

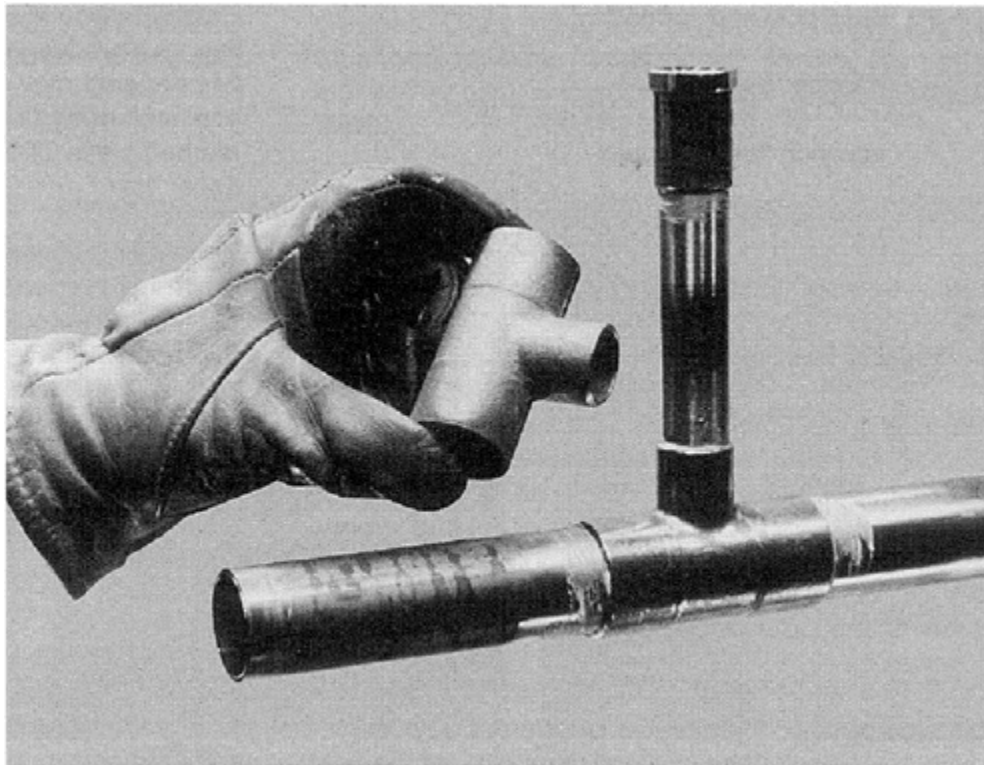
## SOLDERING & BRAZING COPPER TUBE

The Copper Development Association Inc.

### INTRODUCTION

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Copper tube and fittings (Figure 1) may be joined in a number of ways, depending on the purpose of the system. Soldering and brazing with capillary fittings are the methods most commonly used.



**Figure 1**

*Tube and fitting*

The American Welding Society defines soldering as a joining process that takes place below 840°F, and brazing as a similar process that occurs above 840°F but below the melting point of the base metals. In actual practice for copper systems, most soldering is done at temperatures ranging from about 350°F to about 550°F, while most brazing is done at temperatures ranging from about 1100°F to about 1500°F. The choice between soldering and brazing normally will depend on operating conditions. Soldered joints generally are used in applications where the service temperature does not exceed 250°F. Brazed joints can be used in applications where greater strength is required, or where system temperatures are as high as 350°F.

## THE JOINING PROCESS

Soldering and brazing both involve the same basic steps, which you must learn to execute with care and craftsmanship. The eight main steps in the joining process are:

- measuring and cutting
- reaming
- cleaning
- fluxing
- assembly and support
- heating
- applying the filler metal
- cooling and cleaning.

Each step contributes to a strong, dependable joint.

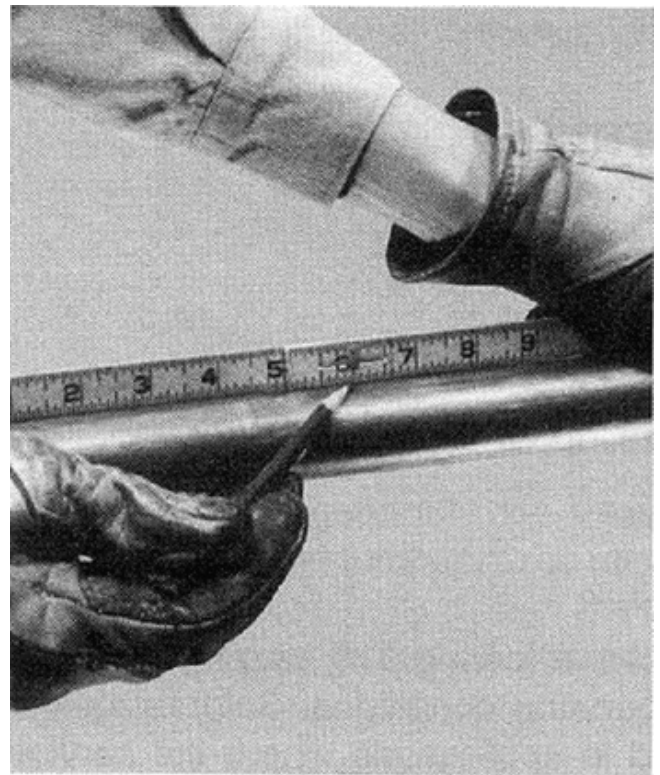
### MEASURING AND CUTTING

Measure the length of each tube segment accurately (Figure 2). Inaccuracy can compromise joint quality. If the tube is too short, it will not reach all the way into the socket of the fitting and a proper joint cannot be made. If the tube segment is too long, there is a danger of cocking the tube in the fitting and putting a strain on the system that could affect service life.

Once the tube is measured, it can be cut. Cutting can be accomplished in a number of different ways to produce a satisfactory square end. You can cut the tube with a disk-type tube cutter (Figure 3), a hacksaw, an abrasive wheel, or with a stationary or portable bandsaw. Make sure that the tube is not deformed while being cut. Regardless of the method used, the cut must be square with the run of the tube so that the tube will seat properly in the fitting socket.

### REAMING

Cutting leaves a small burr on the end of the tube. If this rough edge is not removed by reaming, erosion-corrosion may occur, caused by local turbulence and increased flow velocity in the tube. A properly reamed piece of tube provides a smooth surface for better flow.



**Figure 2**

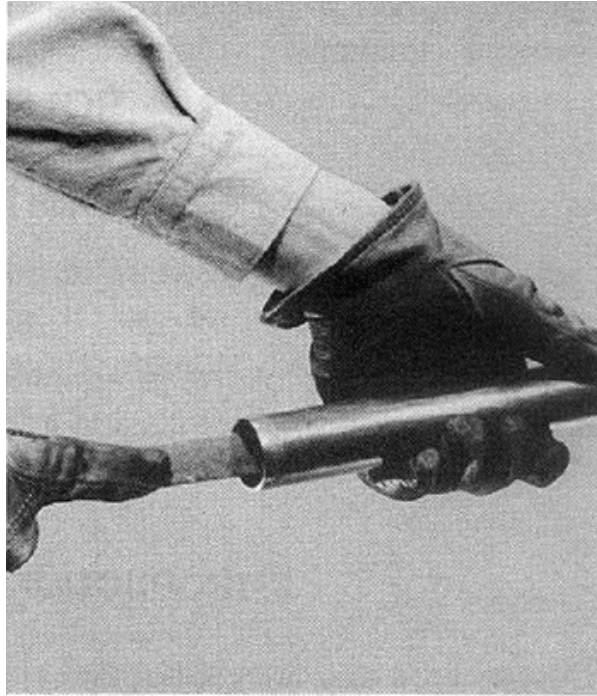
*Measuring*



**Figure 3**

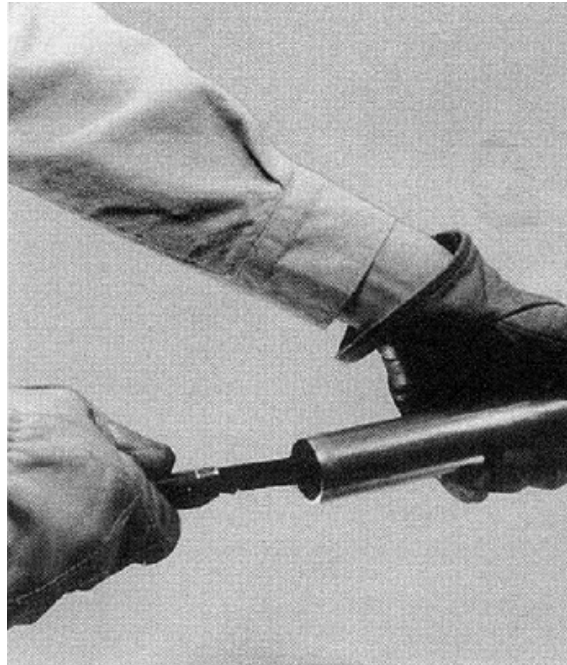
*Cutting*

Tools used to ream tube ends include the reaming blade on the tube cutter, half-round or round files (Figure 4), a pocket knife (Figure 5), and a suitable deburring tool (Figure 6). Both the inside and the outside of the tube may require reaming. With an annealed tube, you must be careful not to deform the tube end by applying too much pressure. If a soft tube is deformed, it can be brought back to roundness with a sizing tool, which consists of a plug and sizing ring.



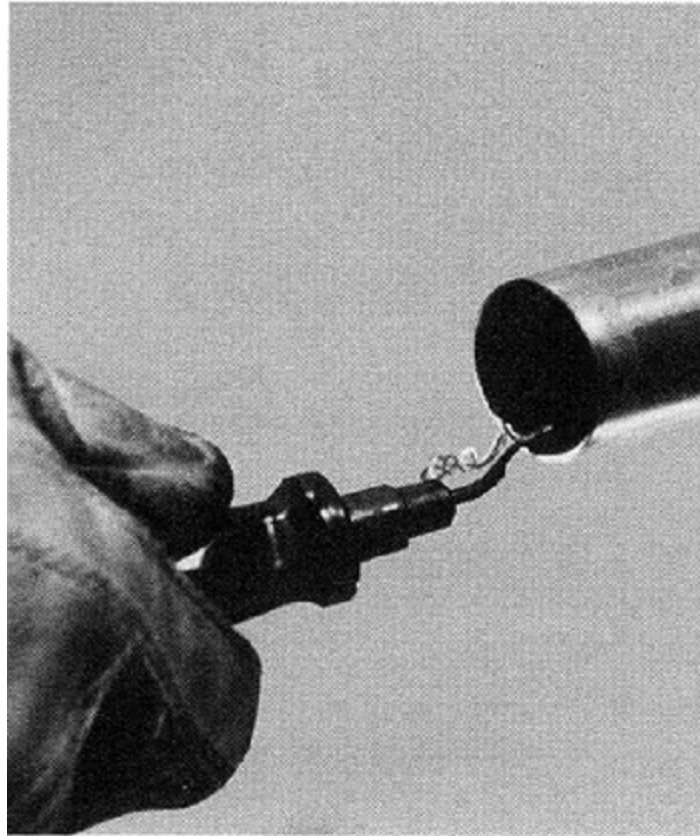
**Figure 4**

*Reaming with a file*



**Figure 5**

*Reaming with a pocket knife*



**Figure 6**

*Reaming with a deburring tool*

## **CLEANING**

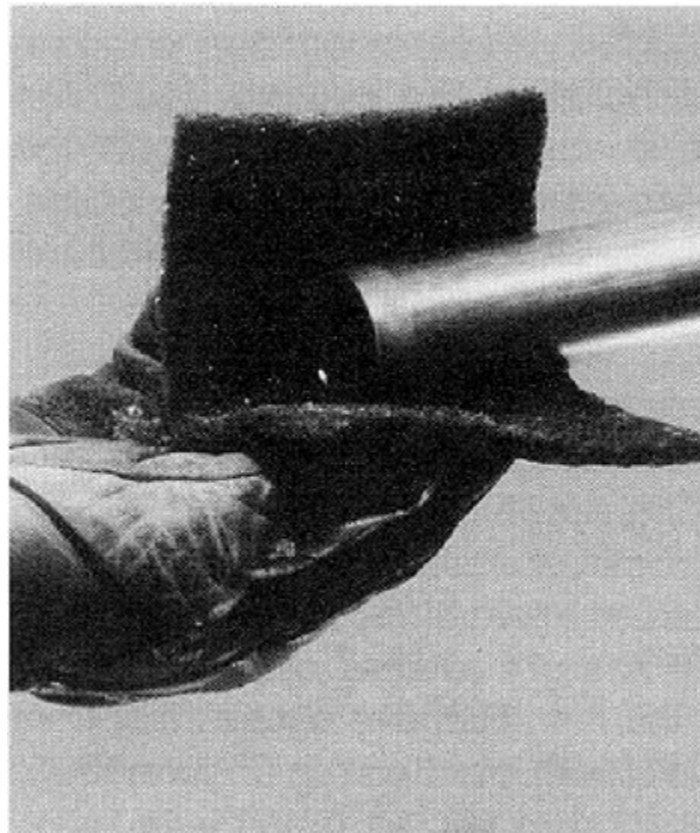
Cleaning is quick and easy to do. The removal of oxides and surface soil is crucial if filler metal is to flow properly into the joint. Unremoved oxide, surface soil, and oil can interfere with the strength of the joint and cause failure.

Mechanical cleaning is a simple operation. Lightly abrade the end of the tube with sand cloth (Figure 7) or nylon abrasive pads (Figure 8) for a distance only slightly more than the depth of the fitting socket. Clean the socket of the fitting with sand cloth, abrasive pads (Figure 9), or a properly sized fitting brush (Figure 10).



**Figure 7**

*Cleaning the tube with sand cloth*



**Figure 8**

*Cleaning the tube with an abrasive pad*

Copper is a relatively soft metal. If too much material is removed, a loose fit will result and interfere with satisfactory capillary action in making the joint. The capillary space (between the tube and the fitting) is approximately 0.004 in. Solder or brazing filler metal can fill this gap by capillary action. Spacing is critical—it must allow the filler metal to flow into the gap and form a strong joint.

Chemical cleaning may be utilized, provided that the tube and fittings are rinsed thoroughly after cleaning according to the recommendations furnished with the cleaner. Once cleaned, surfaces should not be touched with bare hands or oily gloves. Skin oils, lubricating oils, and grease impair solder flow and wetting.

Up to this point, the joining process is the same for both soldering and brazing. This is also true for assembly and support, discussed below. In contrast, there are differences between soldering and brazing in the areas of fluxing, heating, filler metal type, and cooling and cleaning. Accordingly, each of these operations is discussed separately below.

## SOLDERING

The soldering process consists of:

- applying the proper flux
- assembly and support
- heating
- applying the solder
- cooling and clean-up.

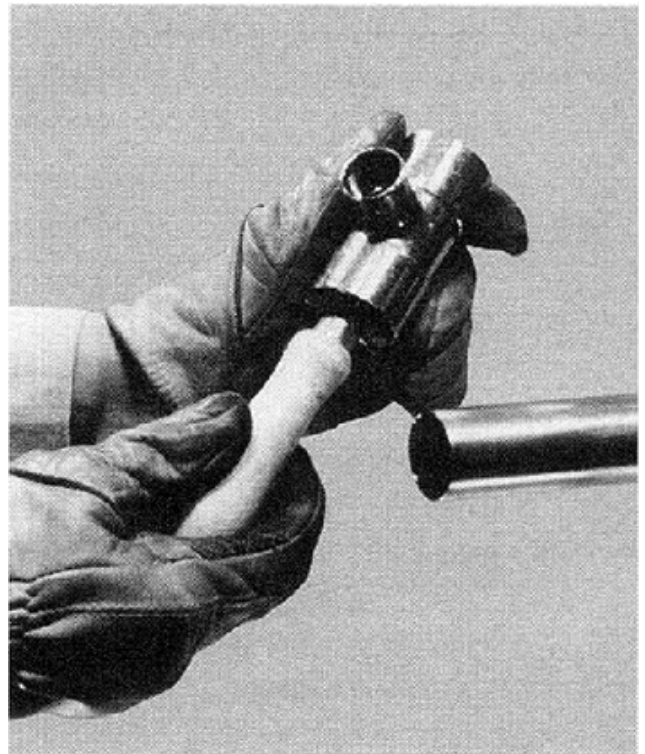
### APPLYING FLUX

Use a non-aggressive soldering flux. Stir the flux before using it (Figure 11). A good flux will:



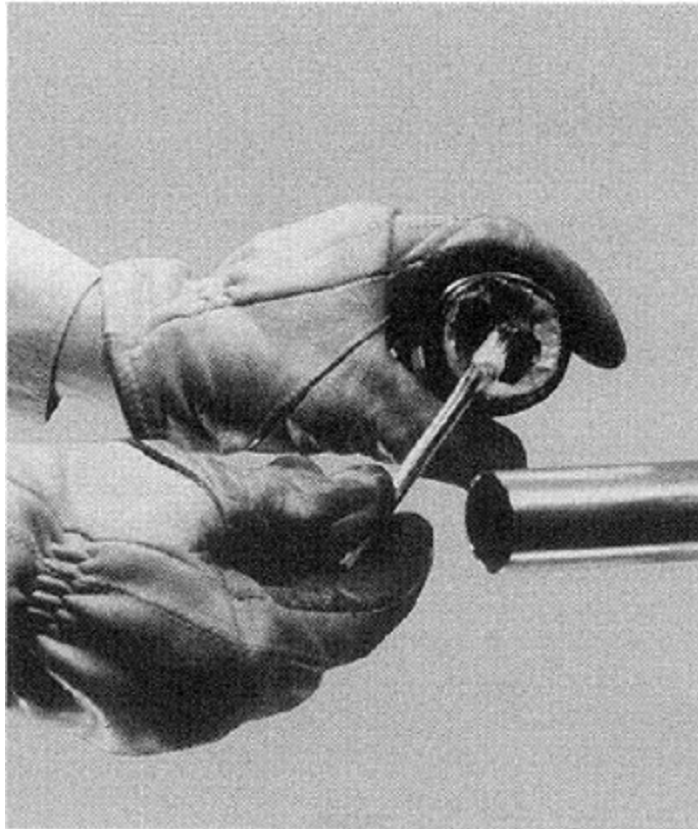
**Figure 9**

*Cleaning the fitting with an abrasive pad*



**Figure 10**

*Cleaning the fitting with a fitting brush*



**Figure 11**

*Stirring the flux*

- dissolve and remove traces of oxide from the cleaned surfaces to be joined
- protect the cleaned surfaces from reoxidation during heating
- promote wetting of the surfaces by the solder.

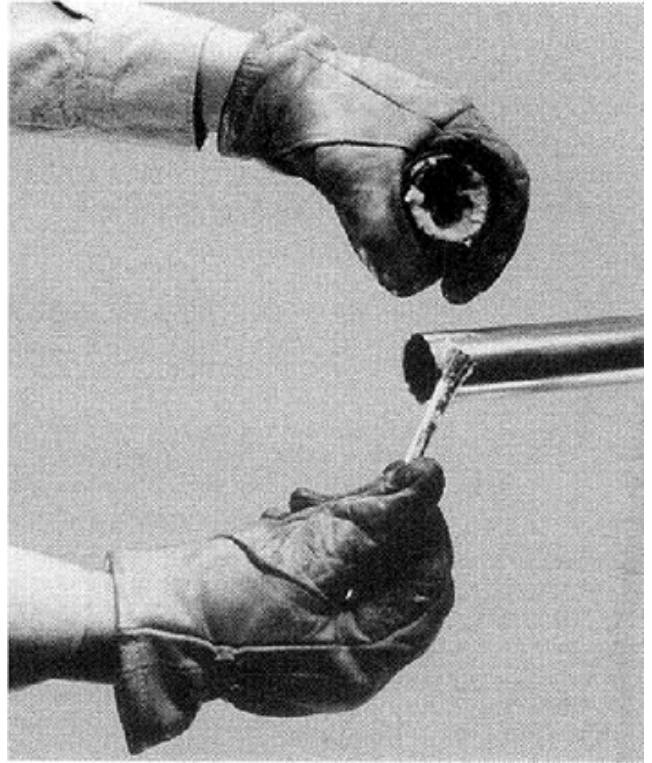
In general, fluxes identified as “self-cleaning” are not recommended. While all fluxes have a slight cleaning effect, those designed to circumvent manual cleaning of the tube and fitting are suspect.

Apply a thin, even coating of flux with a brush to both tube and fitting (Figures 12 and 13) as soon as possible after cleaning. Do not apply flux with your fingers. Chemicals in the flux can be harmful if carried to the eyes or mouth, or if they come in contact with open cuts.

Use care in applying flux. Careless workmanship can cause problems long after the system has been installed. If excessive amounts of flux are used, the flux residue can cause corrosion. In extreme cases, such flux corrosion can perforate the wall of the tube, fitting, or both.

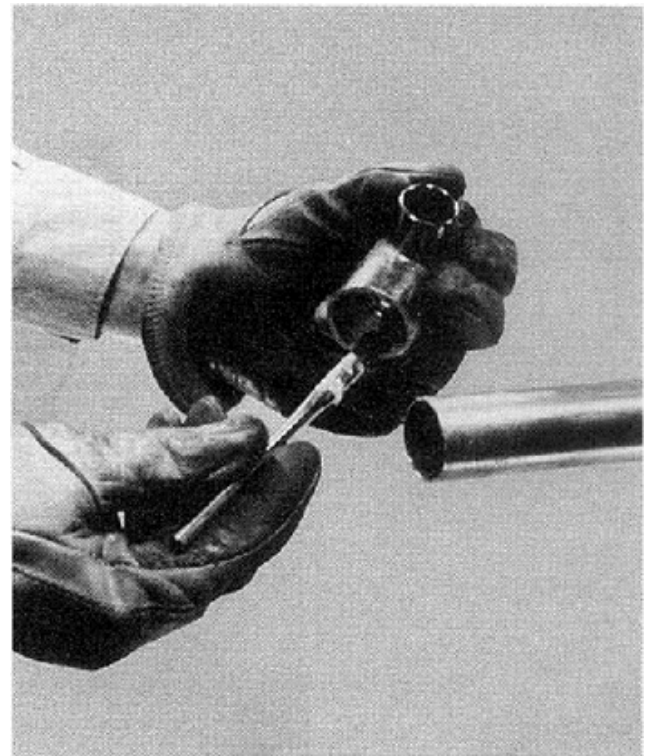
## ASSEMBLY AND SUPPORT

After properly fluxing the surfaces of both the tube and the fitting, you can assemble the joint, making sure that the tube seats against the base of the fitting socket (Figure 14). A slight twisting motion ensures even coverage by the flux. Remove excess flux from the exterior of the joint with a cotton rag (Figure 15).



**Figure 12**

*Applying flux to the tube*



**Figure 13**

*Applying flux to the fitting*

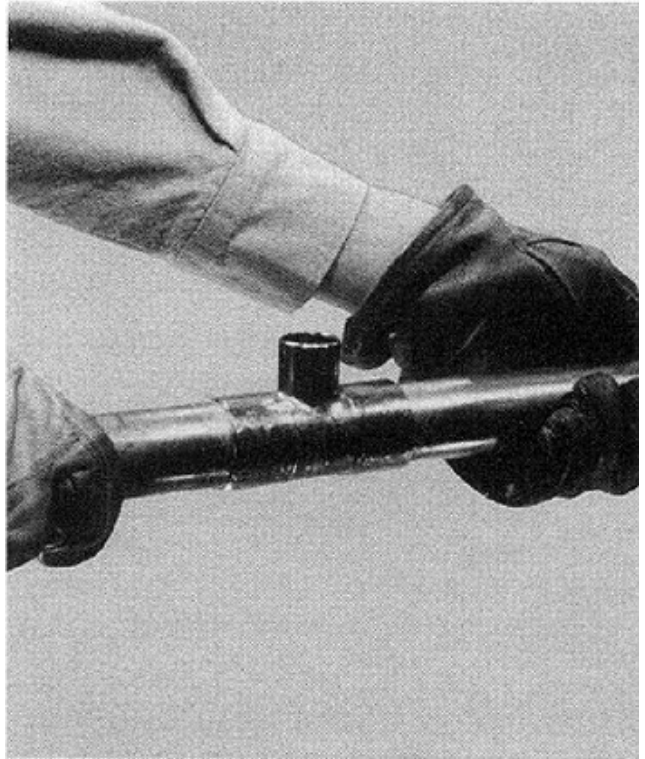


Make sure that the tube and fittings are properly supported, with a uniform capillary space around the entire circumference of the joint. Uniformity of capillary space will ensure good penetration of the filler metal if all other guidelines of successful joint-making are followed. Excessive joint clearance can cause the filler metal to crack under stress or vibration.

The joint is now ready for soldering or for brazing--the assembly and support procedures are the same for both processes. Once prepared, joints should be completed the same day. Do not leave a joint that is ready for soldering or brazing unfinished overnight.

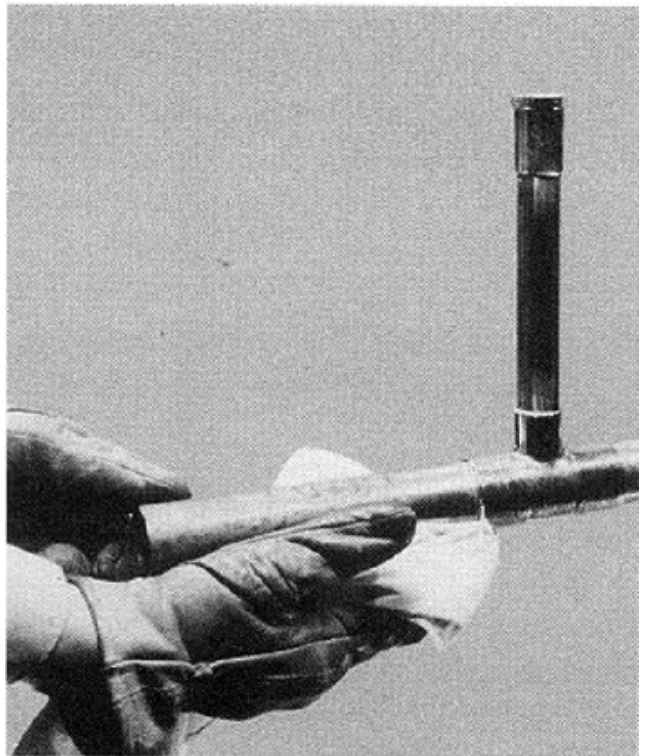
## HEATING

Because an open flame and high temperatures are required for soldering, and because flammable gases are used, safety precautions must be observed. The heat generally is applied with an air/fuel torch (Figure 16). Such torches use acetylene or an LP gas. Electric resistance pliers also can be used (shown with solder in Figure 17). They employ heating electrodes and should be considered in cases where an open flame is a concern.



**Figure 14**

*Assembly*



**Figure 15**

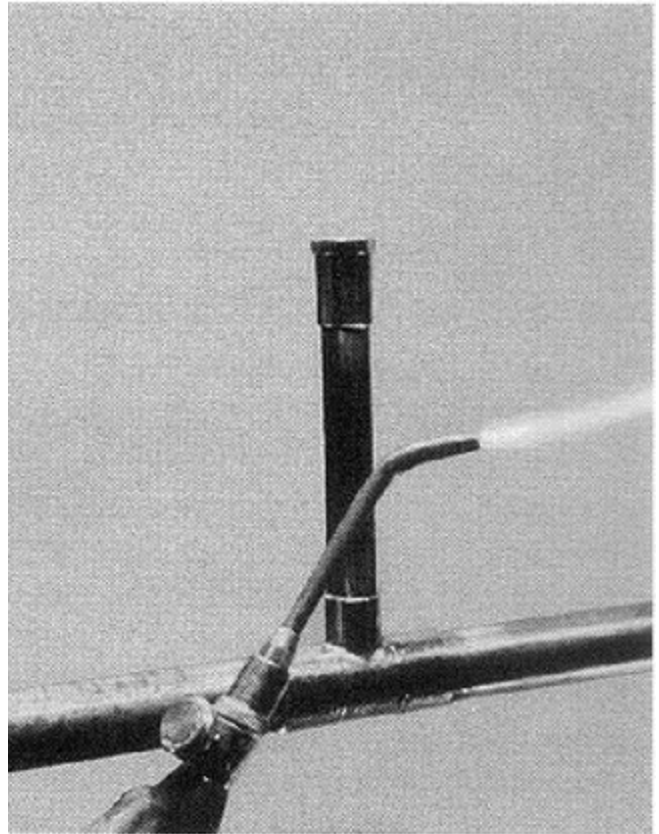
*Removing excess flux*

When heating, the service technician may find it helpful to remember the word "USE." This is a constant reminder that:

- the heat should be Uniform,
- it should be Sufficient,
- but it must not be Excessive.

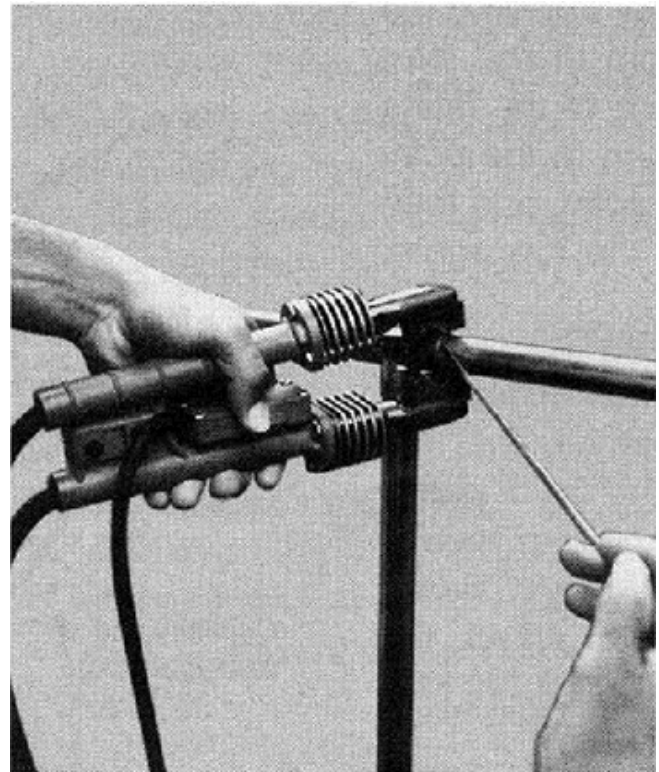
Begin heating with the flame perpendicular to the tube (Figure 18). The copper tube conducts the initial heat into the fitting socket for an even distribution of heat inside and out. The extent of this preheating depends on the size of the joint. Experience will indicate the amount of time needed.

Next, move the flame onto the fitting cup (Figure 19). Then move



**Figure 16**

*Heating with an air/fuel torch*



**Figure 17**

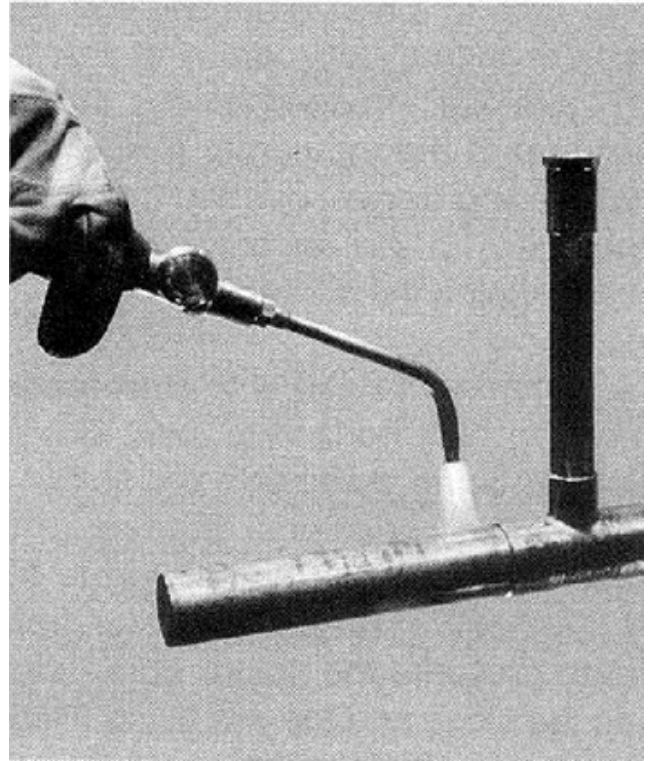
*Using electric resistance pliers*

the flame from the fitting socket back onto the tube a distance equal to the depth of the fitting socket. Touch the solder to the joint. If the solder does not melt, remove it and continue the heating process. Be careful not to overheat or to direct the flame into the face of the fitting cup. This could cause the flux to burn and destroy its effectiveness. When the melting temperature of the solder has been reached, heat may be applied to the base of the cup to aid capillary action in drawing the solder into the cup.

## APPLYING SOLDER

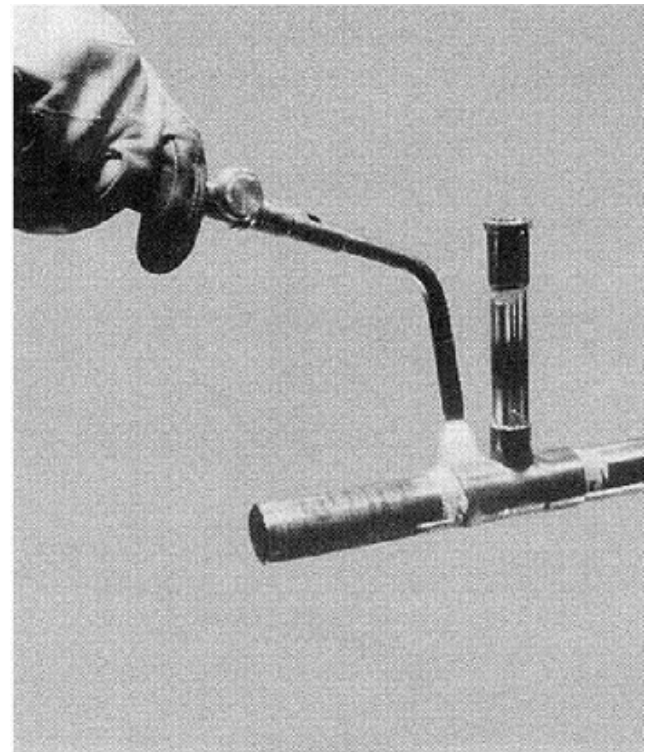
For tube in a horizontal position, start by applying the solder slightly off-center at the bottom of the joint (Figure 20). Proceed across the bottom of the fitting and up to the top center position. Return to the point where you began, overlap the starting point, and then proceed up the uncompleted side to the top again, overlapping the solder.

A common mistake is to start feeding the solder in at the top of a horizontal joint. But remember that the joint is being made with the solder in the solid, pasty, and liquid conditions. Starting at the bottom means that the solidified solder forms an effective "dam." Especially in larger-diameter horizontal joints, the dam prevents the solder from running out of the joint as the sides and top are being filled (Figure 21).



**Figure 18**

*Preheating the tube*



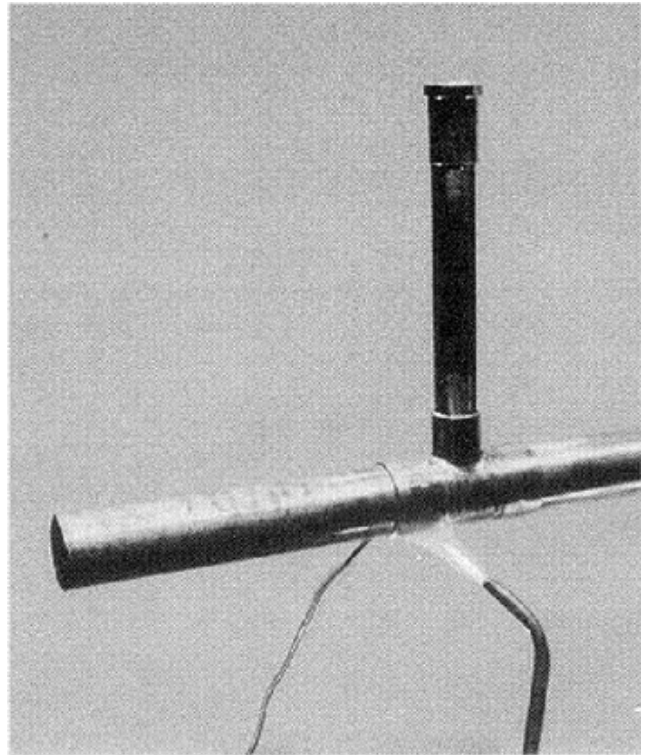
**Figure 19**

*Preheating the fitting*

For joints in a vertical position, you can make a similar sequence of overlapping passes, starting wherever is convenient for you. Molten solder will be drawn into the joint by capillary action regardless of whether the solder is being fed upward, downward, or horizontally.

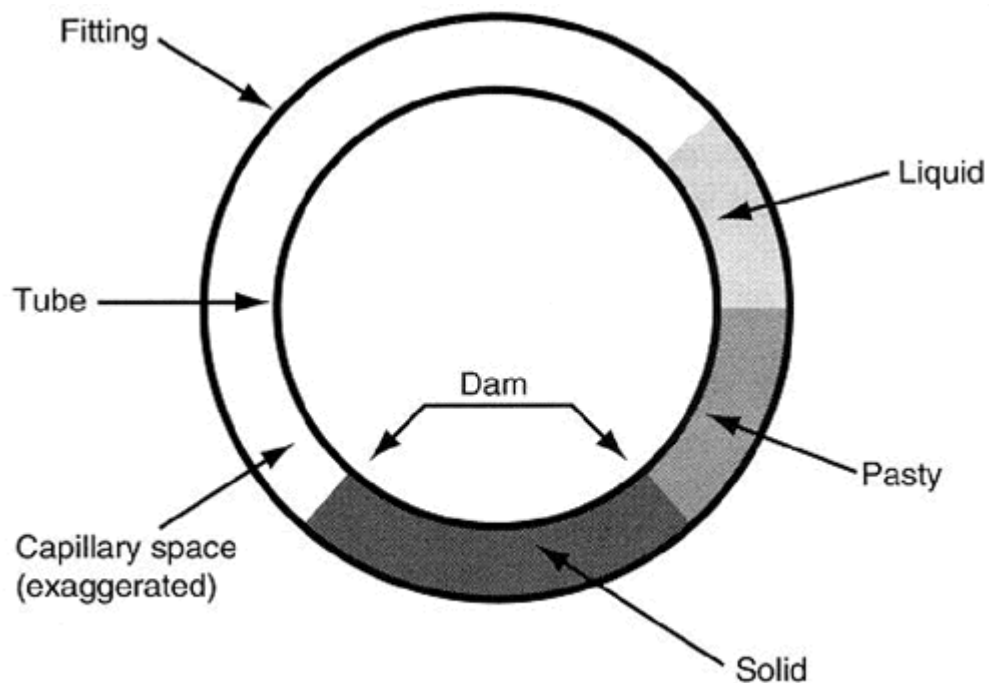
## COOLING AND CLEANING

Allow the completed joint to cool naturally. Shock cooling with water may cause unnecessary stress on the joint and result in its eventual failure. When the joint is cool, clean off any remaining flux with a wet rag (Figure 22). Whenever possible, completed systems should be flushed to remove excess flux and debris.



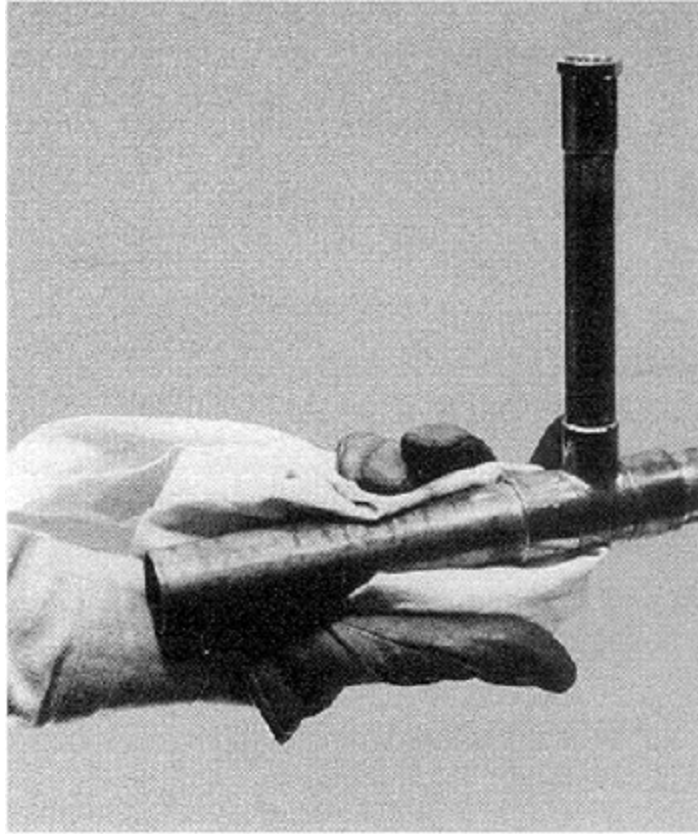
**Figure 20**

*Soldering*



**Figure 21**

*Schematic of a solder joint*



**Figure 22**

*Cleaning*

## **TYPES OF SOLDER**

There is a variety of solders available that produce sound, leak-tight joints. The selection of a solder depends primarily on the type of application--its operating pressure and temperature--and on local codes. A 50-50 tin-lead solder is usually suitable for moderate pressures and temperatures. For higher pressures, or in cases where greater joint strength is required, a 95-5 tin-antimony solder can be used. (For continuous operation at temperatures exceeding 250°F, or where the highest joint strength is required, brazing filler metals should be used.)

For drinking water systems, solders that do not contain lead must be used. Solders containing lead are banned for potable water systems by the 1986 amendment to the Federal Safe Drinking Water Act.

## **BRAZING**

Brazing is the second most commonly used method for joining copper tube. Making brazed joints is similar to making soldered joints with respect to measuring, cutting, reaming, cleaning, and assembly and support techniques. And, as is the case with soldering, the filler metal for brazing is melted by the heat of the tube and fitting and drawn into the joint by capillary action.

The major differences between soldering and brazing are:

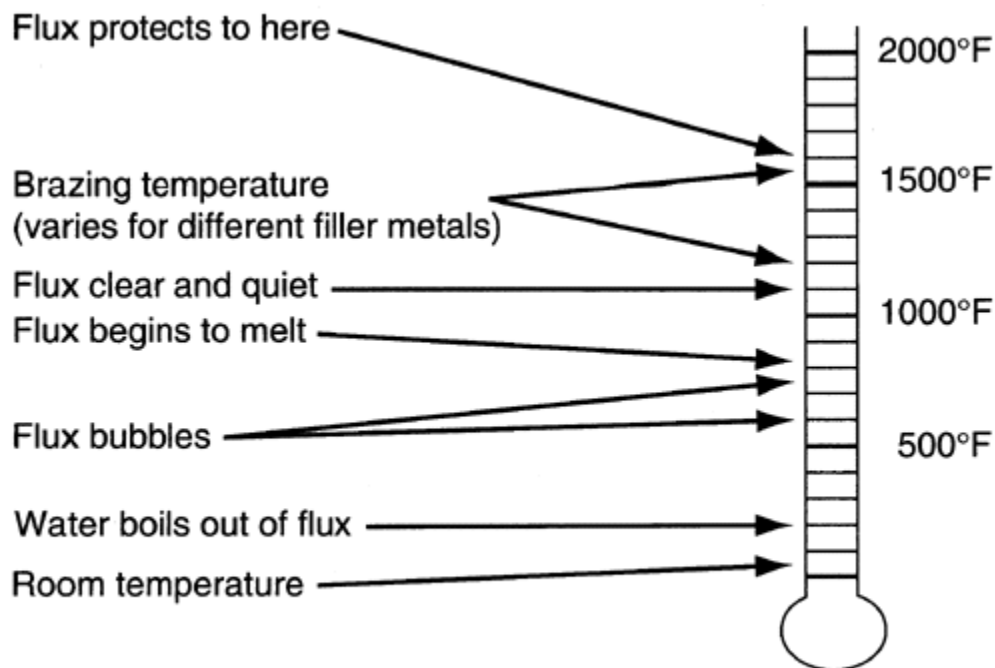
- the type of flux used
- the composition of the filler metal
- the amount of heat required to melt the filler metal.

Brazing filler metals sometimes are referred to as “hard solders” or “silver solders,” but these confusing terms should be avoided.

## APPLYING FLUX

The fluxes used for brazing copper joints are different in composition from soldering fluxes. The two types cannot, and should not, be used interchangeably. Brazing fluxes are water-based, whereas most soldering fluxes are petroleum-based. Similar to soldering fluxes, brazing fluxes dissolve and remove residual oxide from the metal surface, protect the metal from reoxidation during heating, and promote wetting of the surfaces to be joined by the brazing filler metal.

Fluxes also provide the service technician with an indication of the temperature of the joint during the brazing process (Figure 23). Application of the flux is the same as when you are soldering. If the outside of the fitting and the heat-affected area of the tube are covered with flux (in addition to the end of the tube and the cup), oxidation will be prevented and the appearance of the joint will be greatly improved.



**Figure 23**

*Behavior of flux during the brazing cycle*

## BRAZING FILLER METALS

There are two general types of brazing filler metals used for joining copper tube. Classified according to their components, they are:

- BCuP (Brazing-Copper-Phosphorus)
- BAg (Brazing-Silver).

BCuP filler metals are preferred for joining copper tube and fittings. The phosphorus in them acts as a fluxing agent and the lower percentage of silver makes them relatively inexpensive. When copper tube, wrought copper fittings, and a BCuP brazing filler metal are used, fluxing is optional due to the self-fluxing action of the phosphorus.

The choice of filler metals for brazing depends on four main factors:

- the dimensional tolerance of the joint
- the fitting type and material (cast or wrought)
- the desired appearance
- cost.

## HEATING

Oxy/fuel torches generally are used for brazing because of the higher temperatures required (Figure 24). Recent innovations in tip design make air/fuel torches useful on a wider range of sizes for soldering and brazing.



**Figure 24**

*Heating with an oxy/fuel torch*

Working temperatures for brazing are high, and safety precautions must be followed to protect both the operator and the materials being used.

The heating operation is the same as for soldering. First preheat the tube and then the tube and fitting. When the filler metal starts to melt, apply heat at the base of the fitting socket to help draw the brazing filler metal in by capillary action.

## APPLYING BRAZING FILLER METAL

Remember to allow the heat of the joint, not the flame, to melt the filler metal. The melted filler metal will be drawn into the joint by capillary action. It is very important that the flame be in continuous motion. It must not be allowed to remain at any one point long enough to burn through the tube or fitting. The flux may be used as a guide as to how long to heat the tube-continue heating the tube until the flux becomes quiet and transparent, like clear water.

If the filler metal fails to flow, or has the tendency to ball up, it indicates either that there is oxide on the surfaces being joined or that the parts to be joined are not hot enough. If the filler metal refuses to enter the joint, the fitting cup is not hot enough. If it tends to flow over the outside of either part of the joint, it indicates that that part is overheated. When the brazed joint is completed, a continuous fillet should be visible completely around the joint.

## LARGER-DIAMETER TUBE

Larger-diameter tube is more difficult to heat to the desired temperature. It may be necessary to use a heating tip or rosebud to maintain the proper temperature over the area being brazed. Once total heat control is attained, follow the same procedures used for smaller tube.

## COOLING AND CLEANING

When the brazed joint is finished, allow it to cool naturally. Flux residues can be removed by washing with warm water and brushing with a stainless steel wire brush.

## SUMMARY

If the copper tube and fittings to be joined by soldering or brazing are prepared and heated properly, and if the correct filler metal is used, the finished joint will be sound. Soldered or brazed copper piping systems, when installed properly, will provide decades of safe and reliable service. Through the proper application of the installation techniques covered in this chapter, the service technician can achieve consistently reliable soldered and brazed joints in copper tubing systems of all diameters.