Joining Copper and Copper Alloys

Learn about some of the best practices to utilize when joining copper and copper alloys in HVACR systems, and the debunking of some brazing wives' tales.

BY DALE L. POWELL

Images courtesy of Copper Development Association Inc.

Copper tube and fittings have been a preferred material for high-pressure applications as far back as the late 1700s, when copper condenser tubes were used in steam engines. In 1902, Willis Carrier began working on a solution for a humidity problem that was causing magazine pages to wrinkle at a publishing company in Brooklyn, NY. Carrier's experiments led to the first modern electrical air-conditioning unit.

More than 100 years later, design engineers and field technicians still depend on copper tube and fittings for strong, leak-free connections. Today, with our focus on the environment and a steady flow of new refrigerants that operate at increasingly higher pressures, it is more important than ever to fully understand the joining technology and practices that produce these highly effective and long-lasting connections. It is also important to be aware of misconceptions that have developed over the years that can lead to improper applications.

Soldering/Brazing: A well-defined process

While brazing is often the preferred and recommended joining method for HVACR systems—primarily due to its high strength and resistance to creep and fatigue caused by system vibration—the steps necessary to make a sound brazed joint are no different than those used to solder copper tube and fittings. This article does not cover the *exact* technique here; however, techniques can be found at www.copper.org or at www.youtube.com/user/coppervideo. The important thing is to note that the process has been long-researched and well-defined and can be outlined as the series of steps.

The basic technique for soldering and brazing is the same for all sizes of copper tube. The only differences are the temperature necessary to fabricate each joint type, the type of filler metals utilized for each process and the final allowable operating pressure and temperature ratings for the various

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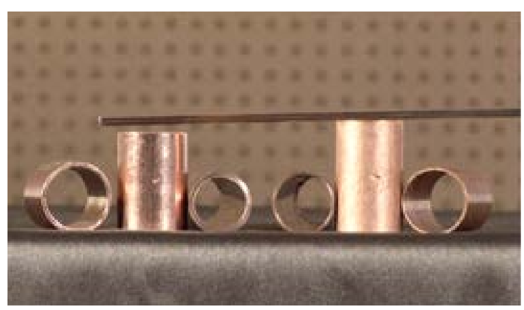
systems for which they are employed. The American Welding Society defines soldering as a joining process that takes place below 840°F/449°C, while brazing takes place above 840°F but below the melting point of the base metal. The following steps outline the basic requirements for making a high-quality soldered or brazed joint:

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

The materials

ASTM B280 copper tube—manufactured from UNS alloy C12200 and most often referred to as AC/R or reefer tube—has been the industry standard tube for air-conditioning and refrigeration applications since the late 1940s to the early 1950s. It is composed of 99.9% copper and silver combined with phosphorous in a range between 0.015%–0.40%. The tube has maximum pressure and temperature ratings of 700 psig and 250°F throughout its size range from 1/8 in. through 4 1/8 in. per UL standard 207. The pressure and temperature rating allows this tube to function well in systems utilizing many of the newer refrigerants, such as R-134, R-134a, R-410 and R-410A, that operate at much higher pressures and temperatures than the old R-22 and R-11 systems.

Copper fittings used for HVACR systems are the same as those used for most all copper piping systems, and they are designed with fitting cup depths deep enough to be used for soldering or brazing. These fittings are made from the same alloy as the copper tube, and when joined to copper tube by brazing with a phosphorous-containing filler metal can be joined without the use of brazing flux. Many specialty fittings, valves, etc. used in HVACR systems are made from other copper alloys, like brass and bronze. When these are brazed to copper tube, regardless of the filler metal used, a brazing flux must be applied to the joint surfaces.



« **Figure 1** Copper iron tube and fitting on left and standard AC/R tube and fitting on the right.

In addition to standard copper tube and fittings, a new alternative for higher-pressure applications has been introduced: copper iron alloy tube and fitting. This tube, designated as UNS alloy C19400, has a very small content of iron, approximately 2%, and a very small percentage of zinc, lead and phosphorous. That small, yet very important percentage of phosphorous allows this tube and fitting, of the same alloy, to be brazed using filler metal alloys and the brazing process to be used with standard AC/R tube as mentioned previously. No brazing flux would be required. This tube and fitting combination, following brazing, attains the maximum operating pressure and temperature ratings of 130 Bar (1885.49 psi) and 250°F. This is well within the operating range of systems using R-744 carbon dioxide refrigerant.

Soldered Joint.

High-pressure HVACR press-connect joint.

Brazed joint.

The wall thickness of copper iron tube and fittings is thicker than the standard AC/R tube and fittings used at lower pressure systems. The thicker wall of the copper iron tube and fitting and the shorter cup depth for the copper iron fitting can be seen in Figure 1. The shorter cup or lap length of the copper iron fitting requires that the joint be brazed and not soldered. Soldering is not permitted for copper iron alloy joints in refrigeration.

Techniques and tales

While soldering and brazing seem like simple procedures, it is important to take your time to accomplish each step of the process correctly. If technique is poor, it can lead to a faulty joint.

Many unsatisfactory brazed joints that result in premature failure or leaks can often be directly attributed to technicians' misunderstanding of the metallurgy and science involved in fabricating solid, reliable brazed joints. Much of that misunderstanding is supported by the perpetuation of many old wives' tales related to brazing circulated throughout the industry. The following paragraphs are an attempt to dispel a few of those industry-perpetuated old wives' tales:

Myth: The tube and fitting do not need to be cleaned prior to making a brazed joint, because the oxide will burn off at the brazing temperature. This is an obvious, and incorrect, misunderstanding that can lead to unsatisfactory joint strength and possible leaks. The oxide layer on the tube and fitting surfaces, usually cuprous oxide, does not burn (just like the copper itself does not burn). The oxide melts at a temperature of 2,255°F (1,235°C), higher than the temperature at which the copper tube itself will melt, 1,981°F (1,083°C). So, trying to "burn off" the oxide layer will not actually work, the tube itself will melt first.

It has been proven that much stronger soldered and brazed capillary space joints are those where the tube and fitting have been mechanically cleaned (oxides removed) prior to the fabrication of either a soldered or brazed joint.

Myth: High silver-bearing BCuP alloys, like BCuP-5 (15% silver), can be used to join copper to brass or bronze without the need for brazing flux, and these high-silver joints produce a stronger joint overall. This is a combination of two common misunderstandings of brazing: While brazing flux is not necessary in all joints, the determining factor on whether it is necessary is dependent on phosphorous, not silver. If there is phosphorous in all three parts of the joint—the tube, fitting and filler metal—no brazing flux is required. Should any one of those components lack phosphorous, brazing flux would be required to assist in capillary action. As for the strength of the joint, for all practical purposes the range of silver in the brazing filler metals commonly used to join copper will not produce meaningful strength differences in the joint. The additional silver may provide better fluidity of the filler metal during the joining process, especially in joints with slightly larger capillary spaces.

Myth: The tube and fitting must be glowing red hot before you should even think about making a brazed joint. Another fallacy that could lead to les-than-satisfactory joint strength. There must be enough heat in the tube, fitting and capillary space to melt the filler metal so it flows into the capillary space. It should be understood that the alloy absorbs heat from all three of those components to cause it to melt. As it absorbs heat to melt, it is actually taking heat from them and cooling the joint to a certain extent. The

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telltale sign that the joint is at the temperature necessary to fabricate a satisfactory brazed joint is when the brazing filler metal (alloy) melts and flows into the capillary space. Observing the filler metal flowing and not balling up on the tube/fitting interface is a sure sign the joint is hot enough to braze.

Myth: Quenching or quick cooling a brazed joint strengthens the joint. This is yet another common mistake that is made when soldering or brazing. Allow the completed joint to cool naturally. Shock cooling with water may stress or crack the joint or fitting material due to rapid contraction.

This list represents only a few of the more common fallacies perpetuated by industry technicians related to brazing that can contribute to decreased system integrity. Trying to address all of the misunderstood procedures and practices would take volumes that cannot possibly be addressed in this short article.

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