 9-11**, is commonly used instead of a propane torch because of the higher temperatures required. Correct torch tip size and the appropriate oxygen and acetylene regulator settings for various pipe and fitting diameters are listed in **Figure 9-12**. For example, to braze 1/2" or 3/4" pipe, a No. 5 torch tip is recommended. This tip requires an oxygen pressure of 5 psi and an acetylene pressure of 5 psi.

Safety Note
When using a welding torch, always wear welding goggles and protective clothing. Shut off tank valves when finished. "Think Safety!"



Figure 9-11. An oxyacetylene torch unit can efficiently provide the higher temperature necessary for brazing. (Goss Inc.)

| Tip size (No.) | Gas pressure regulator settings | | Rod size (inches) | Pipe and fitting dia. (inches) |
|----------------|---------------------------------|-----------|-------------------|--------------------------------|
| | Oxygen | Acetylene | | |
| 4 | 4 | 4 | 3/32 | 1/4-3/8 |
| 5 | 5 | 5 | 1/8 | 1/2-3/4 |
| 6 | 6 | 6 | 3/16 | 1-1 1/4 |
| 7 | 7 | 7 | 1/4 | 1 1/2-2 |
| 8 | 8 | 8 | 5/16 | 2-2 1/2 |
| 9 | 9 | 9 | 3/8 | 3-3 1/2 |
| 10 | 10 | 10 | 7/16 | 4-6 |

Figure 9-12. This table of oxyacetylene torch tip sizes and regulator settings is suggested for brazing various size pipes and fittings. Pressures are not standardized for oxyacetylene units.



Brazing Procedure

1. Clean, flux, and assemble the joint(s) to be brazed.
2. Assemble the correct tip on the torch.
3. Make sure the regulator valves are closed. Open the tank valve. At this point, the pressure gauge on the oxygen tank may read as much as 2000 psi. The acetylene tank pressure gauge may read up to 250 psi. A regulator is shown in **Figure 9-13**.
4. With the valves on the torch closed, adjust the regulator valve to the correct setting (refer to **Figure 9-12**).
5. Open the acetylene torch valve 1/4 turn. Hold the torch away from you and away from any flammable material. Light the gas with a spark lighter.



Figure 9-13. A regulator for controlling oxygen and acetylene pressure. (Goss Inc.)

6. Immediately open the oxygen valve slightly to eliminate the formation of black smoke and soot.
7. Adjust the oxygen and acetylene torch valves until a neutral or slightly carburizing (excess of acetylene) flame is produced, as shown in **Figure 9-14**. A neutral flame is preferred for brazing.
8. Heat the pipe first and watch the flux. It will first turn to a white powder. When the correct brazing temperature is reached, it will become liquid. At this time, shift the flame to the fitting. See **Figure 9-15**.
9. The brazing rod may now be preheated by introducing it into the flame as the fitting is being heated. In a few seconds, the rod is hot enough for insertion into the flux container. A coating of flux melts onto the rod, as illustrated in **Figure 9-16**.

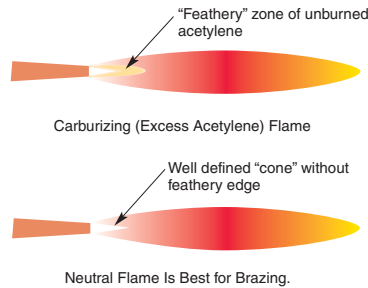


Figure 9-14. A neutral or carburizing flame is necessary for proper brazing.



Figure 9-15. When the flux becomes liquid, shift the cone of the flame to the fitting.

10. Feed the brazing rod into the joint and move the flame back and forth between the pipe and the fitting, **Figure 9-17**.
11. Allow the pipe and fitting to cool before moving, cleaning, or testing the joint.

History Brief
Copper pipe and fittings were introduced in the United States after World War I as a substitute for galvanized iron pipe and fittings. Copper did not, however, come into widespread use until after World War II.

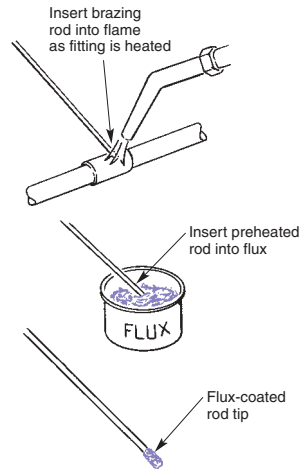


Figure 9-16. The flux will form a coating on a preheated brazing rod.



Figure 9-17. Feed the brazing rod into the joint as the flame is moved back and forth between the pipe and fitting. (The Ridge Tool Co.)

Welding

Welding involves melting the parent material to form a bond. Steel or plastic pipe and fittings can be welded. In the plumbing industry, welding is generally limited to repair work on thermoplastic pipe systems. The surface, or pipe to be welded, is heated by an electrically operated welding unit that forces 500°F to 700°F (260°C to 371°C) air from a blowpipe nozzle.



Welding Procedure

To understand how this tool is used to repair plastic pipe or fittings, study the following procedure for repairing a small fracture in a piece of polyethylene or PVC thermoplastic pipe:

1. Clean the welding surface to remove dirt, oil, and loose particles. Use fine abrasive paper, detergent cleaner, and a cloth.
2. Place the pipe on firebrick or another heat-resistant material for welding.
3. The welding unit must be capable of heating the surface to 550°F (288°C). Position the welding filler rod at approximately a 75° angle to the weld surface. See **Figure 9-18**.

4. Weld one or two beads over the hole in the pipe.
4. Allow the weld to cool completely before testing it with water pressure.

Electric arc welding is used on metal natural gas pipelines, pressure vessels, and storage tanks. The American Welding Society (AWS) has rigorous welding performance tests and information for pipeline welders. Even though pipe, valves, and joints are used, a residential or commercial plumber does not usually perform this type of special work.



Figure 9-18. This welder blows heated air to join thermoplastics. (Laramy Products Co., Inc.)

Test Your Knowledge

Write your answers on a separate sheet of paper.
Do not write in this book.

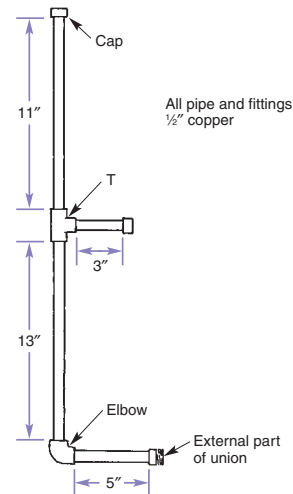
- Thermoplastic piping systems can be repaired by ____.
- The process that removes metal burrs from the inside of pipes is known as ____.
A. brazing
B. chamfering
C. deburring
D. reaming
- The three conditions necessary for good solder joints are clean ____, proper ____, and the correct amount of ____.
- List the four functions of flux.
- The Federal Safe Drinking Act Amendments of 1986 require that ____ solder be used when joining copper pipe that is used for potable water systems.
- Brazing requires a temperature ____ soldering.
A. lower than
B. higher than
C. equal to
D. either higher or lower than
- The amount of oxygen and acetylene should be adjusted to produce a ____ flame before beginning to braze.
A. negative or neutral
B. neutral or carburizing
C. carburizing or negative
D. positive or carburizing
- The joining process that requires a temperature high enough to melt the parent material is known as ____.
A. soldering
B. brazing
C. welding
D. cementing
- If lead pipe is found in an existing plumbing system, it should be ____.
A. replaced
B. lined
C. coated on the outside
D. chemically treated

- When welding PVC pipe, a temperature of ____ is necessary.

- 75°F
- 220°F
- 288°F
- 550°F

Suggested Activities

- Assemble the copper pipe and fittings shown in the following figure. When the assembly is complete, attach it to a water supply or test it with air pressure. Have your instructor test and inspect your work.



- Make the same assembly previously described from brass or bronze pipe and fittings. Have your instructor test and inspect your work.
- Weld a break in a plastic pipe.



Bringing in water and sewer service from the street to a building may call for excavating with the use of a small backhoe. Backfilling the trench after the pipe is installed is often done with an end-loader like the one to left. (Bobcat Company)