3.1 Copper Tubing

Copper tubing used for air conditioning and refrigeration work is called ACR (Air Conditioning and Refrigeration) tubing. It differs from copper tubing used for general plumbing work. When ACR tubing is manufactured, the inside of the tubing is dehydrated to remove all moisture. The tubing is then charged (filled) with low-pressure nitrogen gas and sealed with a cap at each end to keep the tubing safe from contamination by oxygen and moisture in the air. If oxygen atoms were to combine with copper atoms (a process called oxidation), a layer of copper oxide would form inside the tubing. The caps also keep out dirt and other foreign matter that could contaminate a refrigeration system. Caps or plugs should be replaced after cutting a length of tubing.

Plumbing copper tubing is cheaper than ACR copper tubing, but plumbing copper is not used in refrigeration systems because it is not protected against contamination. Plumbing copper also differs from ACR copper in size. Plumbing copper is measured by its nominal inside diameter (ID), while ACR copper is measured by its outside diameter (OD). See Figure 3-1.

#### 3.1.1 Types of Copper Tubing

Copper tubing is available in soft and hard-drawn types. Soft copper tubing has been annealed (softened by heating it to a bright cherry red color and permitting it to cool) so it can be bent easily. Hard-drawn copper tubing is rigid and cannot be bent easily unless it is first annealed. Both soft copper and hard copper are further classified according to the thickness of the tubing wall. Three thicknesses are available: K, L, and M.

- **Type K** is usually hard-drawn and is used in commercial refrigeration systems.
- **Type L** is the most common tubing. It has a medium-wall thickness and is used for residential and commercial applications. Most ACR tubing, both soft and hard, is Type L thickness. When ACR copper tubing is ordered, Type L is automatically provided unless another thickness is specified.
- **Type M** is a thin-walled tubing. It is not used in refrigeration systems because it does not meet safety code requirements. Some manufacturers use Type M copper tubing to construct water-carrying coils. Plumbers may use it for small drain lines and for other noncritical applications.

## Objectives

After studying this chapter, you will be able to:

- Identify types and sizes of copper tubing.
- Select and properly use tubing tools.
- Demonstrate proper use of tube bending tools.
- Describe the steps needed to make flared connections.
- Identify and properly use various types of copper tubing fittings.

## Important Terms

<table>
<thead>
<tr>
<th>ACR tubing</th>
<th>offsets</th>
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<tr>
<td>annealed</td>
<td>outside diameter</td>
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<td>chamfer</td>
<td>oxidation</td>
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<td>compression fittings</td>
<td>P-trap</td>
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<td>coupling</td>
<td>pressure drop</td>
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<td>elbows</td>
<td>psi</td>
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<td>flare</td>
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<td>bonnet</td>
<td>reducing coupling</td>
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<td>cap nut</td>
<td>soft copper tubing</td>
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<td>flare</td>
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<td>fitting</td>
<td>street elbow</td>
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<td>flare</td>
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<td>elbow</td>
<td>sweat soldering</td>
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<tr>
<td>union</td>
<td>telescoping</td>
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<tr>
<td>flaring</td>
<td>tubing cutter</td>
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<tr>
<td>flaring block</td>
<td>union</td>
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<tr>
<td>hacksaw</td>
<td>work-hardening</td>
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<tr>
<td>hard-drawn copper tubing</td>
<td>wrought fittings</td>
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<tr>
<td>inside diameter</td>
<td>lever-type tubing</td>
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<td>benders</td>
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Because soft copper is easily bent, it must be supported with clamps or brackets every four to six feet. Soft copper tubing has a tendency to harden as a result of vibration, oxidation, and bending. This is called work-hardening. Work-hardened copper will crack at stress points, especially when it is flared or formed at the tubing ends. Copper that has become work-hardened can be resoftened by heating it to a bright red surface color and then allowing it to cool. Unrolling soft copper coils. Soft copper coils should be handled with care because the tubing is easily damaged. Kinks, bends, flat spots, or dents will make the material unfit for use. Bending and kinking can be avoided by unrolling the coil properly. As shown in Figure 3-3, unrolling is done by supporting the coil upright with one hand and holding the free end of the tubing stationary on a flat surface with the other hand (or a foot). The coil is then rolled in a straight line to the desired length. Do not unroll an excessive amount because it is difficult to recoil the tubing without bends or kinks. After cutting off the desired length, replace the cap or plug on the end of the coil to prevent contamination.

**Figure 3-1.** ACR copper tubing and plumber’s copper tubing are measured differently. ACR tubing is sized by actual outside diameter. Plumber’s tubing is measured by nominal inside diameter — the OD usually is 1/8” larger than its ID.

**Figure 3-2.** Soft copper ACR tubing is supplied in 50-foot coils. To prevent contamination, it is dehydrated, filled with nitrogen gas, and capped at both ends. (Mueller Brass Co.)

**Figure 3-3.** Uncoil soft copper tubing carefully to avoid kinking. Hold one end flat on the floor or other surface, and unroll as much as needed.

**Hard-drawn copper tubing**

Hard-drawn copper tubing is hard and rigid and either Type L or Type K thickness. It comes in standard 20-foot lengths that are dehydrated, charged with nitrogen, and sealed with rubber plugs at each end. **Figure 3-4.** Hard-drawn copper tubing cannot be bent easily, so soldered or brazed fittings are used when making connections or changing directions. Because of its rigidity, hard-drawn copper tubing requires fewer supports or brackets than soft copper tubing, and assembly is quicker. It is available in sizes ranging from 3/8” OD to over 6” OD.
Chapter 3 Working with Copper Tubing

3.2 Working with Copper Tubing

The ability to properly perform such operations as cutting, bending, and joining copper tubing is a basic requirement for success as an HVAC technician. Careful attention to correct use of tools and the development of good work habits will result in trouble-free installations and satisfied customers.

3.2.1 Cutting Tubing

Cutting copper tubing is a simple task, but it must be performed properly. Care must be exercised not to damage the ends being cut. The most common and accurate way to cut copper tubing is to use a tubing cutter, Figure 3-6.

Figure 3-6. Tubing cutters produce an accurate, clean 90° cut, resulting in strong, well-made joints.

3.2.2 Bending Copper Tubing

Several types of tubing benders are available for making accurate bends in tubing without causing flats, kinks, or dents. Flats and kinks are eliminated, not for the sake of appearance, but because they would restrict the flow of liquid or gas through the tubing.

In a refrigeration system, the tubing must carry motions, plumbers performed the installation and service work. These early systems used ammonia and other corrosive chemicals as refrigerants. Iron and steel pipe had to be used to avoid the chemical reaction that would occur if these chemicals were used with copper tubing and fittings. The development of noncorrosive refrigerants has made possible the use of copper tubing in almost all refrigeration and air conditioning systems today.

The distinction between tubing and pipe is primarily wall thickness and the resulting joining method. Tubing is considered thin-walled material (regardless of whether it is Type K, L, or M) compared to steel and plastic pipe. The term “tubing” is generally applied to materials such as copper and aluminum that are joined by means other than threads. Pipe is the term used to describe thick-walled materials, such as steel or plastic. Threads are cut into the pipe wall, allowing lengths of pipe to be joined with threaded fittings that screw into place.

Fitting different sizes of tubing inside one another is known as telescoping. It is sometimes used to perform emergency repairs when the proper fitting is not available. Telescoping can be performed with ACR tubing because of its OD sizing system and wall thickness. As shown in Figure 3-5, ACR 1/4” copper tubing will fit snugly inside 3/8” copper tubing, 3/8” tubing will fit snugly inside 1/2” tubing, 1/2” will fit snugly inside 5/8”, and so on.

Figure 3-5. Accurate OD sizing allows different diameters of ACR tubing to telescope inside each other.

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In a refrigeration system, the tubing must carry liquid or vapor from one component to another. The...
copper tubing is almost a daily task, especially on installation jobs. Bending is much faster than installing a fitting and does not present a potential leak hazard, as do fittings. Making accurate 45° and 90° bends requires some practice; lever benders are designed to make this task easier and more accurate.

3.3 Connecting Copper Tubing

The walls of copper tubing are too thin to make strong threaded connections, so other means are employed to join lengths of tubing. Two general approaches are used: permanent connections using soldering or brazing on swaged copper tubing or wrought fittings, and mechanical connections using threaded fittings that can be easily disconnected to make repairs or to replace defective parts. The ability to work with copper tubing and the various fittings used to make connections is a basic requirement for anyone entering the HVAC field.

3.3.1 Swaging Copper Tubing

Swaging (pronounced “swedging”) involves enlarging the diameter of one end of a length of soft copper tubing so the end of another length can be slipped into it. See Figure 3-13. The connection is then soldered or brazed to make a strong, leakproof joint. Swaging is the preferred method of joining soft tubing since the process requires little time, and only one brazed joint is needed to complete the connection (compared to two joints for a fitting).

Swaging is done by clamping the tubing in the flaring block, then positioning the proper size swaging punch at the tubing end. A ball peen hammer is used to slowly drive the punch into the tubing end. The punch will enlarge the tubing end to the precise diameter required. The punch should be held firmly and straight during the swaging process. Striking several easy blows is the preferred technique; it permits the copper to swell slowly, resulting in a straighter and more accurate swage. (Using less force is also easier on your knuckles if you miss!) With a little practice, you will be able to determine how hard to strike the punch to obtain the desired swage.

When tubing is inserted into the swage, the fit should be tight and straight. Such a fit is best for proper soldering and brazing. Loose or crooked connections are difficult to solder or braze, resulting in a weak joint. Chapter 5 covers procedures for soldering and brazing tubing.

Punch-type swage. The tubing is clamped into a special tool called a flaring block with just enough tubing protruding through the block to accomplish the enlarging process. See Figure 3-14. The depth of the finished swage should be equal to the original tubing diameter. For example, 1/4″ tubing is swaged 1/4″ deep, and 1/2″ tubing is swaged 1/2″ deep. Swaging punches are available in diameters ranging from 3/16″ to 7/8″.
Chapter 3 Working with Copper Tubing

Couplings are used to connect two pieces of tubing in a straight line. Most couplings have openings of the same diameter at both ends. A reducing coupling, like the one on the right, has openings of different sizes, allowing a larger-diameter piece of tubing to be connected to tubing with a smaller diameter.

Types of fittings

Fittings are available in many different types and sizes, so almost any connection is possible. See Figure 3-16 for examples of wrought fittings. The names and shapes of fittings are common to many trade areas (plumbing, electrical, HVAC), but the sizes, threads, and types of material often differ.

Couplings. The fitting used to connect two lengths of hard copper tubing is the coupling, Figure 3-17. Couplings are available in all sizes and usually have openings of the same diameter on each end. A 5/8" coupling, for example, is used to connect two sections of 5/8" hard copper tubing. These fittings also can be obtained as reducing couplings by specifying the sizes on each end. For example: Reducing coupling, 7/8" × 5/8".

Elbows. Available in either 45° or 90° angles, elbows usually have female fittings on each end. See Figure 3-18. Elbows are used to change the direction of the tubing run. A "short-radius" elbow bends quite sharply, while a "long-radius" elbow makes a more sweeping turn. The long-radius type is preferred because it offers less restriction to the flow of refrigerant. Like couplings, elbows are sized according to the OD of the tubing on which they are used. A 1/2" elbow; for example, would have 1/2" female openings on each end to accept 1/2" copper tubing.

A street elbow contains a female end and a male end. Both openings are normally sized for the same size tubing. The male end of the street elbow is the same size as the tubing; the female end is sized to fit the outer diameter. They are used frequently in HVAC work to make offsets (changes in direction that extend only a short distance). See Figure 3-19. Street elbows reduce the number of brazed connections needed, compared to using regular elbows and short lengths of tubing.

Tees. Fittings called tees are used to connect a branch circuit to an existing line of copper tubing. A tee numbering system guarantees the correct size, type, and placement of an opening. As shown in Figure 3-20, the straight-through connections are numbered 1 and 2, and the branch is assigned number 3. With this numbering system, it is possible to order a tee with different sizes at each opening. For example: Wrought tee, 7/8" × 5/8" × 1/4" OD. (The branch would be 1/4" OD.)

Other fittings. Wrought fittings are available to satisfy almost any need. Special fittings such as P-traps (named for the shape into which the tubing is bent), return bends, unions, and caps can save much time and trouble when installing HVAC equipment.

The union combines aspects of mechanical and permanent-type fittings. It has three parts: two shoulders and a nut for pulling the shoulders together, Figure 3-21. The shoulders of the union are brazed to the ends of the joined copper tubing. The nut pulls on one shoulder while screwing onto the other shoulder, providing a mechanical connection. This results in a leakproof joint that can be disconnected. A union is used in such applications as a drain line that may need to be disconnected for cleaning.

3.3.2 Using Mechanical Connections

Mechanical tubing connections can be divided into two types: those using compression fittings and those using flare fittings. Compression-type connections are rarely used on refrigeration systems since they cannot withstand the high pressure and vibration associated with such systems.
Flared connections, however, are very common on all types of refrigeration systems because they can withstand high pressure and some vibration. Failure of a flare connection can usually be traced to abuse or to lack of skill by the person who made it.

Compression-type connections are commonly used in heating applications that involve only low pressure. They also are widely used for connecting gasoline, natural gas, propane, water, and air lines, where excessive pressure and vibration are not involved. Compression fittings are simple, efficient, and easy to assemble. See Figure 3-22.

Other than making sure tubing ends are cut square and burrs are removed, no special preparation is needed when using compression fittings. Simply slip the nut and compression ring over the tubing, then insert the tubing into the fitting until it rests against a shoulder. Slide the compression ring into position and tighten the nut.

Tightening the nut causes the ring to be compressed between mating surfaces, providing a leakproof connection. When the connection is disassembled, the ring will remain attached to the tubing and cannot be removed. The ring is often called a “sleeve” or “ferrule.”

Compression fittings are never used on refrigeration systems because of vibration and high pressure. However, some residential air conditioning systems use special compression fittings to join tubing from the indoor unit to the outdoor unit. These field connections are simple, inexpensive, and quick.

Compression fittings. Fittings are sized according to the outside diameter of the tubing, ranging from 1/8” to 7/16”. Nuts and compression rings needed for installation are provided with all compression fittings such as unions, elbows, and tees. Many adapters are available to connect tubing with a compression fitting on one side and a flare fitting or pipe connection on the other.

Flare-type connections

Flaring copper tubing is a process of expanding or spreading the end of the tube into a funnel shape with a 45° angle, Figure 3-23. All refrigeration flare fittings are made with a 45° angle so the tubing will fit snugly against the fitting. A flare nut is used to compress the flare against the fitting to obtain a tight, leakproof, metal-to-metal contact.

Refrigeration tubing connections must withstand at least 300 psi (pounds per square inch) of pressure without leaking. Because the flare connection is a mechanical, metal-to-metal contact without gaskets, it is vital that proper attention and care be given to making the flares.

The tubing end should be properly reamed before attempting to make flares. Burrs or rough edges will interfere with the smooth metal-to-metal contact and permit leakage.

The tubing is clamped in a flaring block with its end protruding slightly above the chamfer (beveled edge) on the block’s top side. A screw-type yoke with a special flaring adapter is then clamped onto the block and automatically centered above the tube. See Figure 3-24. Turning the screw will force the cone-shaped adapter into the tubing end, spreading it until it is formed to a 45° angle against the chamfer, Figure 3-25.

Figure 3-21. A union combines permanent connections with a mechanical system that allows the union to be disconnected. The locking nut pulls the shoulders tightly together, making it possible to “break” the connection for cleaning or repair work.

Figure 3-22. Compression connections are made by compressing (squeezing) a sleeve or ring between a fitting and a nut. Compression fittings are used more widely in residential heating and air conditioning.

Figure 3-23. When copper tubing is flared, the tubing end is expanded to a funnel shape. The 45° angle matches the angle used on flare fittings.

Figure 3-24. Forming a flare. A—The tubing is clamped in the flaring block. B—The yoke is slipped over the block and automatically centered above the tube. C—The adapter is screwed into the tubing to form the flare.

Figure 3-25. The flaring tool’s cone-shaped adapter stretches the end of the tubing and forces it against the chamfer, forming a 45° flare.

Figure 3-26. A correctly made flare is vital to achieving a leakproof connection. A—Correctly made flare. B—Flare too small. C—Flare too large. D—Flare uneven.
Chapter 3 Working with Copper Tubing

### Flare Fittings

Flare fittings are mechanical fittings intended for use on soft copper tubing. They are usually drop-forged brass and are accurately machined to form a 45° flare face (area where tubing joins the fitting). See Figure 3-28.

Flare fittings are sized according to the copper tubing size and are commonly available from 3/16" to 3/4". The threads for all flare fittings are Society of Automotive Engineers (SAE) National Fine. This means they cannot be connected to other threads, such as pipe threads, National Coarse, or ISO Metric.

**Flare Nuts.** The **flare nut** is the most frequently used fitting. Flare nuts are sized according to the hole through which the tubing is inserted. Since the hole just fits over the tubing, any flats or kinks in the tubing will interfere with the fit. Threads are located on the inside of the nut, and the bottom of the nut contains a perfect 45° flare to exactly match the flare on the tubing end. The tubing flare should almost fill the area at the bottom of the nut.

When the nut is screwed onto a fitting, the flare on the tubing is compressed between the nut and the fitting. To be leakproof to 300 psi (2000 kPa), this metal-to-metal contact requires a perfect match without burrs or ridges to interfere with the seal.

**Flare Elbows.** The **flare elbow** serves the same function as the flare union while providing an accurate bend of either 45° or 90°. Flare elbows (often called "ells") can be obtained in any tubing size, conventional or reducing. For example: 90° flare elbow, 1/4" MFT X 3/8" MFT (or FFT).

**Flare Tees.** The **flare tee** makes it possible to connect a branch to an existing line of copper tubing. The tee numbering system guarantees the correct size, type, and placement of the opening. With the numbering system, it is possible to order a tee with openings of different sizes. For example: flare tee, 1/2" MFT X 3/8" MFT X 1/4" MFT. Position 1 is 1/2" MFT, position 2 is reduced to 3/8" MFT, and position 3 (the branch) is 1/4" MFT. Of course, any of the positions on the tee can be ordered with female threads.

**Flare Plugs.** Available for all tubing sizes, the **flare plug** is used to seal a flare nut or similar female-threaded opening. This seal can be temporary or permanent but is usually temporary until proper repairs can be made.

**Flare Cap Nuts.** A female nut used to seal off a male-threaded fitting is called a **flare cap nut.** This seal can be either permanent or temporary. The flare cap nut is used extensively on service valves and other such devices. The cap nut prevents dirt and other foreign matter from entering the system through an access fitting.

**Flare Bonnets.** The **flare bonnet** is made of copper and is used to convert an ordinary flare nut into a cap nut. Such devices come in handy when a cap nut is not available. The bonnet is placed inside a flare nut, which can be used to cap a male-threaded fitting.

### Flare Nuts

Flare nuts can be obtained in either short or long style. Figure 3-29. The short flare nut is the most common. The long style is used to provide more tubing support when vibration is a concern.

**Figure 3-28.** Flare fittings are normally machined from brass. A—Short nut. B—Long nut. C—Reducing flare nut. D—Tee. E—90° elbow. F—Reducing union.

**Figure 3-27.** A groove in the roller of the tubing cutter allows just the flare to be cut off so the tubing is not shortened any more than necessary.

**Figure 3-29.** Flare nuts are made in both short and long styles. Connections subjected to vibration should be made with long flare nuts for greater tubing support.

Sometimes, a **reducing flare nut** is used to attach tubing to a fitting of another size. This eliminates the use of additional fittings and reduces the number of possible leaks.

**Flare Unions.** A full **flare union** is a fitting used to connect two flare nuts of the same size. It is called a full union because each end of the fitting is the same size. A 3/8" full union would have a 3/8" male flare on each end. A 3/8" full union is a quick way of saying, "3/8" MFT X 3/8" MFT union." (MFT = Male Flare Thread).

A reducing union performs the same function as a full union, except the sizes of the flare nuts are different. It is used to reduce from one size tubing to another, such as 1/2" MFT X 3/8" MFT. It is possible to obtain a union that has a male fitting on one end and a female fitting on the other. Such a union might be described as 3/8" MFT X 3/8" FFT (FFT = Female Flare Thread).

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### Summary

This chapter has explained the various tools and procedures for connecting copper tubing. Copper tubing is used to connect system components, which must be durable and leakproof. Skill is required to perform tubing connections that will withstand vibration and remain leakproof. Poor connections result in loss of refrigerant and failure of the system to operate properly.

Most technicians can recognize tubing sizes and fittings at a glance. They do not need to measure or double-check sizes. This familiarity comes after constantly using tubing and fittings. Likewise, consistently making swages and flares quickly and accurately the first time results from practice.

Beginning technicians are often assigned to work with copper tubing and fittings. Many never progress beyond this stage. They become professional installers of copper tubing. Their pay scale is very good because such skills are important and valuable.

#### Test Your Knowledge

Please do not write in this text. Write your answers on a separate sheet of paper.

1. Why is ACR tubing dehydrated, filled with gas, and capped at both ends?
2. What gas is used to charge ACR copper tubing after it has been dehydrated?
3. The two types of ACR copper tubing are ____ and ____.
4. The three thicknesses of copper tubing are Type ____ , Type ____ , and Type ____ .
   a. J, K, L
   b. 3, 8, 12
   c. K, L, M
   d. A, P, W
5. ACR tubing is sized by its ____ diameter. Plumber’s copper tubing is sized by nominal ____ diameter.
6. Name two methods for cutting copper tubing. Which is preferred? Why?
7. Why is it important to remove burrs from cut ends of copper tubing?
8. Name three methods used to bend soft copper tubing.
9. What is the advantage of swaging over joining tubing with a fitting?
10. Hard-drawn copper tubing is connected by wrought fittings, also known as ____ fittings.
11. The openings in tee fittings are numbered 1, 2, and 3. Which one is the branch opening?
12. Name the two types of mechanical connections.
13. The angle on flare fittings is ____ degrees.
   a. 30
   b. 45
   c. 60
   d. 90
14. True or false? Flare fittings are intended for use only on hard-drawn copper tubing.
15. The flare ____ is the most frequently used flare fitting.