HVACR technicians using improper techniques for soldering/brazing copper and copper alloys will have joint failures—and customers—to contend with.

By Andrew G. Kireta, Jr.

In actual practice for copper systems, most soldering is done at temperatures from about 350°F to 600°F, while most brazing is done at temperatures ranging from 1,100°F to 1,500°F. Brazed joints are used where greater joint strength is required or where system temperatures are as high as 350°F. Applications for brazing include water supply and distribution; fuel-gas distribution; medical gas; fire protection; and, of course, air-conditioning and refrigeration.

When brazing copper tube, however, the annealing—changes that occur in the metal’s properties to induce ductility, soften material, relieve internal stresses, refine the structure by making it homogeneous, and improve cold-working properties—of the tube and fitting that results from the higher heat used in the brazing process can cause the rated pressure of the system to be less than that of a soldered joint. This should be considered when it is time to choose which joining process to use.

While soldering and brazing seem like simple enough procedures, it is important to take time to accomplish each step of the process correctly. If technique is poor, it can lead to a faulty joint. Common causes for joint failure include several factors:

→ Improper joint preparation;
→ Lack of proper support or hanging during soldering or brazing;
→ Improper heat control and heat distribution throughout the joining process;
→ Improper application of solder or brazing filler metal to the joint;
→ Inadequate amount of filler metal applied to the joint;
→ Sudden shock cooling or wiping the molten filler metal following soldering or brazing; and
→ Pre-tinning of joints prior to assembly and soldering.

The basic technique with soldering and brazing is the same for all sizes of copper tube, with the only differences being the fluxes, filler metals and amount of heat applied. The following steps outline the basic requirements for making a high-quality soldered or brazed joint:

→ Measuring and cutting;
→ Reaming;
→ Cleaning;
→ Fluxing;
→ Assembly and support;
→ Heating;
→ Applying the filler metal; and
→ Cooling and cleaning.

**Measuring and cutting**
The key to this step is accuracy. Inaccuracy while measuring can compromise the joint quality when it is completed. If the tube is too short, it will not reach all the way into the fitting and a proper joint cannot be made. If the tube is too long, system strain may be introduced that could affect the service life. So be sure to cut the tube to the appropriate length.

Several tools can be used to cut a squared end, such as a disc-type tube-cutting tool, a hacksaw, an abrasive wheel, or a stationary or portable band saw. Make sure that the tube is not deformed while being cut. Regardless of how you plan on cutting the tube, the cut must be square to the run of the tube so the tube will seat properly in the fitting.

**Reaming**
Ream all the cut tube ends fully to remove the burr inside the tube that the cutting creates. If this step is skipped, erosion/corrosion may occur due to local turbulence and increased local flow velocity in the tube. A properly reamed tube provides an undisturbed surface for smooth flow.

Remove all burrs on the outside of the tube ends so there will be no problems assembling the tube into the fitting. Reaming tools include the reaming blade itself on a tubing cutter, half-round or round files, a pocketknife and a suitable deburring tool. With soft tube, be careful not to deform the
CdA Project Manager Harold Moret teaches the proper way to solder at the UA Training Program.

tube end by applying too much pressure. If soft-temper tube is deformed, it can be brought back to roundness with a sizing tool consisting of a plug and sizing ring.

**Cleaning**  
To ensure proper flow of filler metal into the joint, it is crucial to remove all oxides and surface soil from the tube end and fittings. Failure to remove this can interfere with capillary action (which is when liquid spontaneously rises in a narrow), and may reduce the strength of the joint and cause failure.

The capillary space between the tube and fitting is approximately 0.004 in. Filler metal occupies this gap by capillary action. This spacing is critical because it determines whether there is a proper flow of filler metal into the gap, ensuring a strong joint.

Gently clean the tube ends using sand cloth or nylon abrasive pads for a distance slightly more than the depth of the fitting. Clean the fittings by using an abrasive cloth, abrasive pads or a properly sized fitting brush. Copper is a relatively soft metal, and if too much material is removed from the tube end or the fitting, a loose fit may result in a poor joint.

Chemical cleaning may be used if tube ends and fittings are thoroughly rinsed after cleaning according to the procedures furnished by the chemical manufacturer. Do not touch the cleaned surface with bare hands or oily gloves because skin oils, lubricating oils and grease impair the adherence of filler metal.

**Fluxing**  
Use a soldering flux that will dissolve and remove traces of oxide from the cleaned surfaces to be joined, protect the cleaned surfaces from re-oxidation during heating, and promote the wetting of the surfaces by the solder metal. Apply a thin, even coating of flux with a brush to the tube and fitting as soon as possible after cleaning. Be sure not to apply flux with fingers. The chemicals in the flux can be harmful if it comes into contact with the eyes, mouth or open cuts.

Be careful when applying flux. Poor workmanship can cause long-term problems after the system has been installed. If too much flux is used, flux residue can cause corrosion. In extreme cases, such flux corrosion could perforate the wall of the tube, fitting or both.

**Assembly and support**  
Take the tube end and insert it into the fitting, making sure the tube is seated against the base of the fitting. A slight twisting motion will ensure even coverage by the flux. Remove all the excess flux from the exterior of the joint with a cotton rag.

Support the tube and fitting assembly to ensure an adequate capillary space around the entire circumference of the joint. Uniformity of capillary space will ensure good capillary flow of the solder metal. Excessive joint clearance can lead to solder metal cracking under stress or vibration.

**Heating**  
When dealing with an open flame, high temperatures and flammable gases, make sure to take proper safety precautions. Apply heat to the parts to be joined, preferably with an oxy-fuel torch with a neutral flame for brazed joints. An air-fuel torch is sometimes used on smaller sizes and is preferred for all soldered joints.

Heat the tube first, beginning about 1 in. from the edge of the fitting, and sweep the flame around the tube in short strokes at right angles to the axis of the tube. It is very important that the flame be kept in motion and not remain on any one point long enough to damage the tube.

The flux may be used as a guide to gauge how long to heat the tube. Switch the flame to the fitting at the base of the cup and heat uniformly, sweeping the flame alternately from the fitting to the tube. Avoid excessive heating of cast fittings, due to the possibility of cracking. When the flux appears liquid and transparent, start sweeping the flame back and forth along the axis of the joint, maintaining heat on the parts to be joined—especially toward the base of the cup of the fitting. The flame must be kept moving so the tube and fitting do not melt.

For brazing larger sizes of pipe, it may be difficult to bring the whole joint up to temperature at one time. A mild preheating of the entire fitting is recommended, and the use of a second torch to retain a uniform preheating of the entire fitting assembly may be necessary in diameters of more than 6 in.

Apply the filler metal at a point where the tube enters the socket of the fitting. When the proper temperature is reached, the filler metal will flow readily into the space between the
tube and fitting socket, drawn in by capillary action. Keep the flame away from the filler metal itself as it is fed into the joint. The temperature of the tube and fitting at the joint should be high enough to melt the filler metal.

Keep both the fitting and tube heated by moving the flame back and forth from one to the other as the filler metal is drawn into the joint. When the joint is properly made, filler metal will be drawn into the fitting socket by capillary action and a continuous fillet of brazing filler metal (or a casting along the outside of a braze joint that shows that the brazing filler metal has melted and flowed along the edge of a braze joint) will be completely visible around the joint.

To aid in the development of this fillet during brazing, the flame should be kept slightly ahead of the point of filler-metal application. Stop feeding the filler as soon as you see a complete fillet. For solder joints, the fillet does not add to joint strength and is not likely to form with today’s lead-free solders.

**Applying filler metal**

Start applying soldering metal slightly off-center at the bottom of the joint for joints in the horizontal position. When the filler metal begins to melt, push it straight into the joint while keeping the torch at the base of the fitting and slightly ahead of the application of the filler metal.

Continue this technique across the bottom of the fitting and up one side to the top, which will produce an effective dam that will prevent the filler metal from running out on the joint as the sides and top are being filled. Return to the beginning point, overlapping slightly, and proceed to heat and add filler metal up the uncompleted side to the top, again overlapping slightly.

When applying filler metal on vertical joints, the starting point does not matter. If the opening of the socket is pointing down, care should be taken to avoid overheating the tube, as this may cause the filler metal to run down the outside of the tube.

**Cooling and cleaning**

Allow the completed joint to cool naturally because cooling with cold water may stress or crack the joint. Once cooled, clean off any remaining flux with a wet rag, and whenever possible, systems should be flushed to remove excess flux and debris. Be sure to test all completed assemblies for joint integrity. Follow the testing procedure prescribed by applicable codes governing the intended service.

**Purging**

Some installations, such as medical gas and air-conditioning and refrigeration systems, require the addition of an inert gas during the heating/joining process. The purge gas displaces oxygen from the interior of the system while it is being subjected to the high temperatures of brazing and therefore eliminates the possibility of oxide formation on the interior tube surface. Since copper oxidizes readily at high temperatures, the inert-gas purge should remain until the system naturally cools to room temperature.

**Standards**

The Copper Development Association created the *Soldering Procedure Specification* in response to the many inquiries regarding the methods and procedures for qualifying installers of soldered copper piping systems. While there is currently no formalized installer certification program, the procedure detailed in the specification does satisfy the requirements of ASTM B 828.

[Editor’s Note: Be sure to check out this feature online at www.rsesjournal.com and link directly to the Soldering Procedure Specification, as well as a complete guide to brazed joints.]

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