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INSTALLING AND MAINTAINING
TUBING AND HOSE SYSTEMS

Lesson One

Tubing Fundamentals

TPC Training Systems

34601

Lesson

1 Tubing Fundamentals

TOPICS

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OBJECTIVES

After studying this Lesson, you should be able to…

- Compare and contrast tubing and pipe.
- List factors to be considered when selecting tubing for a specific application.
- State a common application of various tubing materials.
- Describe various fittings and tell how to select the proper fitting for a given tube.
- Tell why is it sometimes necessary to anneal tubing.
- List the steps to follow when cutting, sawing, and deburring tubing.
- Explain how to calculate tubing length accurately.
- List the steps involved in bending a given length of tubing.

KEY TECHNICAL TERMS

Temper 1.10 the degree of hardness or resiliency of tubing

Ferrule 1.22 a short tube or bushing used to make a tight joint

Anneal 1.27 to soften or make less brittle by heating

Deburr 1.41 to break loose small chips of material left by cutting

Tubing has many characteristics in common with pipe. Most fundamentally, both are used to carry various substances under pressure from one location to another. This Lesson describes some of the advantages of tubing. It presents a number of important factors that you must take into consideration when you select tubing for a particular application.

Different tubing materials and dimensions are discussed, as well as the various types of fittings and their methods of connection. The Lesson explains the proper procedures for handling, cutting, filing, measuring, and bending tubing. You will study the correct way to calculate the total length of tubing needed for an installation.

Tubing or Pipe?

1.01 The decision of whether to use tubing or pipe for a given application depends in part on the substance to be carried and the pressures and flow rates involved. However, other factors such as the ease of installation and maintenance are also important.

1.02 One basic difference between tubing and pipe is that the wall thickness of pipe must be sufficient to retain its strength after threading. That is, since threading reduces the strength of a pipe, the pipe wall must be thick enough to allow for this reduction in strength and still withstand the stress caused by fluid pressure.

1.03 Most tubing connections are made without threading the tubing. This means that the wall thickness of tubing is constant over its entire length and is generally less than that required for pipe. Consequently, a length of tubing is lighter than an equivalent length of pipe.

1.04 There are at least three reasons why tubing can be a better choice than pipe when all the factors related to a system and its cost are considered:

- Tubing weighs less than pipe and is therefore easier to handle and install. Supports for tubing do not have to be as strong or as numerous as those needed for heavier pipe.

- A run of tubing can be bent around obstructions, whereas pipe would require a number of straight sections joined by fittings. This makes tubing preferable in applications where the lines must change direction frequently. The ability to bend tubing not only eliminates many of the extra fittings required by pipe, it also reduces the resistance to flow that those fittings cause. For this reason, a tubing system often requires less pressure than a piping system to produce a given flow rate. The fewer the connections, the fewer places there are for leaks to occur—which means less installation and maintenance work. Leaks can be costly, may affect system performance, and in some cases are unsafe.

- Tubing is not as rigid as pipe. As a result, it can withstand more vibration than pipe. You should avoid short, straight runs of tubing. They do not take advantage of the natural tendency of tubing to deflect under a load and to absorb vibration. The flexibility of tubing also means that a bend in the line can be an advantage in installations where the tubing must accommodate thermal expansion or contraction.

1.05 One additional advantage tubing has over pipe is that connections can be made without rotating or disturbing the tubing lines. Since tubing connections generally consist of compression fittings rather than threaded joints, installation, maintenance, and repair are usually easier.

Tubing Specifications

1.06 The three most important factors to consider when selecting tubing are the material the tubing is made of, the inside diameter (I.D.), and the wall thickness.

1.07 The tubing material is important because there must be no interaction between the tubing and the substance being handled. On the one hand, the tubing must be able to resist any corrosion or other chemical action caused by the substance it carries. And on the other, the substance must not be contaminated by the tubing material. For example, the contact between a fluid and the tubing that carries it must not affect the fluid's odor, taste, or color.

1.08 The I.D. of tubing depends on the flow rate and pressures required by the installation. Conversely, the flow rate depends on the pressure and the tubing I.D. The wall thickness and material strength determine the bursting pressure of tubing and therefore the safe operating limits of system pressure.

Copper Water Tubing

1.09 Copper water tubing can be used to handle steam, air, gas, and oil, but is most commonly used for water (often underground). Table 1-1 gives the nominal size, the actual outside diameter (O.D.), the wall thickness, and weight per foot for the three types of copper water tubing—K, L, and M.

1.10 Types K and L are available in both hard and soft tempers. Hard temper tubing, called rigid tubing, is most often used in straight lengths. A standard length is 20 ft. Special bending equipment must be used if it is to be bent. Type M is made in a hard temper only.

1.11 Soft temper tubing, sometimes called semi-rigid tubing, is used when bends are required and are to be made at the installation site. Special bending equipment may be used but is not necessary. However, care must be taken when handling and transporting soft temper tubing since it can be easily distorted or flattened. Although you can buy soft temper tubing in shorter lengths, it is generally available in 60 ft or 100 ft coils.

1.12 Types K and L are available in either straight lengths or coils. Both are recommended for general heating and plumbing applications. Type K is sometimes used for more severe applications and for underground service. Type L is normally used for interior work.

1.13 Note the difference in wall thickness between Types K and L. The thinner wall of Type L requires a lower working pressure. This is shown in Table 1-2, which lists bursting pressures and safe working pressures for Types K and L. Type M is used for tubing

Table 1-1. Types of copper water tubing

Nominal size (in.)	Actual O.D. (in.)	Type K		Type L		Type M	
		Wall thickness (in.)	Weight per foot (lb)	Wall thickness (in.)	Weight per foot (lb)	Wall thickness (in.)	Weight per foot (lb)
1/4	0.375	0.035	0.145	0.030	0.126	0.025	0.106
3/8	0.500	0.049	0.269	0.035	0.198	0.025	0.145
1/2	0.625	0.049	0.344	0.040	0.285	0.028	0.204
5/8	0.750	0.049	0.418	0.042	0.362	0.030	0.263
3/4	0.875	0.065	0.641	0.045	0.455	0.032	0.328
1	1.125	0.065	0.839	0.050	0.655	0.035	0.465
1 1/4	1.375	0.065	1.04	0.055	0.884	0.042	0.682
1 1/2	1.625	0.072	1.36	0.060	1.14	0.049	0.940
2	2.125	0.083	2.06	0.070	1.75	0.058	1.46
2 1/2	2.625	0.095	2.93	0.080	2.48	0.065	2.03
3	3.125	0.109	4.00	0.090	3.33	0.072	2.68
3 1/2	3.625	0.120	5.12	0.100	4.29	0.083	3.58
4	4.125	0.134	6.51	0.110	5.38	0.095	4.66
5	5.125	0.160	9.67	0.125	7.61	0.109	6.66
6	6.125	0.192	13.9	0.140	10.2	0.122	8.92
8	8.125	0.271	25.9	0.200	19.3	0.170	16.5
10	10.125	0.338	40.3	0.250	30.1	0.212	25.6
12	12.125	0.405	57.8	0.280	40.4	0.254	36.7

Table 1-2. Copper water tubing pressures

Nominal size (in.)	Type K		Type L	
	Bursting pressure (psi)	Safe working pressure (psi)	Bursting pressure (psi)	Safe working pressure (psi)
1/8	7680	1535	6000	1200
1/4	5120	1025	4800	960
3/8	5880	1175	4200	840
1/2	4700	940	3840	770
5/8	3920	785	3360	670
3/4	4460	890	3275	650
1	3460	690	2670	535
1 1/4	2830	565	2400	485
1 1/2	2660	530	2210	440
2	2340	470	1980	390
2 1/2	2170	435	1830	365
3	2090	420	1725	345
3 1/2	1980	395	1650	335
4	1950	390	1600	320
5	1870	375	1460	[illegible]
6	1880	375	1370	[illegible]
8	2000	400	1480	295
10	2000	400	[illegible]	[illegible]
12	2000	400	[illegible]	[illegible]

installations that are not under pressure—such as vent, drain, and waste systems. It is for use only with soldered fittings.

Other Tubing Materials

1.14 Tubing is manufactured in a variety of materials in order to handle a variety of substances at varying pressures. When you select tubing material, you should consider both the pressure that the tubing must withstand and the need to avoid interaction between the tubing and the substance carried.

1.15 Water is usually carried in copper tubing. However, if the pressure is too high, you may need to use stainless steel tubing. The use of copper tubing is limited to pressures of about 1000 psi. Steel tubing can be used for pressures up to 6000 psi. Stainless steel may also be needed to carry corrosive fluids—not because corrosives require a high operating pressure, but because stainless steel resists corrosion better than plain steel or copper.

1.16 Sometimes the environment in which tubing is to be installed is as important as the substance handled. The choice of tubing material may be determined by the atmosphere outside the tubing—corrosive fumes, for example. In other words, check not only what goes through the tubing, but also the conditions surrounding the tubing.

1.17 Common metallic tubing materials besides copper include brass, carbon steel (SAE 1010), and stainless steel (Types 304 and 312), all of which are used extensively in hydraulic systems. Aluminum tubing, because of its light weight, has found wide application in aircraft control systems. Most tubing is available in both rigid and semi-rigid tempers. The temper of tubing can also determine the types of fittings required.

1.18 Plastic tubing is available for light-duty applications and to handle some corrosive fluids. It is also frequently used to handle products intended for human consumption, such as foods, beverages, and medicines. Nylon, vinyl, polyethylene, and polyvinyl chloride are some common thermoplastic tubing materials.

Fittings

1.19 You should generally use fittings for tubing that are made of the same material as the tubing—stainless steel fittings for stainless steel tubing, aluminum fittings for aluminum tubing, and so on. A fitting can be made of a material that is harder than the tubing. Steel fittings are sometimes used with copper tubing. Brass fittings are often used on plastic tubing. (But you may have to wrap brass fittings used on plastic tubing with a plastic tape if the operating atmosphere is corrosive to brass.)

1.20 The I.D. of a fitting should be, of course, the same as the O.D. of the tubing that requires the connection. As you have seen in Tables 1-1 and 1-2, however, Types K, L, and M of copper water tubing have both "nominal" and "actual" O.D.s. The nominal size is simply the standard way in which these types of copper tubing are bought and sold—it is not the same as the actual, measured O.D. of the tubing. Thus when you buy "$\frac{1}{2}$ in." Type K copper water tubing, you are buying tubing with an actual O.D. of 0.625 in. This can be somewhat confusing. However, all other types of tubing are sold by their actual O.D.s. Likewise, when you wish to specify the dimensions of a particular fitting (its I.D.), you should refer to the actual O.D. of the tubing on which the connector is to fit.

1.21 **Flareless fittings**. The flareless compression fittings shown in Fig. 1-1A can be used in water, coolant, lubrication, and instrumentation services. Sizes range from $\frac{1}{8}$ in. to 1 in. (again, these sizes refer to the actual O.D. of the tubing). They are commonly made of brass and can be used with plastic tubing.

1.22 Tightening the nut on a flareless fitting moves the ferrule into the angle on the fitting seat (see Fig. 1-1 B). This causes the ferrule to compress around the tubing and to "bite" into its outer surface to make the seal.

1.23 Another design of flareless fitting acts by compressing a two-piece ferrule around the tubing (see Fig. 1-2A). This deforms the tubing slightly and locks the ferrules in place. These flareless mechanical grip fittings are available in sizes up to 1 in. for most tubing materials.

1.24 Figure 1-2B shows the installation of a Swagelok® fitting. The nut, with the ferrules inside it, should be fingertight on the body of the fitting when you insert the tubing. Being careful not to scratch the tubing, make a pencil mark on the nut at 6 o'clock. Hold the fitting in place and tighten the nut $1\frac{1}{4}$ turns. The mark on the nut should make one complete revolution around to 6 o'clock, and then an additional quarter turn to 9 o'clock.

1.25 **Flared fittings**. If a length of tubing is to have its end flared or flanged to a larger diameter, a flared fitting is necessary. The three-piece fitting in Fig. 1-3 consists of a fitting body, a nut, and a flanged sleeve. The nut is placed on the tubing first, followed by the sleeve. The end of the tubing is then flared to an angle of 37°. When the nut and sleeve are screwed onto the body of the fitting, the flared tubing is compressed between the nut and the body, forming a tight seal. Flared fittings—they are also available with a flare of 45°—are usually made of brass or steel. They are widely used in hydraulic systems and refrigeration lines.

Handling Tubing

1.26 Cutting, flaring, and bending can be difficult with hard temper tubing. Tubing that has been fully

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Fig. 1-1. Flareless compression fittings

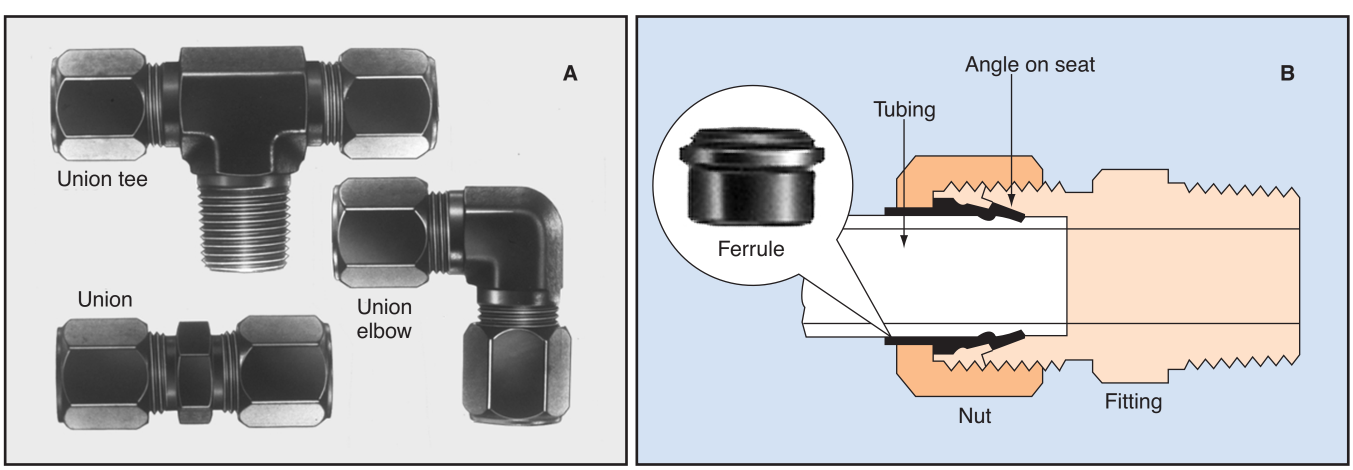
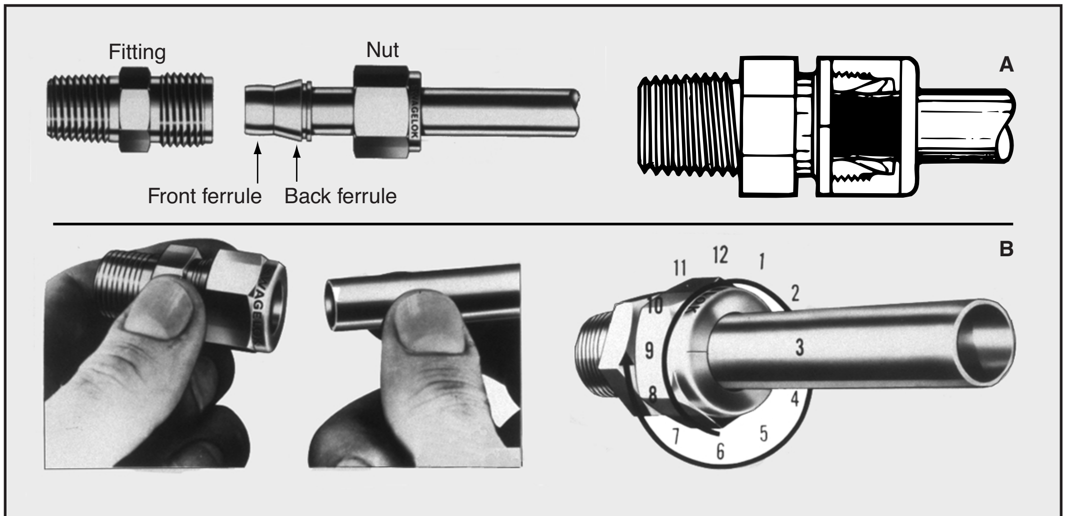


Fig. 1-2. Flareless mechanical grip fitting



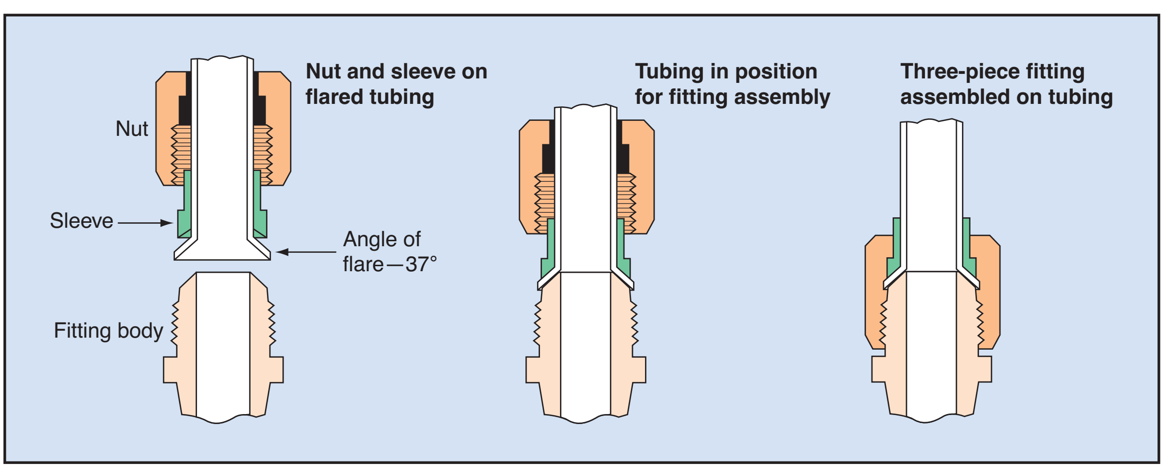
annealed to a soft temper is much easier to work with, but even soft temper tubing has a tendency to harden. This can happen if the tubing is kept in storage for a long time, or if it becomes "work hardened." Any type of bending or "working" can cause tubing to harden. You will then find it difficult to flare or bend until you anneal it again.

1.27 Annealing is done by applying heat to the affected areas. Copper tubing can be annealed by heating it until it takes on a dull red color. It should then be cooled in a water bath. The rapid cooling in water helps prevent an oxide buildup on the heated surfaces. Oxide can hinder a good soldered or brazed connection. Do not heat copper tubing above 1900°F (1038°C)—the approximate temperature at which it melts. Aluminum melts at about 1200°F (649°C), so keep the temperature below this point when annealing aluminum tubing.

1.28 Steel does not work harden as easily as other tubing materials. It can be annealed if it does harden, but the methods are somewhat more complicated. Always check the manufacturer's recommendations for annealing temperatures and procedures, regardless of the tubing material.

1.29 Soft temper tubing is normally purchased in coils because it is too flexible to be handled in straight lengths. The proper way to unwind soft

Fig. 1-3. Flared fitting



temper tubing is to hold the end of the tubing down on a flat surface with one hand while supporting the coil with your other hand. Then unroll the coil by pulling the tubing straight ahead until you have laid out the required length.

1.30 Never unwind tubing by pulling it sideways off the coil. This causes work hardening and can also twist and kink the tubing. Kinks in tubing can sometimes be hammered out by placing the tubing on a flat surface and carefully hitting the high points with a blunt instrument. However, there is a danger that you might strike the tubing too hard and flatten it. Never leave kinks or dents in an area where the tubing is to be bent. They cause weak spots in the line which can collapse and leak.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the REVEAL KEY from the back of your Book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

1-1. A tubing system often requires __________ pressure than a piping system to produce a given flow rate.	1-1. LESS Ref: 1.04
1-2. Short, straight runs of tubing do not take advantage of its natural tendency to withstand __________.	1-2. VIBRATION Ref: 1.04
1-3. The three most important factors to consider when selecting tubing are the material the tubing is made of, the I.D., and the __________.	1-3. WALL THICKNESS Ref: 1.06
1-4. Copper water tubing Types K and L are available in two __________.	1-4. TEMPERS Ref: 1.10
1-5. Copper water tubing Type M is for use only with __________ fittings.	1-5. SOLDERED Ref: 1.13
1-6. Corrosive fluids are most frequently carried by plastic or __________ tubing.	1-6. STAINLESS STEEL Ref: 1.15
1-7. What type of tubing is normally used to handle products intended for human consumption?	1-7. PLASTIC Ref: 1.18
1-8. Can brass fittings be used with plastic tubing?	1-8. YES Ref: 1.19

Cutting Tubing

1.31 Figure 1-4A shows a midget cutter used to cut small-diameter tubing (up to about 1 in. in O.D.). The rollers opposite the cutting wheel make it easier to rotate the tool around the tube. This cutter, because it is designed for use in extremely close quarters, is more difficult to use than the standard size cutters.

1.32 The cutter in Fig. 1-4B is capable of cutting copper, brass, aluminum, and plastic tubing with diameters ranging from 1/4 in. to 6 in. A special release nut allows the cutter to slide away from the tubing when the cut is completed.

1.33 In Fig. 1-4C you can clearly see the rollers, cutting wheel, and handle of a tubing cutter. This cutter also has an enclosed feed screw which keeps chips from clogging and jamming the screw.

1.34 When using a tubing cutter, hold the tubing in one hand and the cutter in the other. With the tubing between the rollers and the cutting wheel, tighten the handle until the cutting wheel just touches the tubing. Rotate the entire cutter around the tubing once, lightly scoring the tubing. Tighten the handle slightly to feed the cutting wheel farther into the tubing and rotate the cutter again.

1.35 Do not feed the cutting wheel into the tubing too fast—you will dent the tubing or create burrs on its I.D. Continue to rotate the cutter while gradually feeding the cutting wheel into the tubing until the cut is complete.

1.36 A typical cutting wheel tapers from its center to the outer cutting edge. This produces a corresponding angle on the end of the length of tubing where it is cut. Leave this angle alone for soldered joints and compression fittings—it makes it easier to slip the fitting onto the end of the tubing. If, however, the tubing is to be flared, you should file the angled end to a 90° straight cut.

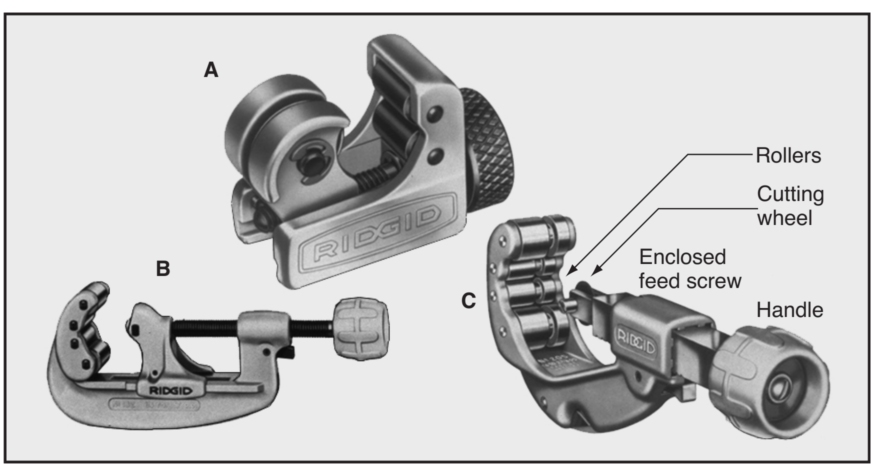
Sawing Tubing

1.37 Carbon steel, stainless steel, and other types of hard temper tubing should be cut with a hacksaw. Cutting with a tubing cutter can be difficult and has a tendency to work harden some of these materials. Large-diameter or thick-walled tubing should also be sawed.

1.38 The most difficult part of cutting tubing with a hacksaw is to get a straight cut. Most sawing vises may be bolted to a bench or work table and can be used for tubing from 1/16 in. to 2 in. in diameter. The tubing rests in V-shaped grooves while a handle is turned, lowering a clamp onto the top of the tubing. Do not apply too much pressure on the handle of the clamp or the tubing could be damaged.

1.39 Slots in the vise on both sides of the tubing hold the hacksaw blade in position. Use a fine-tooth blade with the teeth pointing forward. Cut ONLY on the forward stroke. The saw will tend to leave a ragged edge, even though the cut is straight.

Fig. 1-4. Tubing cutters



Filing and Deburring Tubing

1.40 After tubing has been cut with a hacksaw, place it in a vise block with the ragged edge extending just beyond the flat surfaces of the block. Tighten the vise so that the tubing is held firmly but will not be damaged. Then simply file the end of the tubing until it is even with the flat surfaces of the block.

1.41 Deburr the end of a length of cut tubing both on the inside and on the outside to break loose any small burrs or chips of material left by the cutting. Burrs can interfere with soldered fittings or tubing ends that are to be flared.

1.42 Use a knife reamer to deburr the tubing I.D. (Fig. 1-5A). Insert the point of the reamer into the tubing as far as it will go. Always rotate the reamer, not the tubing. Attempting to rotate the tubing could cause kinks and bends in the line, especially in long pieces. The end of the tubing should always be pointed downward, so that burrs and chips drop out of the tubing, not into it.

1.43 Another type of deburring tool, shown in Fig. 1-5B, is designed so that one end deburrs the I.D. of the tubing and the other end the O.D. Position the tubing on the cutting blades and rotate the tool. The blades are replaceable. This tool can be used with tubing up to 1$^1/_8$ in. in O.D.

1.44 Always exercise caution when deburring. If you gouge the tubing or remove any of the tubing wall, the tubing will be weakened and may crack or split when flared.

Calculating Tubing Length

1.45 Obviously, it is easier to calculate the total length of tubing needed for a straight run than it is for a run with one or more bends in it. Figure 1-6A on the following page shows a tubing run with two 90° bends. The horizontal distance from end to end is 16 in. The vertical offset between points A and D is 8 in.

1.46 The distance from A to B is measured on the horizontal centerline from the end of the tubing (A) to the point of intersection (B) with the centerline of the vertical leg at the first 90° bend. The centerline is the reference for all tubing measurements. Figure 1-6B illustrates this in a tubing run with multiple bends.

1.47 Look at Fig. 1-6A again. Although the measurement from A to B is 8 in. and the offset distance from B to C is also 8 in., the total length of tubing needed from A to C is not 16 in. but something less. How do you determine the amount that must be subtracted from 16 in.?

1.48 In Fig. 1-7 on the following page, the arc formed by the 90° angle is considered as part of an imaginary circle. You need to find the difference between XY + YZ (the distance between X and Z when measuring straight centerlines) and the arc XZ (the actual length of tubing required to make the bend). Both XY and YZ are equal to the radius of this imaginary circle, so XY + YZ = 2r. The arc XZ forms

Fig. 1-5. Deburring tools

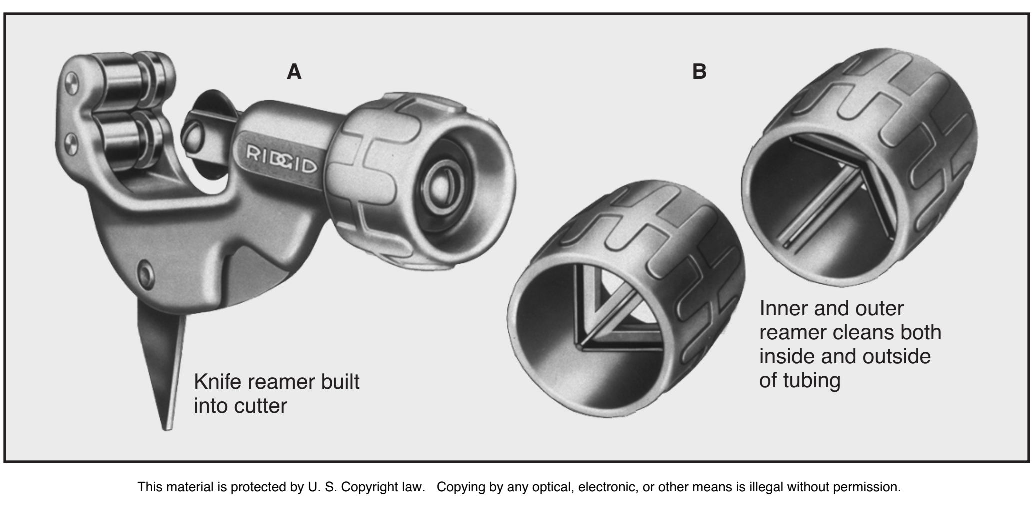
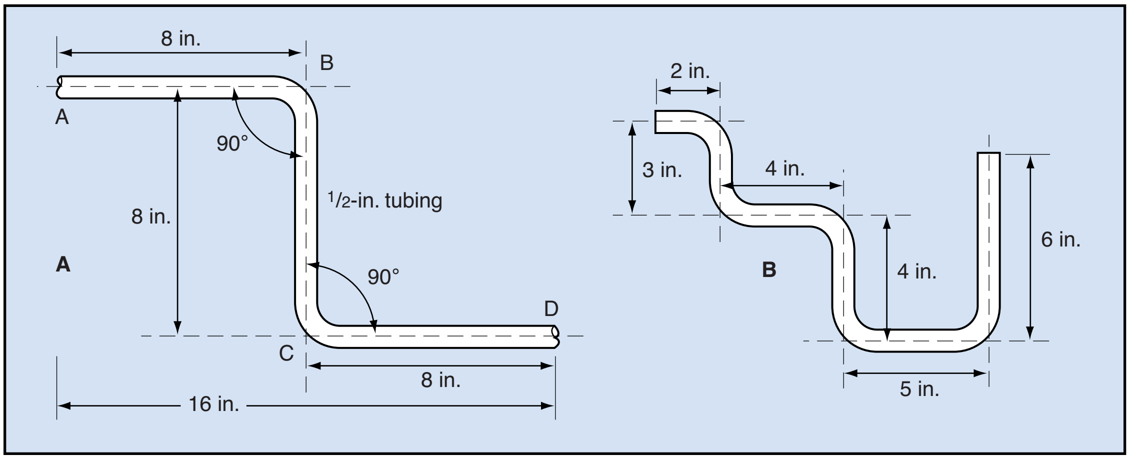


Fig. 1-6. Measuring table



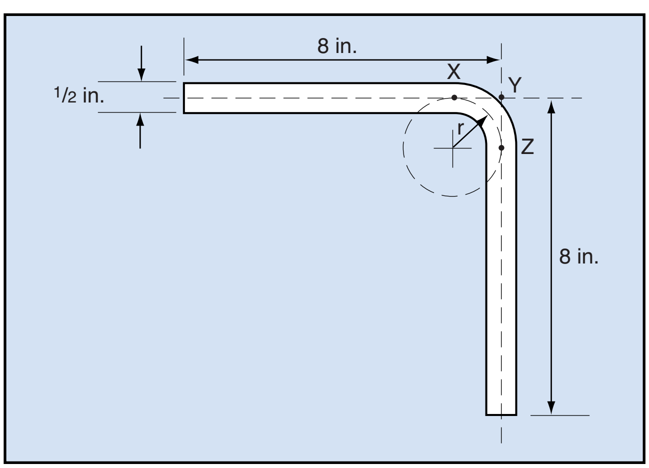
one quarter of the circumference of the circle. The total circumference of a circle is 2πr, so:

$$XZ = \frac{2\pi r}{4} = \frac{\pi r}{2}$$

1.49 When 1/2 in. tubing is used to form a 90° bend, the typical radius (XY or YZ) is 1 1/2 in. Remember that π = 3.14. You can now insert the values into the equation XY + YZ - XZ:

$$\begin{aligned} 2r - \frac{\pi r}{2} &= 2 \times 1.5 \text{ in.} - \frac{3.14 \times 1.5 \text{ in.}}{2} \\ &= 3 \text{ in.} - 2.355 \text{ in.} \\ &= 0.645 \text{ in.} \end{aligned}$$

Fig. 1-7. Calculating tubing length through a bend



This is the amount to subtract from the original 16 in. distance:

16 in. 1 0.645 in. = 15.355 in.

Thus, the actual straight length of tubing from point A to point C in Fig. 1-6A is 15.355 in. To calculate the straight length of tubing needed from A to D, multiply 0.645 in. by 2 (because there are two 90° bends) and subtract your answer from 24 in. (3 2 8 in.):

24 in. - 1.29 in. = 22.71 in.

1.50 There is another formula you can use to make this type of calculation. Regardless of the angle of the bend, multiply the typical radius of the bend by the included angle and multiply that product by the constant 0.017453. This gives you the length of the arc that is to be subtracted from twice the radius. This may be written as:

2r - (r × included angle × 2 0.017453).

and is the measurement you wish to find.

1.51 Suppose that the drawing in Fig. 1-6A represented 5/8-in. tubing instead of 1/2 in. tubing. The typical radius for a 90° bend of 5/8 in. tubing is 2 in. Table 1-3 lists standard bend radii for tubing of various O.D.s. Remember that the radius of a bend is measured to the centerline of the tubing.

2r - (r × included angle × 0.01745 3) =

2×2 in. - (2 in. $\times 90 \times 0.017453$) =

4 in. - 3.14 in. = 0.86 in.

Multiply this figure by 2 for the two bends and subtract from 24 in. The straight tubing length actually required is:

24 in. - 1.72 in. = 22.28 in.

Bending Tubing

1.52 This 22.28 in. length of straight tubing can now be marked for bending. Use a sharp pencil, not a marker that makes a wide line. Draw a clear, thin line all the way around the tubing, using a sleeve or ferrule as a guide (Fig. 1-8A). Do not scratch the tubing when you mark it. This weakens the tubing, causing stress points where corrosion can start.

1.53 Make the mark for the first bend 8 in. from the end of the tubing (see Fig. 1-8B). To determine where to make the mark for the second bend, you may again use the formula 2r - (r × included angle × 0.017453). Recall that for 5/8-in. tubing, this formula yielded an answer of 0.86 in. Subtract 0.86 in. from 8 in. and make your second mark 7.14 in. from the first mark. As you can see in Fig. 1-8B, this divides the length of tubing into three sections—8 in., 7.14 in., and 7.14 in.—which add up to 22.28 in. When making multiple bends, however, you may find that as a general rule it is better to measure and bend, measure and bend.

Table 1-3. Standard bend radii

Tubing O.D. (in.)	Standard radius (in.)
1/8	3/8
3/16	7/16
1/4	9/16
5/16	11/16
3/8	15/16
1/2	1 1/2
5/8	2
3/4	2 1/2
7/8	3
1	3 1/2

1.54 Manual tubing benders operate in only one direction and produce bends without wrinkling or flattening the tubing. A direction-of-bend mark can be made on the side of the tubing opposite the direction in which it will be bent (see Fig. 1-8C). Place the tubing in the bender with the mark opposite the groove in the handle. This ensures that you bend in the correct direction and also gives you a reference mark to come back to in case you must leave your work unfinished.

1.55 Figure 1-9 on the following page shows a typical lever-type tubing bender and a length of tubing. The tubing is inserted along a groove in handle #1 and through the link member. When the tubing is clamped in place, handle #2 is used to bend the tubing until the desired angle of bend is reached.

1.56 Figure 1-10A on the following page shows how to position tubing for a 90° bend. The mark you

Fig. 1-8. Measuring and marking tubing

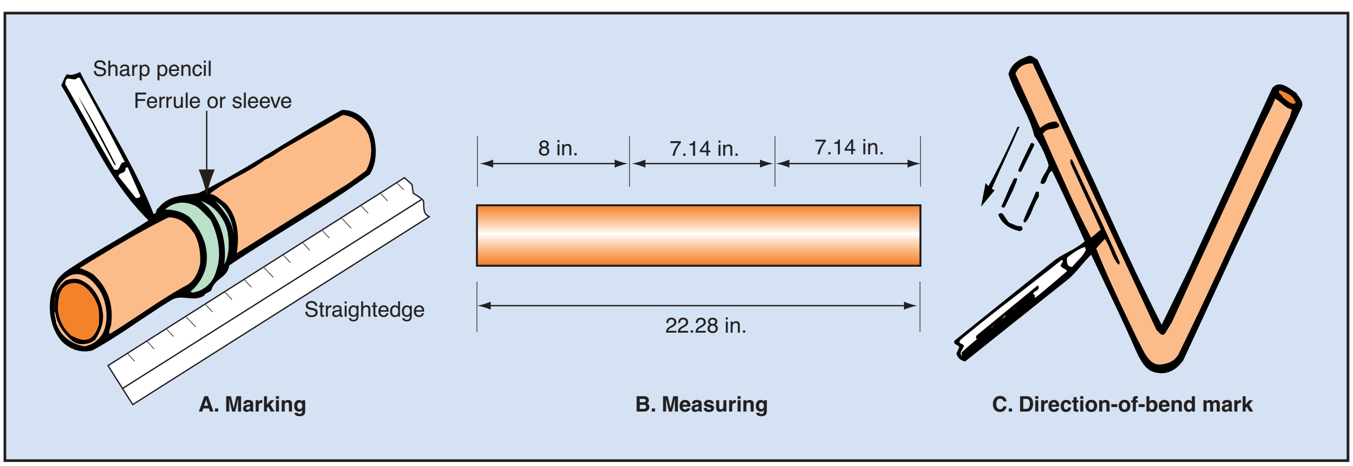
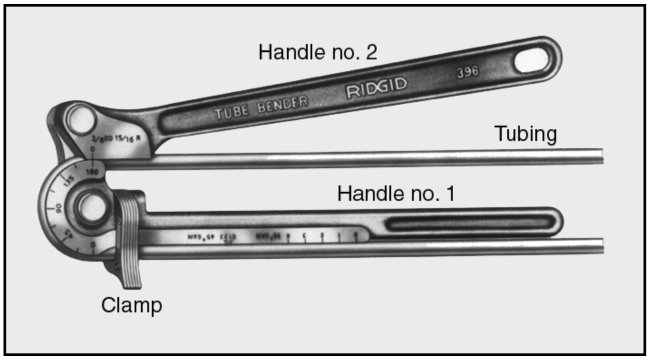


Fig. 1-9. Lever-type tubing bender



made on the tubing must line up with a line tangent to the 90° mark on the radius block. A tangent line is one that touches a circle at a single point—the circle in this case being the radius block and the point the 90° mark.

1.57 For bending angles less than 90°, the tangent line must touch the circle of the radius block at the desired angle and intersect the mark on the tubing at the centerline of the tubing. Figure 1-10B shows tubing positioned for a 60° bend.

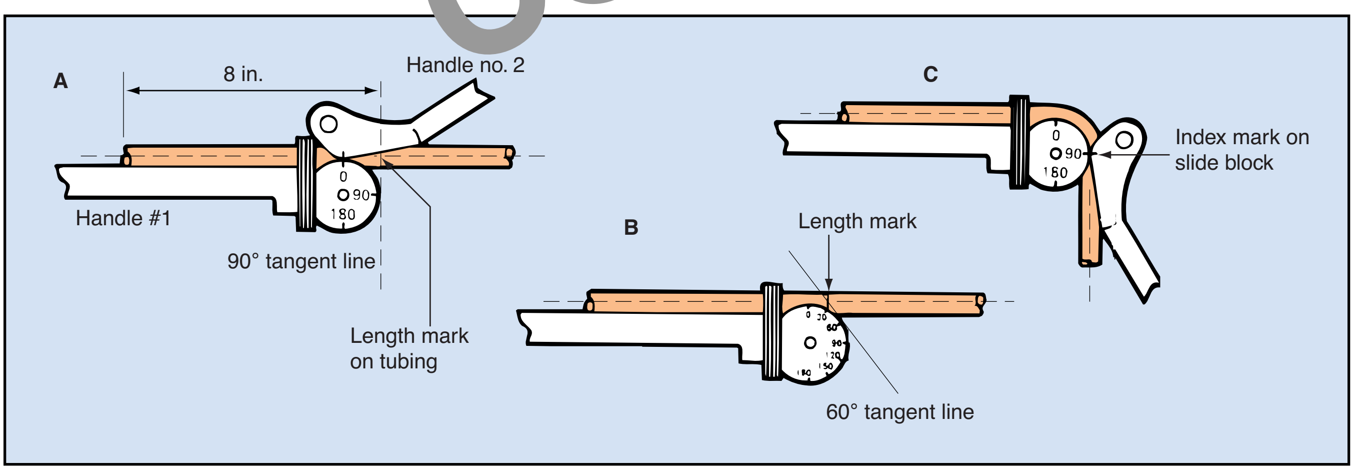
1.58 To make the 90° bend, handle #2 is pulled down until the index mark on the slide block is even with the 90° mark on the radius block (see Fig. 1-10C). For a 60° bend, the handle is pulled down until the index mark on the slide block meets the 60° mark on the radius block.

1.59 For bends over 90°, the tubing is initially positioned as it would be for a 90° bend. That is, the tangent line at 90° is lined up with the length mark on the tubing. The tubing is then bent past 90° to the desired angle.

1.60 Tubing has a tendency to spring back a small amount after bending. The amount varies with the material, temper, and size of the tubing. You can test a sample piece of tubing by making a 90° bend and measuring the angle of the spring back. You will then have some idea of how much farther you need to bend the tubing so that it springs back to the desired angle. However, it is always safer to bend the tubing, check the angle, and then bend a little farther if necessary. It is very difficult, if not impossible, to straighten a bend once the tubing is set at an angle.

1.61 It is most important that you measure exactly and bend accurately. An error in measurement or an incorrect bend angle will result in the end of the tubing being out of position so that it cannot make its final connection. Never force the end of a length of tubing into alignment. This causes undue stress on the fitting and on the tubing.

Fig. 1-10. Positioning tubing in a bender



1-9. Which do you rotate when cutting tubing, the tubing or the cutter?	1-9. CUTTER Ref: 1.34
1-10. Hard temper tubing should be cut with a(n) __________.	1-10. HACKSAW Ref: 1.37
1-11. In order to remove any small chips of material left by cutting, you should __________ the end of a length of tubing.	1-11. DEBURR Ref: 1.41
1-12. The reference mark for all tubing measurements is the __________ of the tubing.	1-12. CENTERLINE Ref: 1.46
1-13. In order to calculate tubing length through a bend, you need to know the typical __________ of the bend.	1-13. RADIUS Ref: 1.48 -1.51
1-14. Manual tubing benders operate in __________ direction(s).	1-14. ONE Ref: 1.54
1-15. When making a 120° bend in a length of tubing, you should line up the scribed mark on the tubing with a line tangent to the __________° mark on the radius block.	1-15. 90 Ref: 1.59
1-16. Tubing has a tendency to __________ a small amount after bending.	1-16. SPRING BACK Ref: 1.60

Answer the following questions by marking an "X" in the box next to the best answer.

1-1. Which of the following statements is not true?

- ☐ a. Tubing weighs less than pipe
- ☐ b. Tubing is more flexible than pipe
- ☐ c. Tubing requires fewer supports than pipe
- ☐ d. Tubing requires more fittings than pipe

1-2. Which of the following types of tubing is most likely to be used in waste drainage systems?

- ☐ a. Copper Type K
- ☐ b. Copper Type L
- ☐ c. Copper Type M
- ☐ d. Aluminum

1-3. In order to specify the size of a fitting, you should refer to the

- ☐ a. actual O.D. of the tubing
- ☐ b. nominal O.D. of the tubing
- ☐ c. I.D. of the tubing
- ☐ d. O.D. of the fitting

1-4. The short tube or bushing used to make a tight joint in a flareless fitting is called a

- ☐ a. nut
- ☐ b. swage
- ☐ c. ferrule
- ☐ d. sleeve

1-5. Flared fittings are available at angles of

- ☐ a. 30° and 60°
- ☐ b. 37° and 45°
- ☐ c. 45° and 90°
- ☐ d. 54° and 75°

1-6. Work hardened tubing can be ________ to make it easier to bend.

- ☐ a. swaged
- ☐ b. flared
- ☐ c. flanged
- ☐ d. annealed

1-7. Copper tubing should not be heated above ________ ° F.

- ☐ a. 500
- ☐ b. 1000
- ☐ c. 1200
- ☐ d. 1900

1-8. When cutting hard temper tubing with a hacksaw, you should follow all of the following instructions except

- ☐ a. use a fine-tooth blade
- ☐ b. make sure the saw teeth point forward
- ☐ c. cut only on the forward stroke
- ☐ d. cut on both the forward and return strokes

1-9. When deburring tubing, you should

- ☐ a. deburr the I.D. only
- ☐ b. deburr the O.D. only
- ☐ c. point the end of the tubing downward
- ☐ d. hold the reamer and rotate the tubing

1-10. Which of the following formulas should be used to calculate tubing length through a bend?

- ☐ a. $2r - (r \times \text{included angle} \times 0.017453)$
- ☐ b. $r - (2r \times \text{included angle} \times 0.017453)$
- ☐ c. $2\pi r - (r \times \text{included angle} \times 0.0\,17453)$
- ☐ d. $2r - (\pi \times \text{included angle}) + 0.0\,17453$

SUMMARY

Tubing may be used as an alternative to pipe and, in some applications, is better than pipe. Since tubing is not threaded like pipe, tubing material is generally thinner, lighter, and easier to handle. It can be bent around obstacles and therefore needs fewer connections. The flexibility of tubing also offers advantages over pipe in certain installations.

Copper is perhaps the most common tubing material. Copper tubing comes in different wall thicknesses and tempers and may be used for a variety of applications, including water and air lines. Other tubing materials include stainless steel for high pressure installations and various plastics for food preparation applications.

Some tubing fittings can be soldered, welded, or brazed. Others compress or swage the tubing. For flared fittings, the end of the tubing must be flared or flanged before the nut is tightened. Since tubing fittings make union connections, installation, maintenance, and repair are relatively simple. Tubing cutters and saws leave burrs and rough edges which you must ream or file before making a connection.

When measuring tubing, it is important that your calculations are accurate. Always use the center-line of the tubing as a reference for measurement. The angle of a bend, the direction of the bend, the radius of the bend, the O.D. of the tubing—you must have a thorough understanding of all of these in order to use a bending tool correctly.

Answers to Self-Check Quiz

1-1. d. Tubing requires more fittings than pipe. Ref: 1.04

1-2. c. Copper Type M. Ref: 1.13

1-3. a. Actual O.D. of the tubing. Ref: 1.20

1-4. c. Ferrule. Ref: 1.22

1-5. b. 37° and 45°. Ref: 1.25

1-6. d. Annealed. Ref: 1.27

1-7. d. 1900°F. Ref: 1.27

1-8. d. Cut on both the forward and return strokes. Ref: 1.39

1-9. c. Point the end of the tubing downward. Ref: 1.42

1-10. a. $2r - (r \times \text{included angle} \times 0.017453)$. Ref: 1.50

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