# Lesson Four — Tubing

## Preface

Previous lessons described both metallic and nonmetallic piping systems. You have also studied basic maintenance considerations for piping systems, and should now have a more detailed knowledge of some of them.

This lesson describes tubing, the materials used to make it, how sections are joined, and many of its applications. This lesson also tells you what the difference is between piping and tubing. There *is* a difference, and an important one, which you will learn in the next few paragraphs.

## Tubing

4.01 A common question is: Just what is the difference between pipe and tubing? Many of the differences in physical characteristics, methods of installation, as well as the advantages and disadvantages of tubing will become clear as you read this lesson.

4.02 The term TUBING refers to tubular products made EITHER to an outside OR inside diameter expressed in even inches or fractions of an inch. Because tube walls are relatively much thinner than those of pipes, wall thickness in tubes is of particular importance. In fact, wall thickness is usually given in thousandths of an inch rather than as a fraction of an inch, so closely are the wall thickness tolerances held. At times, a gage number is used to indicate the thickness according to a given system. If none is specifically mentioned, the Birmingham Wire Gage (BWG) system is ordinarily meant.

4.03 Tubing of different diameters has different wall thicknesses. An example from the standardized codes for piping and tubing illustrates the difference between pipe and tubing. The wall thicknesses of two types of 8-inch iron pipe (one light and one heavy) are 0.250" (light) and 0.406" (heavy). A light-wall 8 inch copper tube has a wall thickness of 0.170", and a heavy-wall 8 inch tube has a wall thickness of 0.271". When you compare these figures, it is clear that tubing has a thinner wall than piping of the same general diameter. And you will note that the range between thin and thick is narrower for tubes than for pipes.

4.04 The list of tubing applications includes carrying compressed air; gases (including liquefied gas); steam; water; lubricating oil; fuel oil; chemicals; fluids used in hydraulic systems; and waste products. Some types are used as conduits for

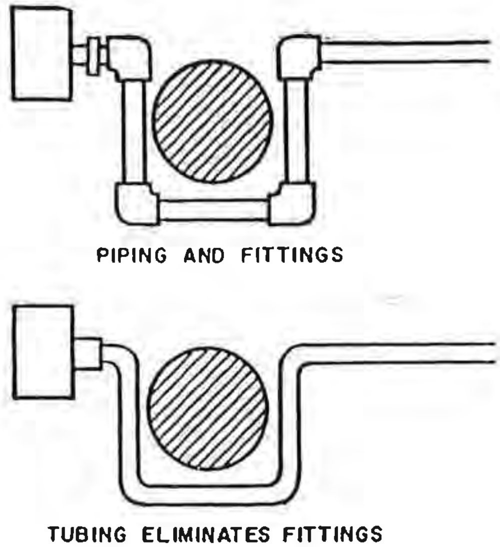



*Fig. 4-1. Advantage of tubing over pipe.*

electric wires. Tubing is made from both metals and plastics.

4.05 Tubing (metallic) is made from strong materials such as steel, copper, stainless steel, and aluminum to allow for applications carrying fluids under pressure. The wall thickness increases slightly as the diameter of the tubing increases.

4.06 Tubing ranges in size from 1/32″ to 12″ in diameter, although most is in the smaller sizes. Standard copper tubing is from 1/32″ to 10″; steel from 3/16″ to 10¾″; aluminum from 1/8″ to 12″; and titanium is furnished up to 8″ in diameter. Pressures that tubing carries can be as much as 6000 psi. Relatively few applications require 6000 lbs pressure, of course. Stainless steel tubing is used when high pressure strength is required.

4.07 Materials used for metal tubing ordinarily have high resistance to corrosive fluids. Although metal tubing may be more expensive than iron pipes in terms of first cost, it may be the best or only product that will do the job in many applications. For example, tubing can be connected to a component that vibrates, because a tube is flexible, and has "give" to it. (Take a look at the gasoline line connected to a vibrating engine block in any automobile.) Rigid iron pipe would not hold up in such a situation.

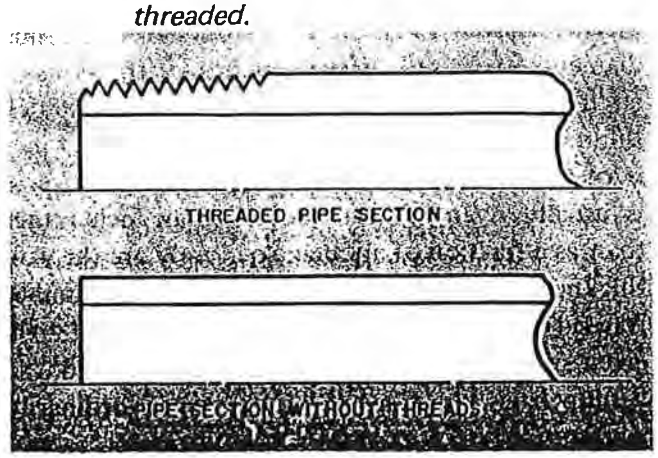
4.08 Where there is an even choice between pipe and tubing, the higher original cost of tubing over pipe must be balanced against such considerations as ease of installation, length of life, and maintenance requirements. These considerations apply when comparing metal tubing with metal pipe. Plastic tubing is discussed later in this lesson.

4.09 Although metal tubing has a relatively thin wall, its major advantage over piping is that it is quite strong. Having thin walls, small tubes (soft materials up to 1″ O.D.) can be bent fairly easily by hand. Larger diameters require power equipment. Being flexible, tubes can be run from one point to another with fewer fittings than if pipe were used.

4.10 Figure 4-1 shows how the use of tubing in a common application eliminated four pipe fittings. The advantages: (1) four potential sources of leaks were eliminated; (2) the cost of four 90° elbow fittings was eliminated; (3) the time required to cut, thread, and join separate sections of pipe was saved (it takes far less time to bend tubing); and (4) the tubing was much lighter in weight than the pipe and fittings would have been. It was also much easier to install, because pipe lengths and a number of fittings weigh considerably more than a single length of tubing bent to follow the same general pathway.

4.11 Mention has already been made of the relatively thin walls of tubing, as contrasted with iron pipe. One reason that iron pipe has a thick wall is that it is often installed with threaded connections, which means that part of the material at the threaded end of the pipe is cut away. However, the pipe must have sufficient wall thickness left to handle the fluid pressure in the line.

*Fig. 4-2. Pipe wall must be thick enough to be threaded.*



Although threads will be cut in only one area of the pipe, the wall thickness for the rest of the pipe section is greater. Because most tubing is designed for brazed and soldered connections, rather than threaded ones, its wall thickness can be made uniformly thin. This advantage of tubing over iron pipe is shown in Fig. 4-2. The lighter weight of tubing also means lower shipping costs, as well as greater ease of handling.

### Advantages of Tubing

4.12 Because of its relatively small diameter and its flexibility, tubing can be used in tight spaces where pipes would be very difficult to install. Its flexibility in absorbing shock from water hammer as the fluid flow is started or stopped is also an asset. Many lines have a frequent on-off cycle. In an iron pipe, this may produce vibration which is transmitted along the rigid line, shaking joints, valves, and fittings. The damage that can result causes leaks and need for recaulking. The pipe supports can also be affected. Because tubing has considerable "give," much of the shock and vibration is absorbed by the line. This means far less wear and tear on the fittings and other connections.

4.13 Sections of tubing are normally connected by brazing, welding, or soldering, rather than by threaded joints. In addition to the advantages in time saved, not using threaded joints avoids other difficulties. Threading would weaken thin-wall tubing, for example, although steel tubing is sometimes joined by threading. It is true, of course, that threaded connections are widely used for pipes, where, properly made, they present no problem.

4.14 Another major advantage of tubing is that it has a smoother, more even, inner-wall surface than iron pipe. For this reason, fluid flow in a tube is more highly LAMINAR, with little or no turbulence. Anything described as LAMINAR is made up of a number of thin layers. (Plywood is a familiar laminar or laminated material.)

4.15 What is laminar flow inside a tube? If you could look straight down the inside of the tube, with the fluid flowing away from you, you would see that the flow is most rapid at the center of the tube. It barely moves at all along the surface of the inside wall. In an example of a perfect situation, all fluid one inch away from the center of the tube would be moving at the same speed. All fluids two inches away from the center of the tube would be moving evenly but at a slightly slower speed than the inner fluid. It is something like the effect when you pull a telescoping radio antenna out to its full length from your car fender. When fluid flows smoothly in a tube, it is LAMINAR flow. If, however, there are dents or bumps on the tube's inner wall, the fluid will be jolted across the otherwise smooth stream at a different velocity. This causes a disturbance or turbulence.

4.16 Iron pipe, in contrast to tubing, has more irregularities along its inner walls. These "bumps" produce turbulence in the fluid flowing along the pipe. For an example of what can happen, a 3 inch iron pipe delivered 110 gallons per minute (gpm) when first installed. It later acquired 1/8" of scale on its inner surface. That might not seem to be much of a coating, but it caused enough turbulence in the flow of the fluid to reduce the delivery rate of the pipe to 89 gpm, a reduction of almost 20%.

4-1. The wall thickness of tubing is expressed in ________ of an inch.

4-2. The materials used for tubing are ________ and ________.

4-3. As tubing diameter increases, the wall thickness ________.

4-4. Stainless steel tubing can handle pressures up to ________ psi.

4-5. Metal tubing ordinarily has high resistance to ________ fluids.

4-6. Pound for pound, metal tubing is ____________ than metal pipe.

4-7. Sections of tubing are normally connected by ________, ________, or ________ joints rather than threaded ones.

4-8. Smooth fluid flow is called ________ flow.

## Advantages of Tubing—Continued

4.17 The advantages of tubing that have been given up to this point have primarily been mechanical advantages, or the result of mechanical conditions (laminar flow, for example). Tubing also has chemical advantages, which come from the corrosion-resistant properties of the metals used to make the tubing. Against some corrosive fluids, all of the tubing materials mentioned earlier do very well; against other corrosives, some metals perform better than others. In some cases, only one type of tubing material is effective. For example, of all the common tubing metals, stainless steel is one of the best to resist the corrosive effects of salt and salt water. (Plastic piping is also excellent.)

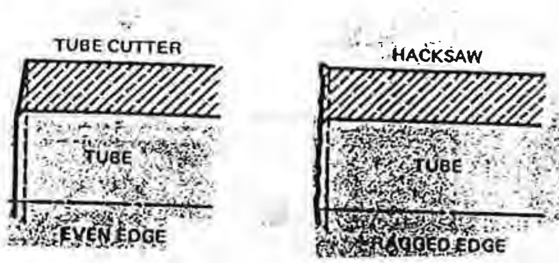
4.18 Tubing can also have an effect on the fluid carried. For example, if the fluid must be kept pure and free from contaminants as in the food-processing operations or in "clean rooms" where conditions of particular cleanliness are necessary, stainless steel, aluminum, or a special plastic tubing must be used.

## Tube Joining

4.19 Tools include: The tube cutter; hacksaw; three-cornered scraper; burring tool; flat file; flaring tool; pre-setting tool for flareless fittings; heavy hammer; suitable wrenches; and tube benders. These are variously used to make either a soldered joint, or a compression joint (where joint sections are pressed together).

4.20 For making either joint, it is important to cut the tubing squarely and cleanly. This can be done with a hacksaw or a tube cutter. Figure 4-3 shows an enlarged section of tube cut off with a tube cutter (left) and a hacksaw (right). Figure 4-4 shows tube cutters for tube sizes 1/8" to 1" (top)

*Fig. 4-3. Difference in cuts made by tube cutter and hacksaw.*



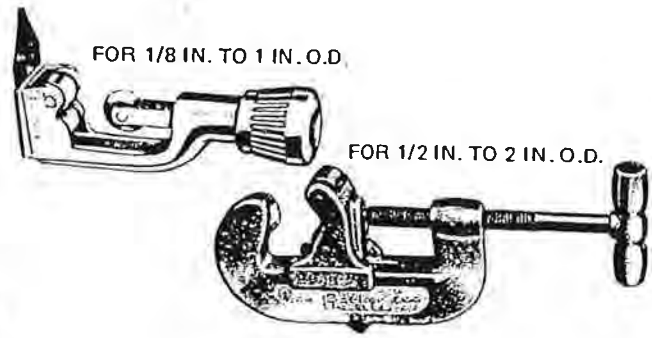




*Fig. 4-4. Tube cutters.*

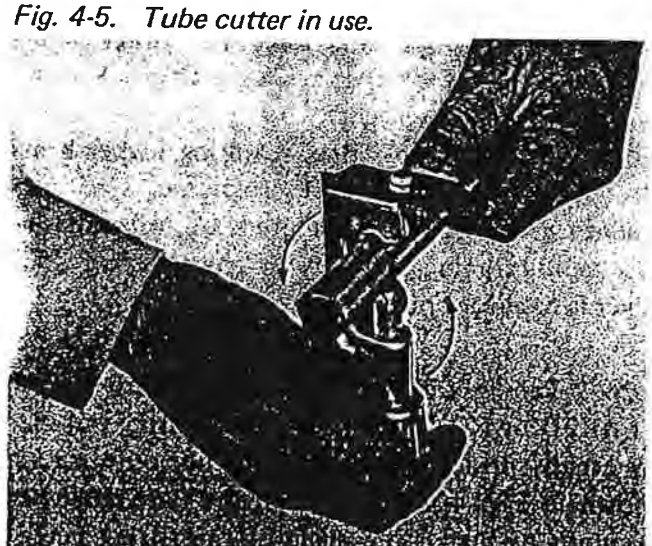
and ½" to 2" (bottom). The cutter has a pair of rollers on one side, a cutting wheel on the other, thus making an open jaw. Figure 4-5 shows such a tube cutter in use. The cutter is turned around the tube, making a clean cut.

4.21 Stainless steel is workhardened more by a tube cutter than by a hacksaw. That is, stainless steel will tend to harden as it is being cut. For this reason, stainless steel tubing should be cut rapidly with as few strokes as possible.

4.22 The rough edge of the cut must be smoothed with a burring tool to remove the small metal whiskers or burrs. One type of burring tool has a cone of blades that fit into the tubing to remove internal whiskers, and a second set of blades, inside a cylindrical end, which smooth the outer surface. If a hacksaw is used, the tube end should be filed until it is straight and square to the length of the tube.

4.23 The soldering operation is the same whether connecting two sections of tubing to-

*Fig. 4-5. Tube cutter in use.*



Parker Hannifin

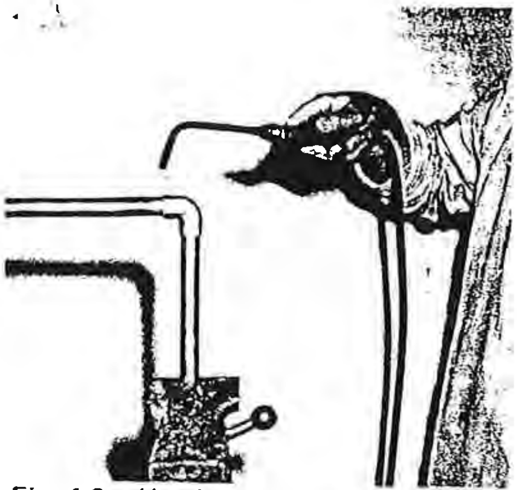


Fig. 4-6. Heating a joint to be soldered.

Revere Copper and Brass

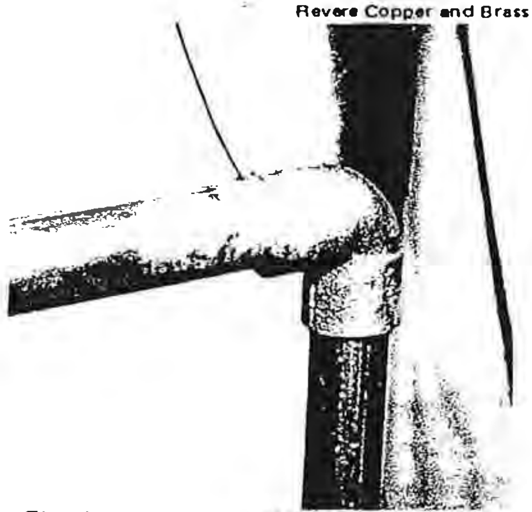


Fig. 4-7. Applying solder.

gether, or joining a tube to a fitting, such as an elbow. The two pieces to be soldered are first cleaned, using emery cloth or a wire brush. Then both tube (outside) and fitting (inside) are covered with flux and fitted together. Where two tube ends are joined, the fitting is just a short sleeve into which the tube ends are inserted from opposite sides. The fit is snug.

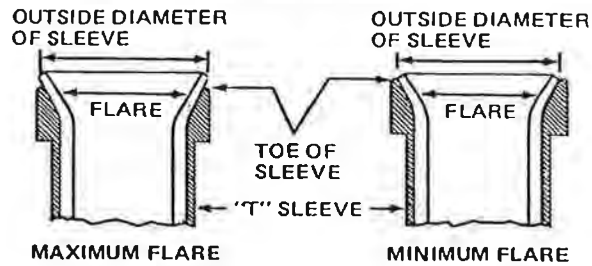



Fig. 4-8. Flared tube ends.

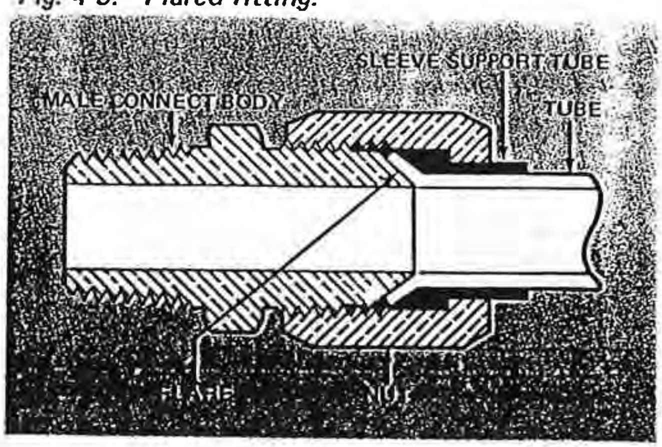
4.24 The joint is then heated, starting with the tubing next to the fitting, then moving to the fitting. See Fig. 4-6. When the flux begins to "fry," solder is added, as in Fig. 4-7. The heat sucks it into the space between tubing and sleeve. The fitting is then heated, on and off, and more solder is applied until the joint is fully penetrated. It is important in these steps to apply the heat evenly around the tubing. In a properly made joint, a continuous line of solder will appear where the fitting and tubing meet – at each end of the sleeve.

4.25 An oxyacetylene torch or other high temperature heat source is necessary to provide the high temperature needed for a brazed joint. Brazing is "hard" soldering, requiring higher heat than that needed for "soft" soldering. For soft soldering, the solder is a tin-lead alloy, which has a low melting point. An alloy of copper, zinc, and silver is used for brazing.

4.26 Tubing can also be connected by either FLARED or NON-FLARED joints. Flaring is done by evenly spreading the end of the tube outward as shown in Fig. 4-8. The angle of the flare must be accurate to match the angle of the fitting being used. The flaring tool is inserted into the squared end of the tubing, and then hammered into the tube a short distance, spreading the tube end as required. This is called the IMPACT METHOD. (An alternate method uses a screw-type flaring tool.)

4.27 The resulting flared joint is shown in Fig. 4-9. Note that the flared section is inserted into the fitting in such a way that the flared edge of the tube rests against the angled face of the male connector body. In this fitting a sleeve supports

Fig. 4-9. Flared fitting.



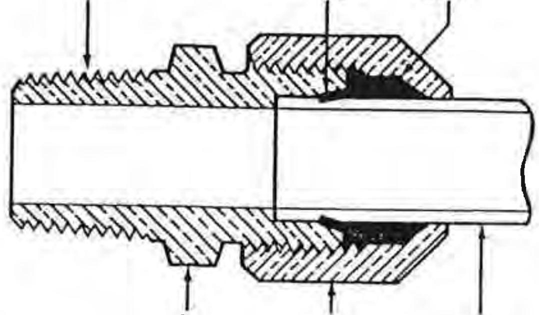



*Fig. 4-10. Flareless fitting.*

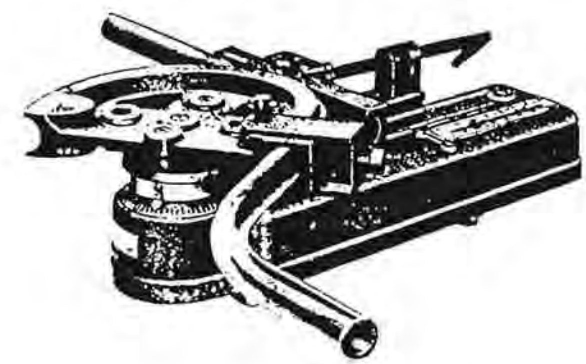


*Fig. 4-12. Hydraulic tube bender.*

the tubing. The nut outside the sleeve is tightened firmly on the male connector body, making a firm joint that will not leak, even if the tubing ruptures because of excess pressure.

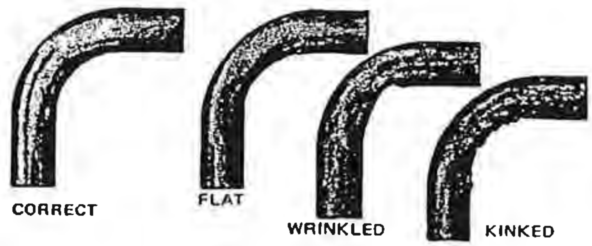
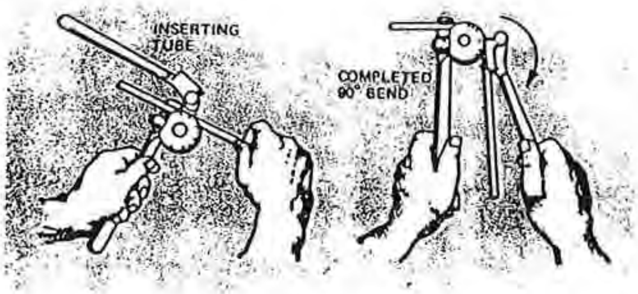



*Fig. 4-13. Correct and incorrect tube bends.*

4.28 Figure 4-10 shows a flareless fitting. The plain tube end is inserted into the body of the fitting. As in Fig. 4-9, there are two threaded outer sections but in this case a ferrule or bushing is located between them. As the threaded members are tightened, the ferrule bites into the tubing, making a tight joint.

*Fig. 4-11. Use of a hand bender.*




4.29 Tools for bending tubing include hand benders, each designed for a specific diameter tube, and production benders, which have different attachments for various sizes of tubing. Figure 4-11 shows a hand bender in use. Figure 4-12 shows a hydraulic tube bender for bending heavy tubes. It is important to get the desired bend without flattening, kinking, or wrinkling the tubing. Earlier, you learned that distortion of the smooth, inner wall of a pipe or tube causes turbulence, which lowers the pressure. Figure 4-13 shows one correct bend and three incorrect ones. Incorrect bends cause turbulence and lower pressure.

4-9. A joint made so that the sections are pressed together is a __________ joint.

4-10. When making a joint, it is important to cut the tubing __________ and __________.

4-11. For cutting stainless steel tubing use a __________, not a __________ __________.

4-12. The rough edge of cut tubing should be removed with a __________ tool or a __________.

4-13. Before two pieces are soldered, they must first be __________.

4-14. When soldering, apply the heat __________.

4-15. Tubing can be connected not only by soldered joints but by __________ or __________ joints.

4-16. Incorrect tube bends can cause __________ and __________ pressure.

## Types of Tubing

4.30 Common types of metal tubing in industrial service are as follows: COPPER (seamless, fully annealed, furnished in coils or in straight lengths); STEEL (seamless, fully annealed; also welded and suitable for bending and flaring); STAINLESS STEEL (seamless, fully annealed; also as a welded type, suitable for bending and flaring); and ALUMINUM (seamless) annealed and suitable for bending and flaring. Titanium tubing is also made for carrying corrosive materials.

4.31 Metal tubing is made in either the welded or seamless type, as is metal piping. Welded tubing begins as flat strips of metal which, after a number of rolling operations, are formed into a tube or cylinder. The seam is then welded.

4.32 Seamless tubing is made by forming a long, hot metal ingot into a cylindrical shape, and then passing the cylinder through a die (a process called extruding). This produces tubing in the larger sizes and wall thicknesses. The extruded tubing can be reworked by drawing it through another die to produce a tube smaller in size, which has thinner walls and closer tolerances.

4.33 Annealing is the process of reheating a metal and then letting it cool slowly to make it softer and less brittle. That is an important treatment if the tubing is going to be bent when it is installed. To connect tubing by using a flared joint also requires that the metal be annealed. Tubing undergoes other heat treating processes and mechanical operations to provide needed properties of strength, hardness, and smoothness of surface.

## Tubing Applications

4.34 Copper tubing comes in types K, L, and M, all available in hard-tempered copper in straight lengths for exposed piping where neat appearance is important. Hard-tempered tubing requires special tools if it is to be bent. Copper Types K and L are also furnished soft-tempered, and used in concealed-tubing installations. Available in coils, soft-tempered tubing can be bent by hand. (Type M, light wall tubing, is available only in the hard-tempered state.)

4.35 Type K, heavy wall, is used for underground services, interior plumbing, heating and cooling systems, gas, oxygen, steam, and oil lines. It is the type used in snow-melting systems buried in the concrete or blacktop surface of driveways and parking lots. Type L is medium wall, and is used for general plumbing and heating applications. Type M is used in inside plumbing applications, hot water heating systems, chilled water lines, and for inside waste and drainage lines. Type M is not used in high-pressure applications.

4.36 Steel tubing includes cold- and hot-rolled types. Cold-rolled steel tubing is used where close tolerances are required for the inside diameter or wall thickness; where a quality finish is necessary for polishing, plating, or protective lacquering; and where close control of temper or hardness is needed. Cold-rolled steel tubing is made from rolls of flat steel that have been processed. The rolls have an accurate thickness and a very smooth surface. The steel is fed through a number of forming rolls that form the flat ribbon into a cylindrical shape. The tube then passes between two pressure rolls that press the seam edges tightly together. The tube next enters an electric welding machine where the seam is continuously welded.

4.37 Always remember that each tubing material has its own characteristics which determine its best use. Hot-rolled steel tubing has wider wall thickness tolerances than cold-rolled tubing because the forming and sizing operations are done from outside the material. Where more precise tube dimensions are required, cold-rolled tubing is indicated.

4.38 Steel tubing is widely used in high-pressure hydraulic systems. Aluminum and plastic tubing are often used for low-pressure applications. Copper tubing is not used in hydraulic systems when pressure exceeds 1000 psi. It has poor resistance to high vibration. Another reason is that, as water aids in the formation of rust, copper enables various elements in hydraulic oils to oxidize. The oxides form on the wall of the tube, spoiling the smooth laminar flow mentioned earlier in this lesson.

4.39 Welded steel tubing can be subjected to every known tube-fabricating operation. It can be bent, flanged, flared, and flattened. It has great mechanical strength, and can be joined by any of the conventional welding methods. It is also strong enough, despite its thin walls, to take tapered pipe threads and straight threads. (To be covered in a later lesson about pipe and tube fittings.)

4.40 Stainless steel, in its many varieties, has a number of advantages including: (1) corrosion resistance; (2) heat resistance; (3) cold resistance; and (4) great resistance to pressure (up to 6,000 psi).

4.41 Stainless tubing is used by chemical industries in evaporators, cooling units, and regular fluid lines. In the paper industry, it is used for digester lines. Stainless steel tubing is used in pharmaceutical (drug) industry production lines, food-processing equipment, and as sanitary tubing for the dairy industry.

4.42 Stainless steel tubing can be furnished polished on the inside, outside, or both, to provide a smooth easy-to-clean surface. Such a surface eliminates the danger of bacteria buildup, because food particles and other deposits do not cling to it. In addition, there is no danger of metallic contamination of the foods being processed.

4.43 Easy cleaning is a definite advantage where the same tubing line is used for several different processes, because there is no problem of contaminating one food or flavor by an earlier one passed through the same tube. Stainless steel is very strong. It is popular in the beverage, soda fountain, and brewing industries for flow lines, cooling and refrigeration lines, carbonated water lines, and automatic beverage dispensers.

4.44 For many of these sanitary uses, aluminum tubing is also used. Aluminum withstands many fluids and gases that attack other commonly used tubing materials. For low temperature (cryogenic) lines used to carry liquefied gases, aluminum offers a plus value: its strength increases as temperature drops to as low as -255°C (-423°F). Joints are made by brazing, and by gas or arc welding.

### Plastic Tubing

4.45 As plastics have become very important as nonmetallic piping, they have also become firmly established for tubing. The most common types are: plexiglass (acrylic) tubing; polycarbonate; vinyl; and polyethylene (PE). Where it has suitable corrosion resistance, and the temperatures are within its working range, plastic tubing is used in chemical processes. Some types have Food and Drug Administration (FDA) approval for use with fluids that must be kept sanitary. Plastics are durable and easily formed.

4.46 The methods of joining plastic tubes include two kinds of fusing (solvent-cementing and heating); fusion welding; and cement-plus-binding (the butt-and-strip method). Fused joints are made by reducing the plastic ends of the tubing to a soft, molten state, then pressing them together. In the solvent-cement method, the ends of the tubing are coated with a solvent that dissolves the plastic. The tube ends are firmly pressed together, and as the plastic hardens, are securely joined. The second method of fusing involves heating the tube ends by holding them against a hot plate. When molten, the ends are joined and the operation is complete. Welding is done with a hot-air torch using a welding rod made from the plastic used in the tubing itself.

### Other Applications

4.47 The increase in the number of automated processes has created the need for new types of tubing to be connected to instruments, control panels, and process-control points. An application may require that various measurements (for example, the temperature of a solution, or its thickness) be made continuously as the batch comes to the desired condition. At that point, a different operation is called for, and it is switched in automatically. In a sense, the control centers are somewhat like automatic telephone switchboards.

4.48 Single-line instrument tubing made of copper, aluminum, or steel tubing with a protective outer sheath of plastic is widely used. Groups of bundles of tubes are also used. Copper, aluminum, and `polyethylene tubes may be arranged side by side in a flat ribbon. This type of harness has a chemically resistant sheath.

4.49 Metal tubing is widely used in plants and buildings as RACEWAYS or containers for electric wires. The tubes are under no pressure, but protect the wires against moisture and mechanical wear. And, of course, the mechanical strength of the conduit or raceway supports the wires. Normally the tube lines are installed first, then the wiring drawn through them. Since this can involve wear or breakage of the insulation, building codes may limit the number of bends that can be used in a given tube system. The limit may be two 90° turns plus four 45° turns, for example. The codes also limit the number of wires per tube.

4.50 Joints in this type of tubing must be mechanically strong and highly moisture proof. Types of metallic tubing used in this application include hot-dipped galvanized (zinc-coated) rigid steel; galvanized electrical metallic tubing (EMT); black enameled rigid steel; and flexible metal tubing. Several forms of plastic tubing are also used.

### Tubing Maintenance

4.51 Tubing maintenance does not differ from piping maintenance in any really significant way. The same practice of routine maintenance checks should be followed. Leakage must be watched for, and the tightness of the supports should be checked. Because of the high pressures in some tubing applications, it is especially important to check joints to be certain that they remain tight. If tubing has to be replaced, follow recommended procedures to be sure that the job is done right.

4-17. Copper tubing is furnished in ________ and in ________ lengths.

4-18. Tubing to be connected by a flared joint must be ________.

4-19. Copper tubing is furnished both ________- and ________-tempered.

4-20. High-pressure hydraulic systems use ________ tubing.

4-21. In addition to its resistance against pressure and corrosion, stainless steel has resistance to ________ and ________.

4-22. When the equipment used in food processing is made of stainless steel, the risk of ________ contamination of food is removed.

4-23. As temperature decreases, the strength of aluminum tubing ________.

4-24. One process used to join plastic tubing is ________ welding.