Chapter 7
Fluid Lines & Fittings

Aircraft fluid lines are usually made of metal tubing or flexible hose. Metal tubing (also called rigid fluid lines) is used in stationary applications and where long, relatively straight runs are possible. They are widely used in aircraft for fuel, oil, coolant, oxygen, instrument, and hydraulic lines. Flexible hose is generally used with moving parts or where the hose is subject to considerable vibration.

Occasionally, it may be necessary to repair or replace damaged aircraft fluid lines. Very often the repair can be made simply by replacing the tubing. However, if replacements are not available, the needed parts may have to be fabricated. Replacement tubing should be of the same size and material as the original tubing. All tubing is pressure tested prior to initial installation, and is designed to withstand several times the normal operating pressure to which it will be subjected. If a tube bursts or cracks, it is generally the result of excessive vibration, improper installation, or damage caused by collision with an object. All tubing failures should be carefully studied and the cause of the failure determined.

Rigid Fluid Lines

Tubing Materials

Copper

In the early days of aviation, copper tubing was used extensively in aviation fluid applications. In modern aircraft, aluminum alloy, corrosion resistant steel or titanium tubing have generally replaced copper tubing.

Aluminum Alloy Tubing

Tubing made from 1100 H14 (1/2-hard) or 3003 H14 (1/2-hard) is used for general purpose lines of low or negligible fluid pressures, such as instrument lines and ventilating conduits. Tubing made from 2024-T3, 5052-O, and 6061-T6 aluminum alloy materials is used in general purpose systems of low and medium pressures, such as hydraulic and pneumatic 1,000 to 1,500 psi systems, and fuel and oil lines.

Steel

Corrosion resistant steel tubing, either annealed CRES 304, CRES 321 or CRES 304-1/8-hard, is used extensively in high pressure hydraulic systems (3,000 psi or more) for the operation of landing gear, flaps, brakes, and in fire zones. Its higher tensile strength permits the use of tubing with thinner walls; consequently, the final installation weight is not much greater than that of the thicker wall aluminum alloy tubing. Steel lines are used where there is a risk of foreign object damage (FOD); i.e., the landing gear and wheel well areas. Although identification markings for steel tubing differ, each usually includes the manufacturer's name or trademark, the *Society of Automotive Engineers* (SAE) number, and the physical condition of the metal.

Titanium 3AL-2.5V

This type of tubing and fitting is used extensively in transport category and high performance aircraft hydraulic systems for pressures above 1,500 psi. Titanium is 30 percent stronger than steel and 50 percent lighter than steel. Cryofit fittings or swaged fittings are used with titanium tubing. Do not use titanium tubing and fittings in any oxygen system assembly. Titanium and titanium alloys are oxygen reactive. If a freshly formed titanium surface is exposed in gaseous oxygen, spontaneous combustion could occur at low pressures.

Material Identification

Before making repairs to any aircraft tubing, it is important to make accurate identification of tubing materials. Aluminum alloy, steel, or titanium tubing can be identified readily by sight where it is used as the basic tubing material. However, it is difficult to determine whether a material is carbon steel or stainless steel, or whether it is 1100, 3003, 5052-O, 6061-T6 or 2024-T3 aluminum alloy. To positively identify the material used in the original installation, compare code markings of the replacement tubing with the original markings on the tubing being replaced.

Aluminium Alloy Number	Color of Band
1100	White
3003	Green
2014	Gray
2024	Red
5052	Purple
6053	Black
6061	Blue and Yellow
7075	Brown and Yellow

Figure 7-1. Painted color codes used to identify aluminum alloy tubing.

On large aluminum alloy tubing, the alloy designation is stamped on the surface. On small aluminum tubing, the designation may be stamped on the surface; but more often it is shown by a color code, not more than 4" in width, painted at the two ends and approximately midway between the ends of some tubing. When the band consists of two colors, one-half the width is used for each color. [Figure 7-1]

If the code markings are hard or impossible to read, it may be necessary to test samples of the material for hardness by hardness testing.

Sizes

Metal tubing is sized by outside diameter (o.d.), which is measured fractionally in sixteenths of an inch. Thus, number 6 tubing is 6/16" (or ⅜") and number 8 tubing is 8/16" (or ½"), and so forth. The tube diameter is typically printed on all rigid tubing. In addition to other classifications or means of identification, tubing is manufactured in various wall thicknesses. Thus, it is important when installing tubing to know not only the material and outside diameter, but also the thickness of the wall. The wall thickness is typically printed on the tubing in thousands of an inch. To determine the inside diameter (i.d.) of the tube, subtract twice the wall thickness from the outside diameter.

For example, a number 10 piece of tubing with a wall thickness of 0.063" has an inside diameter of 0.625" – 2(0.063") = 0.499".

Fabrication of Metal Tube Lines

Damaged tubing and fluid lines should be repaired with new parts whenever possible. Unfortunately, sometimes replacement is impractical and repair is necessary. Scratches, abrasions, or minor corrosion on the outside of fluid lines may be considered negligible and can be smoothed out with a burnishing tool or aluminum wool. Limitations on the amount of damage that can be repaired in this manner are discussed in this chapter under "Rigid Tubing Inspection and Repair." If a fluid line assembly is to be replaced, the fittings can often be salvaged; then the repair will involve only tube forming and replacement.

Tube forming consists of four processes: Cutting, bending, flaring, and beading. If the tubing is small and made of soft material, the assembly can be formed by hand bending during installation. If the tube is ¼" diameter or larger, hand bending without the aid of tools is impractical.

Tube Cutting

When cutting tubing, it is important to produce a square end, free of burrs. Tubing may be cut with a tube cutter or a hacksaw. The cutter can be used with any soft metal tubing, such as copper, aluminum, or aluminum alloy. Correct use of the tube cutter is shown in Figure 7-2. Special chipless cutters are available for cutting aluminum 6061-T6, corrosion resistant steel and titanium tubing.

A new piece of tubing should be cut approximately 10 percent longer than the tube to be replaced to provide

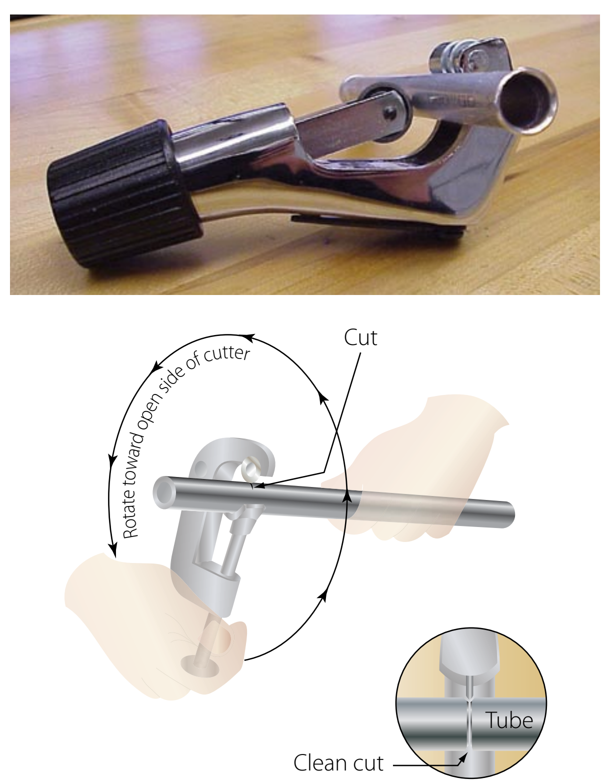

Figure 7-2. Tube cutting.

for minor variations in bending. Place the tubing in the cutting tool, with the cutting wheel at the point where the cut is to be made. Rotate the cutter around the tubing, applying a light pressure to the cutting wheel by intermittently twisting the thumbscrew. Too much pressure on the cutting wheel at one time could deform the tubing or cause excessive burring. After cutting the tubing, carefully remove any burrs from inside and outside the tube. Use a knife or the burring edge attached to the tube cutter. The deburring operation can be accomplished by the use of a deburring tool as shown in Figure 7-3. This tool is capable of removing both the inside and outside burrs by just turning the tool end for end.

When performing the deburring operation, use extreme care that the wall thickness of the end of the tubing is not reduced or fractured. Very slight damage of this type can lead to fractured flares or defective flares which will not seal properly. Use a fine-tooth file to file the end square and smooth.

If a tube cutter is not available, or if tubing of hard material is to be cut, use a fine-tooth hacksaw, preferably one having 32 teeth per inch. The use of a saw will decrease the amount of work hardening of the tubing during the cutting operation. After sawing, file the end of the tube square and smooth, removing all burrs.

An easy way to hold small diameter tubing, when cutting it, is to place the tube in a combination flaring tool and clamp the tool in a vise. Make the cut about one-half inch from the flaring tool. This procedure keeps sawing vibrations to a minimum and prevents damage to the tubing if it is accidentally hit with the hacksaw frame or file handle while cutting. Be sure all filings and cuttings are removed from the tube.

Tube Bending

The objective in tube bending is to obtain a smooth bend without flattening the tube. Tubing under ¼" in diameter usually can be bent without the use of a bending tool. For larger sizes, either portable hand benders or production benders are usually used. Table 7-1 shows preferred methods and standard bend radii for bending tubing by tube size.

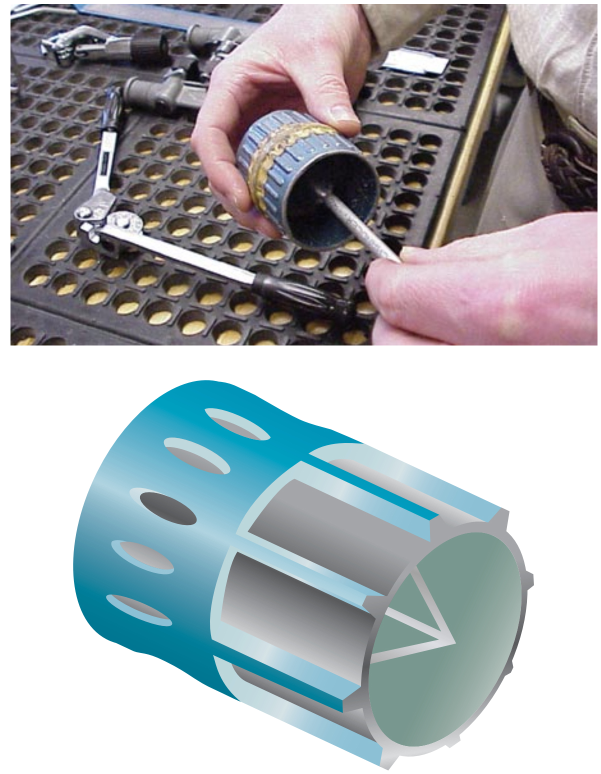

Figure 7-3. Deburring tool.

Using a hand bender, insert the tubing into the groove of the bender, so that the measured end is left of the form block. Align the two zeros and align the mark on the tubing with the L on the form handle. If the measured end is on the right side, then align the mark on the tubing with the R on the form handle. With a steady motion, pull the form handle till the zero mark

Type Bender	**AB**	**AB**	**B**	**B**	**B**	**BC**	**B**	**BC**	**B**	**BC**	**C**	**BC**	**C**
Tube od	⅛"	3⁄16"	¼"	5⁄16"	⅜"	⅜"	7⁄16"	½"	½"	⅝"	⅝"	¾"	¾"
Standard Bend	⅜"	7⁄16"	9⁄16"	11⁄16"	11⁄16"	15⁄16"	1⅜"	1½"	1¼"	2"	1½"	2½"	1¾"
Type Bender	**C**	**B**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**	**C**
Tube od	⅞"	1"	1"	1⅛"	1¼"	1⅜"	1⅜"	1½"	1½"	1¾"	2"	2½"	3"
Standard Bend	2"	3½"	3"	3½"	3¾"	5"	6"	5"	6"	7"	8"	10"	12"

A – Hand   B – Portable hand benders   C – Production bender

Table 7-1. Standard bend radii to which standard bending tools will form the various sizes of tubes.

Figure 7-4. Tube bending.

on the form handle lines up with the desired angle of bend, as indicated on the radius block. [Figure 7-4]

Bend the tubing carefully to avoid excessive flattening, kinking, or wrinkling. A small amount of flattening in bends is acceptable, but the small diameter of the flattened portion must not be less than 75 percent of the original outside diameter. Tubing with flattened, wrinkled, or irregular bends should not be installed. Wrinkled bends usually result from trying to bend thin wall tubing without using a tube bender. Excessive flattening will cause fatigue failure of the tube. Examples of correct and incorrect tubing bends are shown in Figure 7-5.

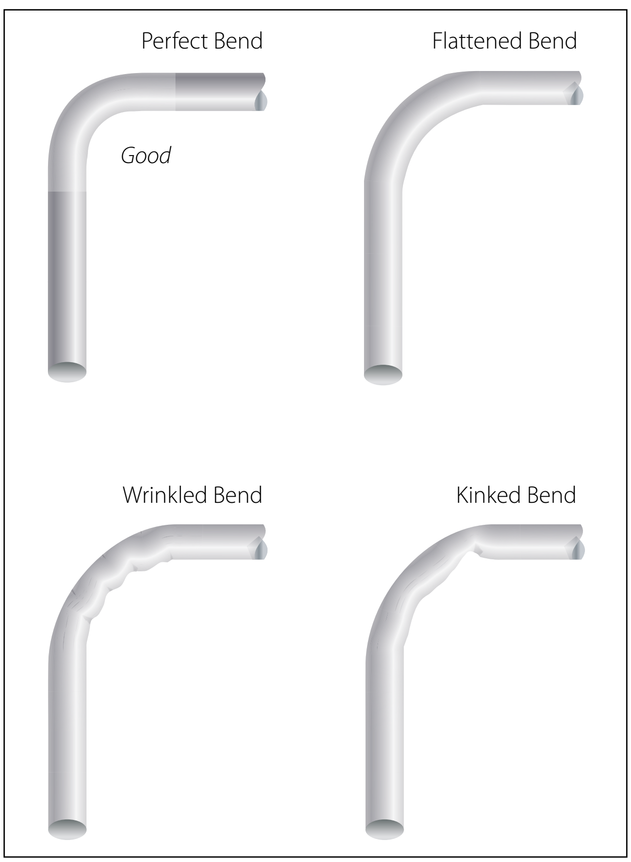

Figure 7-5. Correct and incorrect tubing bends.

Tube bending machines for all types of tubing are generally used in repair stations and large maintenance shops. With such equipment, proper bends can be made on large diameter tubing and on tubing made from hard material. The production CNC™ tube bender is an example of this type of machine. [Figure 7-6]

The ordinary production tube bender will accommodate tubing ranging from $\frac{1}{4}$" to $1\frac{1}{2}$" outside diameter. Benders for larger sizes are available, and the principle of their operation is similar to that of the hand tube bender. The radius blocks are so constructed that the radius of bend will vary with the tube diameter. The radius of bend is usually stamped on the block.

Alternative Bending Methods

When hand or production tube benders are not available or are not suitable for a particular bending operation, a filler of metallic composition or of dry sand may be used to facilitate bending. When using this method, cut the tube slightly longer than is required. The extra

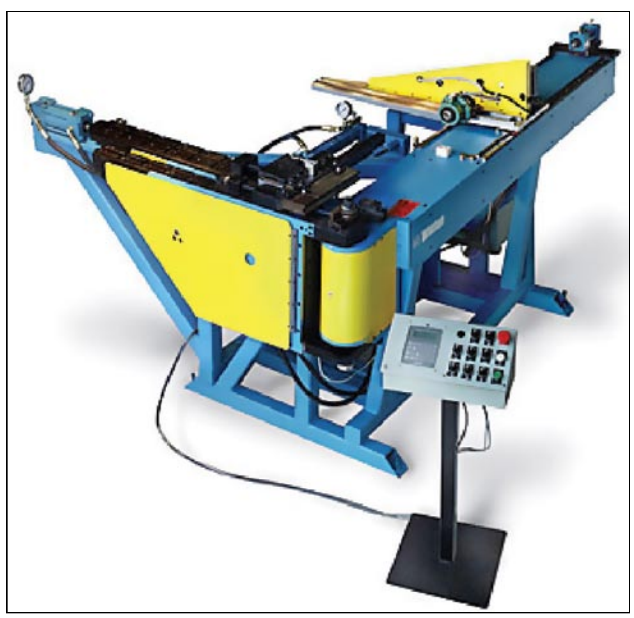

Figure 7-6. CNC tube bending machine.

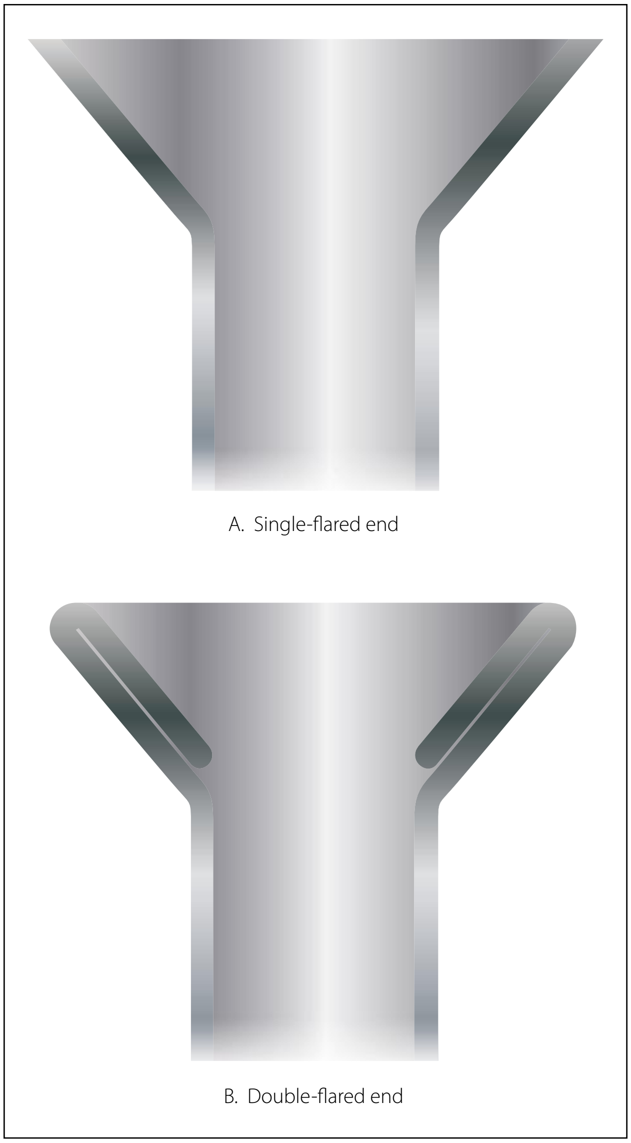

Figure 7-7. Cutaway view of single and double-flared tube ends.

length is for inserting a plug (which may be wooden) in each end. The tube can also be closed by flattening the ends or by soldering metal disks in them.

After plugging one end, fill and pack the tube with fine, dry sand and plug tightly. Both plugs must be tight so they will not be forced out when the bend is made. After the ends are closed, bend the tubing over a forming block shaped to the specified radius. In a modified version of the filler method, a fusible alloy is used instead of sand. In this method, the tube is filled under hot water with a fusible alloy that melts at 160 °F. The alloy-filled tubing is then removed from the water, allowed to cool, and bent slowly by hand around a forming block or with a tube bender. After the bend is made, the alloy is again melted under hot water and removed from the tubing. When using either filler methods, make certain that all particles of the filler are removed. Visually inspect with a borescope to make certain that no particles will be carried into the system in which the tubing is installed. Store the fusible alloy filler where it will be free from dust or dirt. It can be remelted and reused as often as desired. Never heat this filler in any other way than the prescribed method, as the alloy will stick to the inside of the tubing, making them both unusable.

Tube Flaring

Two kinds of flares are generally used in aircraft tubing: the single flare and the double flare. [Figure 7-7 (A and B)] Flares are frequently subjected to extremely high pressures; therefore, the flare on the tubing must be properly shaped or the connection will leak or fail. A flare made too small produces a weak joint, which may leak or pull apart; if made too large, it interferes with the proper engagement of the screw thread on the fitting and will cause leakage. A crooked flare is the result of the tubing not being cut squarely. If a flare is not made properly, flaws cannot be corrected by applying additional torque when tightening the fitting. The flare and tubing must be free from cracks, dents, nicks, scratches, or any other defects.

The flaring tool used for aircraft tubing has male and female dies ground to produce a flare of 35° to 37°. Under no circumstance is it permissible to use an automotive-type flaring tool which produces a flare of 45°. [Figure 7-8]

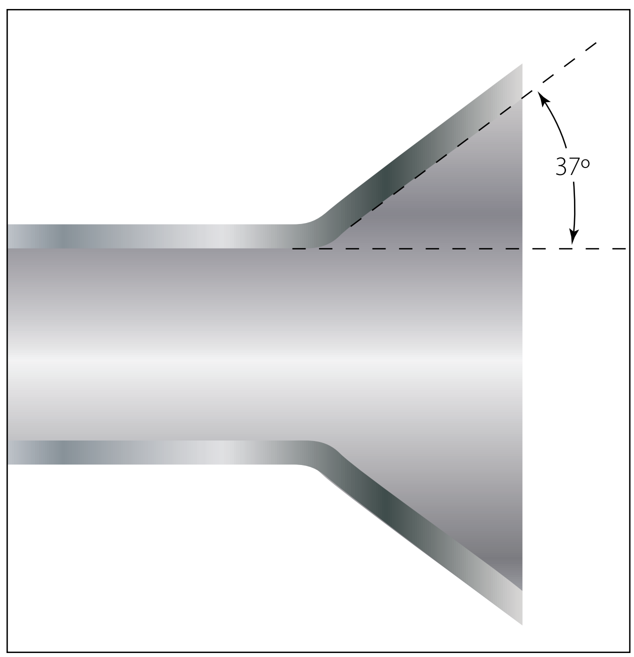

Figure 7-8. Flaring tool.

Figure 7-9. Hand flaring tool.

The single-flare hand flaring tool, similar to that shown in Figure 7-9, is used for flaring tubing. The tool consists of a flaring block or grip die, a yoke, and a flaring pin. The flaring block is a hinged double bar with holes corresponding to various sizes of tubing. These holes are countersunk on one end to form the outside support against which the flare is formed. The yoke is used to center the flaring pin over the end of the tube to be flared. Two types of flaring tools are used to make flares on tubing: the impact type and the rolling type.

Instructions for Rolling-Type Flaring Tools

Use these tools only to flare soft copper, aluminum, and brass tubing. Do not use with corrosion resistant steel or titanium. Cut the tube squarely and remove all burrs. Slip the fitting nut and sleeve on the tube. Loosen clamping screw used for locking the sliding segment in the die holder. This will permit their separation. The tools are self-gauging; the proper size flare is produced when tubing is clamped flush with the top of the die block. Insert tubing between the segments of the die block that correspond to the size of the tubing to be flared. Advance the clamp screw against the end segment and tighten firmly. Move the yoke down over the top of the die holder and twist it clockwise to lock it into position. Turn the feed screw down firmly, and continue until a slight resistance is felt. This indicates an accurate flare has been completed. Always read the tool manufacturer's instructions, because there are several different types of rolling-type flaring tools that use slightly different procedures.

Double Flaring

A double flare is used on soft aluminum alloy tubing $\frac{3}{8}$" outside diameter and under. This is necessary to prevent cutting off the flare and failure of the tube assembly under operating pressures. A double flare is smoother and more concentric than a single flare and therefore seals better. It is also more resistant to the shearing effect of torque.

Double Flaring Instructions

Deburr both the inside and outside of the tubing to be flared. Cut off the end of the tubing, if it appears damaged. Anneal brass, copper, and aluminum by heating to a dull red and cool rapidly in cold water. Open the flaring tool by unscrewing both clamping screws. Select the hole in the flaring bar that matches the tubing diameter and place the tubing with the end you have just prepared, extending above the top of the bar by a distance equal to the thickness of the shoulder of the adapter insert. Tighten clamping screws to hold tubing securely. Insert pilot of correctly sized adapter into tubing. Slip yoke over the flaring bars and center over adapter. Advance the cone downward until the shoulder of the adapter rests on the flaring bar. This bells out the end of the tubing. Next, back off the cone just enough to remove the adapter. After removing the adapter, advance the cone directly into the belled end of the tubing. This folds the tubing on itself and forms

Figure 7-10. Double flare tool.