CHAPTER 5

FLUID LINES AND FITTINGS

GENERAL

The term "aircraft plumbing" refers not only to the hose, tubing, fittings, and connectors used in the aircraft, but also to the processes of forming and installing them.

Occasionally it may be necessary to repair or replace damaged aircraft plumbing 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 line. 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.

PLUMBING LINES

Aircraft plumbing lines usually are made of metal tubing and fittings or of flexible hose. Metal tubing is 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.

Generally, aluminum alloy or corrosion-resistant steel tubing have replaced copper tubing. The high fatigue factor of copper tubing is the chief reason for its replacement. It becomes hard and brittle from vibration and finally breaks, however it may be restored to its soft annealed state by heating it red hot and quenching it in cold water. Cooling in air will result in a degree of softness but not equal to that obtained with the cold water quench. This annealing process must be accomplished if copper tubing is removed for any reason. Inspection of copper tubing for cracks, hardness, brittleness and general condition should be accomplished at regular intervals to preclude failure. The workability, resistance to corrosion, and lightweight of aluminum alloy are major factors in its adoption for aircraft plumbing.

In some special high-pressure (3,000 p.s.i.) hydraulic installations, corrosion-resistant steel tubing, either annealed or $\frac{1}{4}$-hard, is used. Corrosion-resistant steel tubing does not have to be annealed for flaring or forming; in fact, the flared section is somewhat strengthened by the cold working and strain hardening during the flaring process. 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.

IDENTIFICATION OF MATERIALS

Before making repairs to any aircraft plumbing, it is important to make accurate identification of plumbing materials. Aluminum alloy or steel tubing can be identified readily by sight where it is used as the basic plumbing material. However, it is difficult to determine whether a material is carbon steel or stainless steel, or whether it is 1100, 3003, 5052–0, or 2024–T aluminum alloy.

It may be necessary to test samples of the material for hardness by filing or scratching with a scriber. The magnet test is the simplest method for distinguishing between the annealed austenitic and the ferritic stainless steels. The austenitic types are nonmagnetic unless heavily cold worked, whereas the straight chromium carbon and low alloy steels are strongly magnetic. Figure 5–1 gives the methods for identifying five common

Material	Magnet test	Nitric acid test
Carbon steel	Strongly magnetic.	Slow chemical action, brown.
18–8	Nonmagnetic.	No action.
Pure nickel	Strongly magnetic.	Slow action, pale green.
Monel	Slightly magnetic.	Rapid action, greenish blue.
Nickel steel	Nonmagnetic.	Rapid action, greenish blue.

FIGURE 5–1. Identification of metallic materials.

metallic materials by using the magnet and concentrated nitric acid tests.

By comparing code markings of the replacement tubing with the original markings on the tubing being replaced, it is possible to identify definitely the material used in the original installation.

The alloy designation is stamped on the surface of large aluminum alloy tubing. On small aluminum alloy tubing, the designation may be stamped on the surface, but more often it is shown by a color code. Bands of the color code, not more than 4 inches in width, are 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.

Painted color codes used to identify aluminum alloy tubing are:

Aluminum 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

Aluminum alloy tubing, 1100 (½-hard) or 3003 (½–hard), is used for general purpose lines of low or negligible fluid pressures, such as instrument lines and ventilating conduits. The 2024–T and 5052–0 aluminum alloy materials are used in general purpose systems of low and medium pressures, such as hydraulic and pneumatic 1,000 to 1,500 p.s.i. systems and fuel and oil lines. Occasionally, these materials are used in high-pressure (3,000 p.s.i.) systems.

Tubing made from 2024–T and 5052–0 materials will withstand a fairly high pressure before bursting. These materials are easily flared and are soft enough to be formed with handtools. They must be handled with care to prevent scratches, dents, and nicks.

Corrosion-resistant steel tubing, either annealed or ¼–hard, is used extensively in high-pressure hydraulic systems for the operation of landing gear, flaps, brakes, and the like. External brake lines should always be made of corrosion-resistant steel to minimize damage from rocks thrown by the tires during takeoff and landing, and from careless ground handling. Although identification markings for steel tubing differ, each usually includes the manufacturer's name or trademark, the SAE number, and the physical condition of the metal.

Metal tubing is sized by outside diameter, which is measured fractionally in sixteenths of an inch. Thus Number 6 tubing is 6/16 (or ⅜ inch) and Number 8 tubing is 8/16 (or ½ inch), etc.

In addition to other classification 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.

FLEXIBLE HOSE

Flexible hose is used in aircraft plumbing to connect moving parts with stationary parts in locations subject to vibration or where a great amount of flexibility is needed. It can also serve as a connector in metal tubing systems.

Synthetics

Synthetic materials most commonly used in the manufacture of flexible hose are: Buna-N, Neoprene, Butyl and Teflon (trademark of DuPont Corp.). *Buna-N* is a synthetic rubber compound which has excellent resistance to petroleum products. Do not confuse with Buna-S. Do not use for phosphate ester base hydraulic fluid (Skyrol®). *Neoprene* is a synthetic rubber compound which has an acetylene base. Its resistance to petroleum products is not as good as Buna-N but has better abrasive resistance. Do not use for phosphate ester base hydraulic fluid (Skydrol ®). *Butyl* is a synthetic rubber compound made from petroleum raw materials. It is an excellent material to use with phosphate ester based hydraulic fluid (Skydrol ®). Do not use with petroleum products. *Teflon* is the DuPont trade name for tetrafluoroethylene resin. It has a broad operating temperature range (−65° F. to +450° F.). It is compatible with nearly every substance or agent used. It offers little resistance to flow; sticky viscous materials will not adhere to it. It has less volumetric expansion than rubber and the shelf and service life is practically limitless.

Rubber Hose

Flexible rubber hose consists of a seamless synthetic rubber inner tube covered with layers of cotton braid and wire braid, and an outer layer of rubber-impregnated cotton braid. This type of hose is suitable for use in fuel, oil, coolant, and hydraulic systems. The types of hose are normally classified by the amount of pressure they are designed to withstand under normal operating conditions.

1. Low pressure, any pressure below 250 p.s.i. Fabric braid reinforcement.

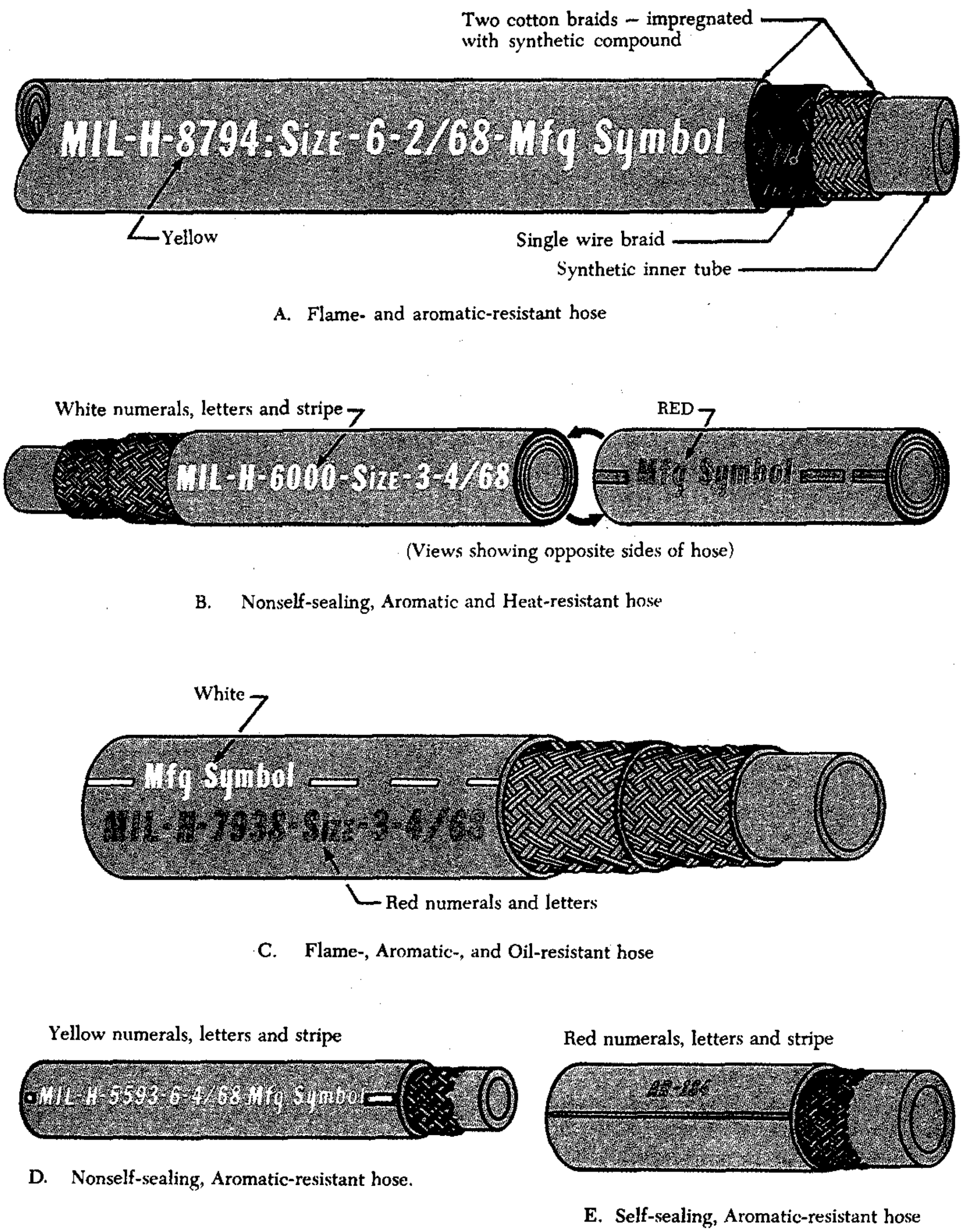


FIGURE 5–2. Hose identification markings.

2. Medium pressure, pressures up to 3,000 p.s.i.
   One wire braid reinforcement.
   Smaller sizes carry pressure up to 3,000 p.s.i.
   Larger sizes carry pressure up to 1,500 p.s.i.
3. High pressure (all sizes up to 3,000 p.s.i. operating pressures).

Identification markings consisting of lines, letters, and numbers are printed on the hose. (See figure 5–2.) These code markings show such information as hose size, manufacturer, date of manufacture, and pressure and temperature limits. Code markings assist in replacing a hose with one of the same specification or a recommended substitute. Hose suitable for use with phosphate ester base hydraulic fluid will be marked "Skydrol R use". In some instances several types of hose may be suitable for the same use. Therefore, in order to make the correct hose selection, always refer to the maintenance or parts manual for the particular airplane.

Teflon Hose

Teflon hose is a flexible hose designed to meet the requirements of higher operating temperatures and pressures in present aircraft systems. It can generally be used in the same manner as rubber hose. Teflon hose is processed and extruded into tube shape to a desired size. It is covered with stainless steel wire, which is braided over the tube for strength and protection.

Teflon hose is unaffected by any known fuel, petroleum, or synthetic base oils, alcohol, coolants, or solvents commonly used in aircraft. Although it is highly resistant to vibration and fatigue, the principle advantage of this hose is its operating strength.

Size Designation

The size of flexible hose is determined by its inside diameter. Sizes are in one-sixteenth-inch increments and are identical to corresponding sizes of rigid tubing, with which it can be used.

Identification of Fluid Lines

Fluid lines in aircraft are often identified by markers made up of color codes, words, and geometric symbols. These markers identify each line's function, content, and primary hazard, as well as the direction of fluid flow. Figure 5–3 illustrates the various color codes and symbols used to designate the type of system and its contents.

In most instances, fluid lines are marked with 1-inch tape or decals, as shown in figure 5–4 (A).

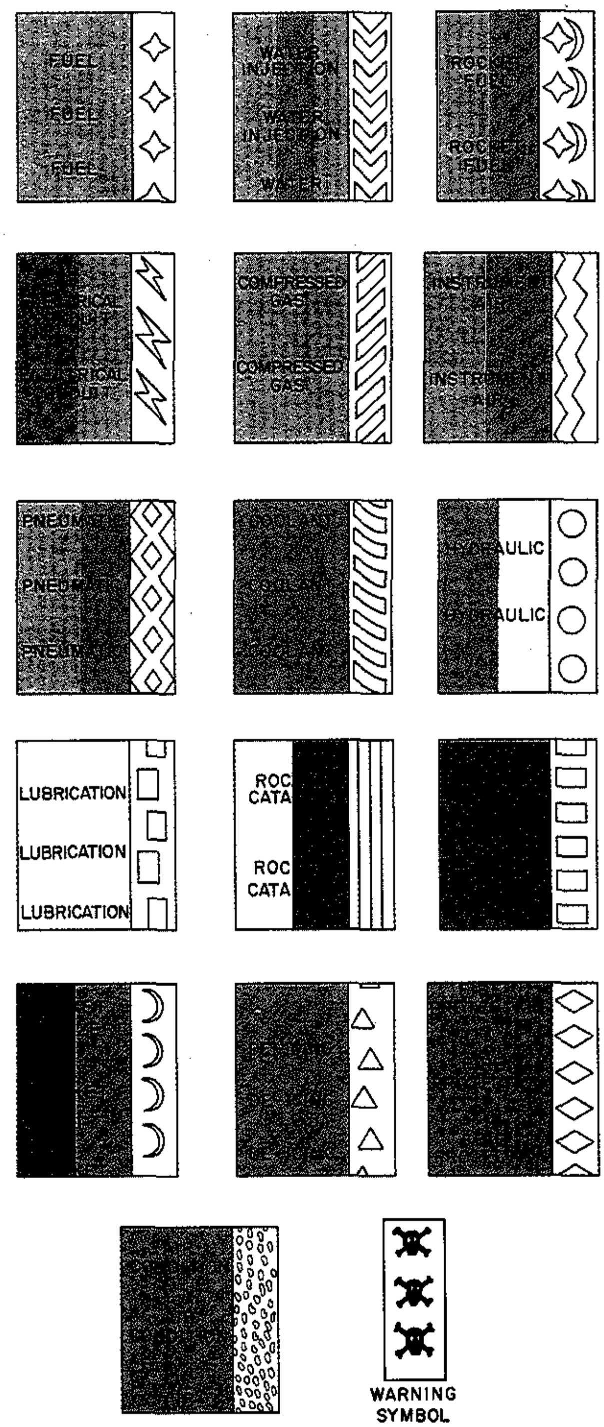


FIGURE 5–3. Identification of aircraft fluid lines.

On lines 4 inches in diameter (or larger), lines in oily environment, hot lines, and on some cold lines, steel tags may be used in place of tape or decals, as shown in figure 5–4 (B). Paint is used on lines in engine compartments, where there is the possibility of tapes, decals, or tags being drawn into the engine induction system.

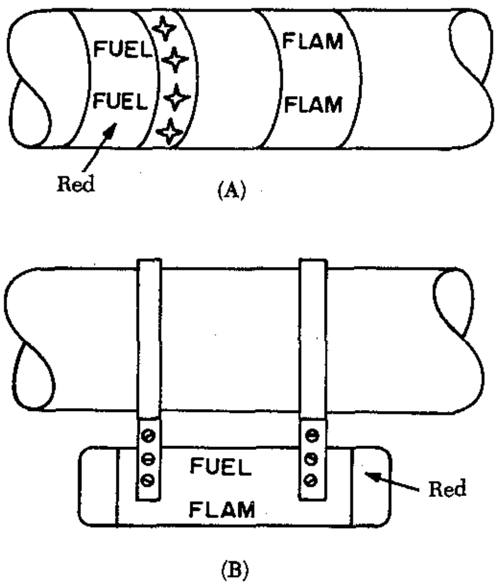


FIGURE 5–4. Fluid line identification using: (A) tape and decals and (B) metal tags.

In addition to the above-mentioned markings, certain lines may be further identified as to specific function within a system; for example, DRAIN, VENT, PRESSURE, or RETURN.

Lines conveying fuel may be marked FLAM; lines containing toxic materials are marked TOXIC in place of FLAM. Lines containing physically dangerous materials, such as oxygen, nitrogen, or freon, are marked PHDAN.

The aircraft and engine manufacturers are responsible for the original installation of identification markers, but the aviation mechanic is responsible for their replacement when it becomes necessary.

Generally, tapes and decals are placed on both ends of a line and at least once in each compartment through which the line runs. In addition, identification markers are placed immediately adjacent to each valve, regulator, filter, or other accessory within a line. Where paint or tags are used, location requirements are the same as for tapes and decals.

PLUMBING CONNECTORS

Plumbing connectors, or fittings, attach one piece of tubing to another or to system units. There are four types: (1) Flared fitting, (2) flareless fitting, (3) bead and clamp, and (4) swaged. The amount of pressure that the system carries is usually the deciding factor in selecting a connector. The beaded type of joint, which requires a bead and a section of hose and hose clamps, is

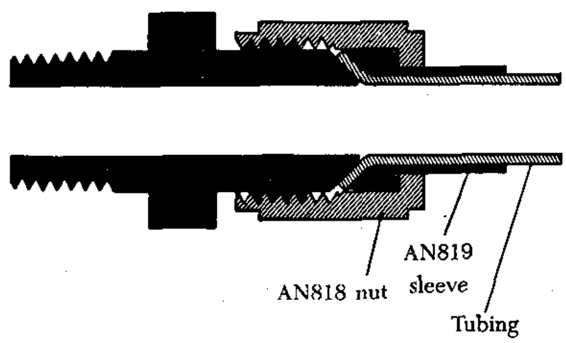
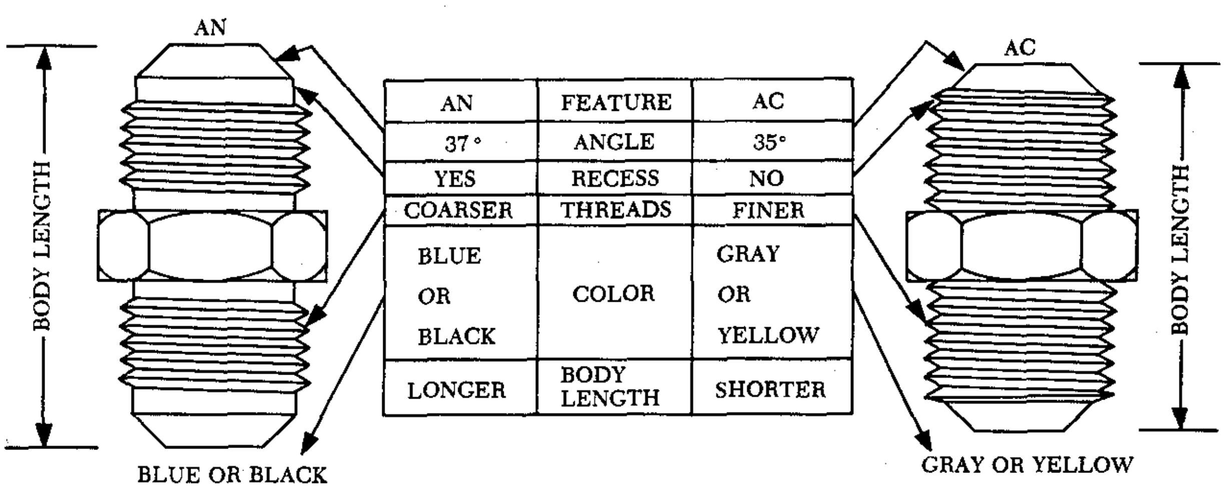


FIGURE 5–5. Flared-tube fitting.



AN	FEATURE	AC
37°	ANGLE	35°
YES	RECESS	NO
COARSER	THREADS	FINER
BLUE OR BLACK	COLOR	GRAY OR YELLOW
LONGER	BODY LENGTH	SHORTER

FIGURE 5-6. AN and AC fitting differences.

used only in low- or medium-pressure systems, such as vacuum and coolant systems. The flared, flareless, and swaged types may be used as connectors in all systems, regardless of the pressure.

Flared-Tube Fittings

A flared-tube fitting consists of a sleeve and a nut, as shown in figure 5–5. The nut fits over the sleeve and, when tightened, draws the sleeve and tubing flare tightly against a male fitting to form a seal. Tubing used with this type of fitting must be flared before installation.

The male fitting has a cone-shaped surface with the same angle as the inside of the flare. The sleeve supports the tube so that vibration does not concentrate at the edge of the flare, and distributes the shearing action over a wider area for added strength. Tube flaring and the installation of flared-tube fittings are discussed in detail later in this chapter.

The AC (Air Corps) flared-tube fittings have been replaced by the AN (Army/Navy) Standard and MS (Military Standard) fittings. However, since AC fittings are still in use in some of the older aircraft, it is important to be able to identify them. The AN fitting has a shoulder between the end of the threads and the flare cone. (See figure 5–6.) The AC fitting does not have this shoulder.

Other differences between the AC and AN fittings include the sleeve design, the AC sleeve being noticeably longer than the AN sleeve of the same size. Although certain flared-tube fittings are interchangeable, the pitch of the threads is different in most cases. Figure 5–7 shows the AN and AC811 fittings that can be safely interchanged. Combinations of end connections, nuts,

Tube Sizes OD	Type End Connection (Male Thread)	Type Nut (Female Thread)	Type Sleeve	Type Tube Flare
All Sizes[1]	AN[1]	AN[1]	AN[1]	AN[1]
All Sizes[2]	811[2]	811[2]	811[2]	811[2]
All Sizes	AN	AN	AN	811
All Sizes	AN	AN	811	811
All Sizes	AN	AN	811	AN
All Sizes	811	811	811	AN
All Sizes	811	811	AN	AN
All Sizes	811	811	AN	811
1/8, 3/16, 1/4, 5/16, 1 3/4, 2	AN	811	AN	811
1/8, 3/16, 1/4, 5/16, 1 3/4, 2	AN	811	AN	AN
1/8, 3/16, 1/4, 5/16, 1 3/4, 2	AN	811	811	AN
1/8, 3/16, 1/4, 5/16, 1 3/4, 2	AN	811	811	AN

[1] This is the normal assembly of AN fittings.
[2] This is the normal assembly of AC811 fittings.

FIGURE 5–7a. Interchangeability of AN and AC811 fittings.

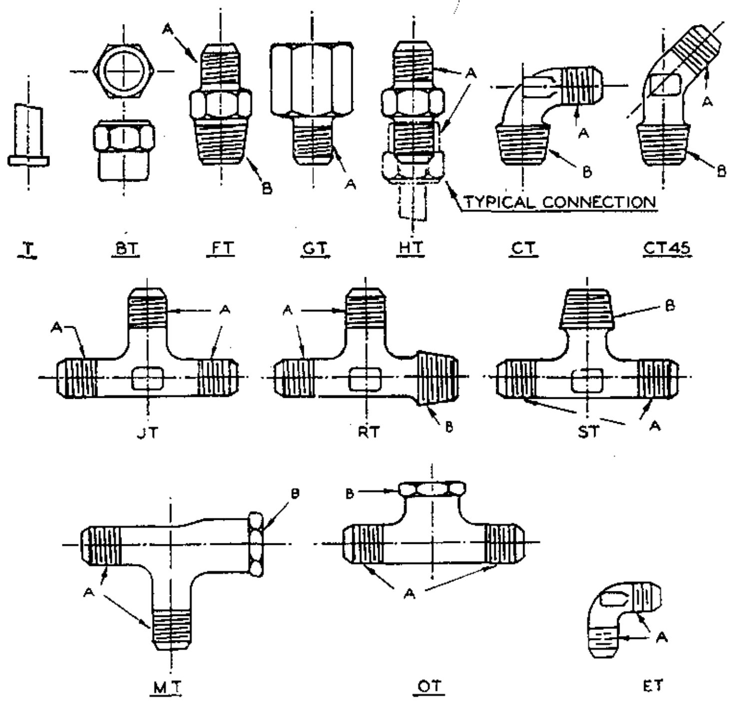


FIGURE 5–7 b. AC811 solderless fittings.

—— AN744 to AN932 ——

Material:

Aluminum alloy .... (code D)
Steel .... (code, absence of letter)
Brass .... (code B)
Aluminum bronze .... (code Z—for AN819 sleeve)

Size:

The dash number following the AN number indicates the size of the tubing (or hose) for which the fitting is made, in 16ths of an inch. This size measures the O. D. of tubing and the I. D. of hose. Fittings having pipe threads are coded by a dash number, indicating the pipe size in 8ths of an inch. The material code letter, as noted above, follows the dash number.

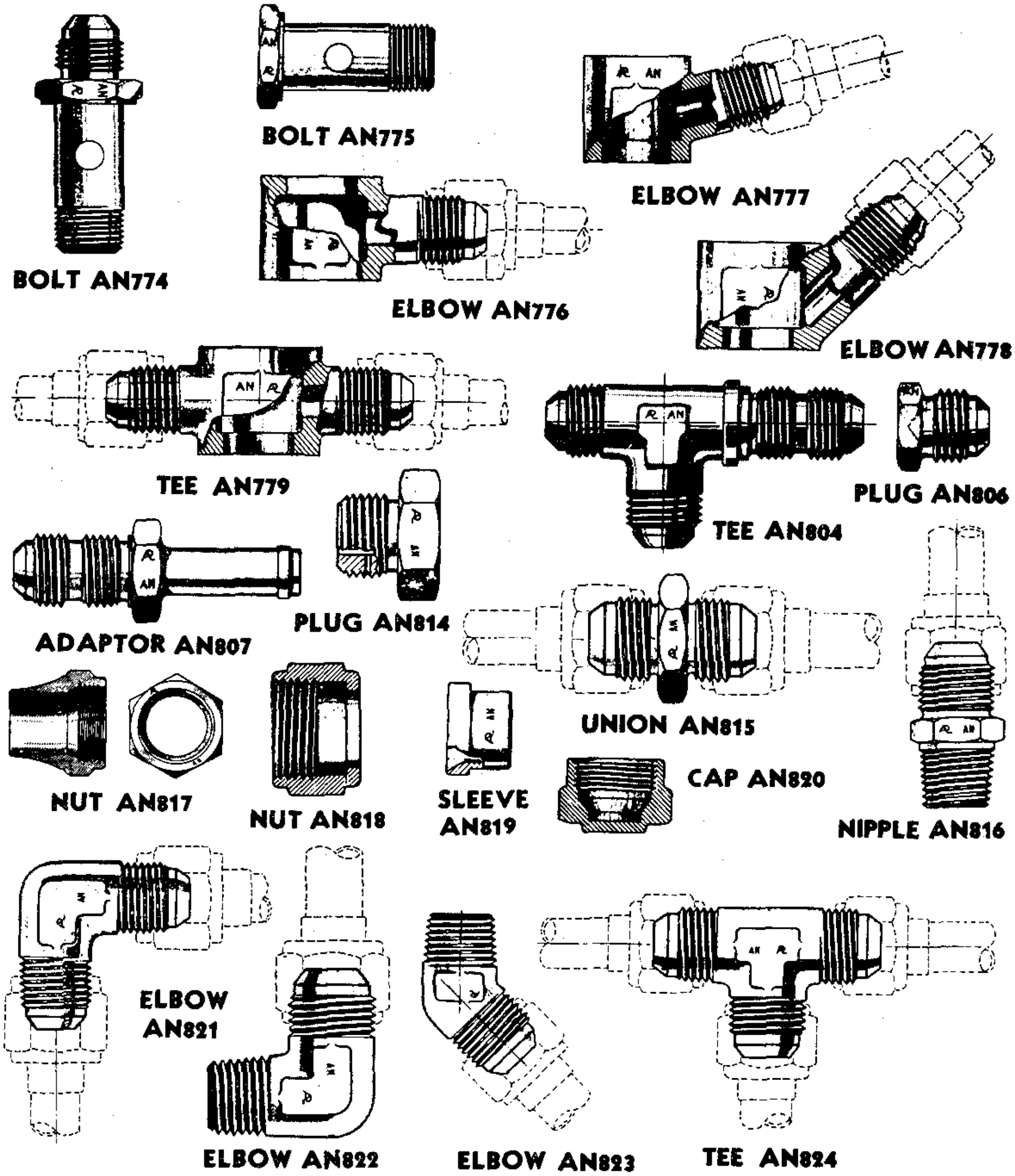


Figure 5–8. AN plumbing fittings.

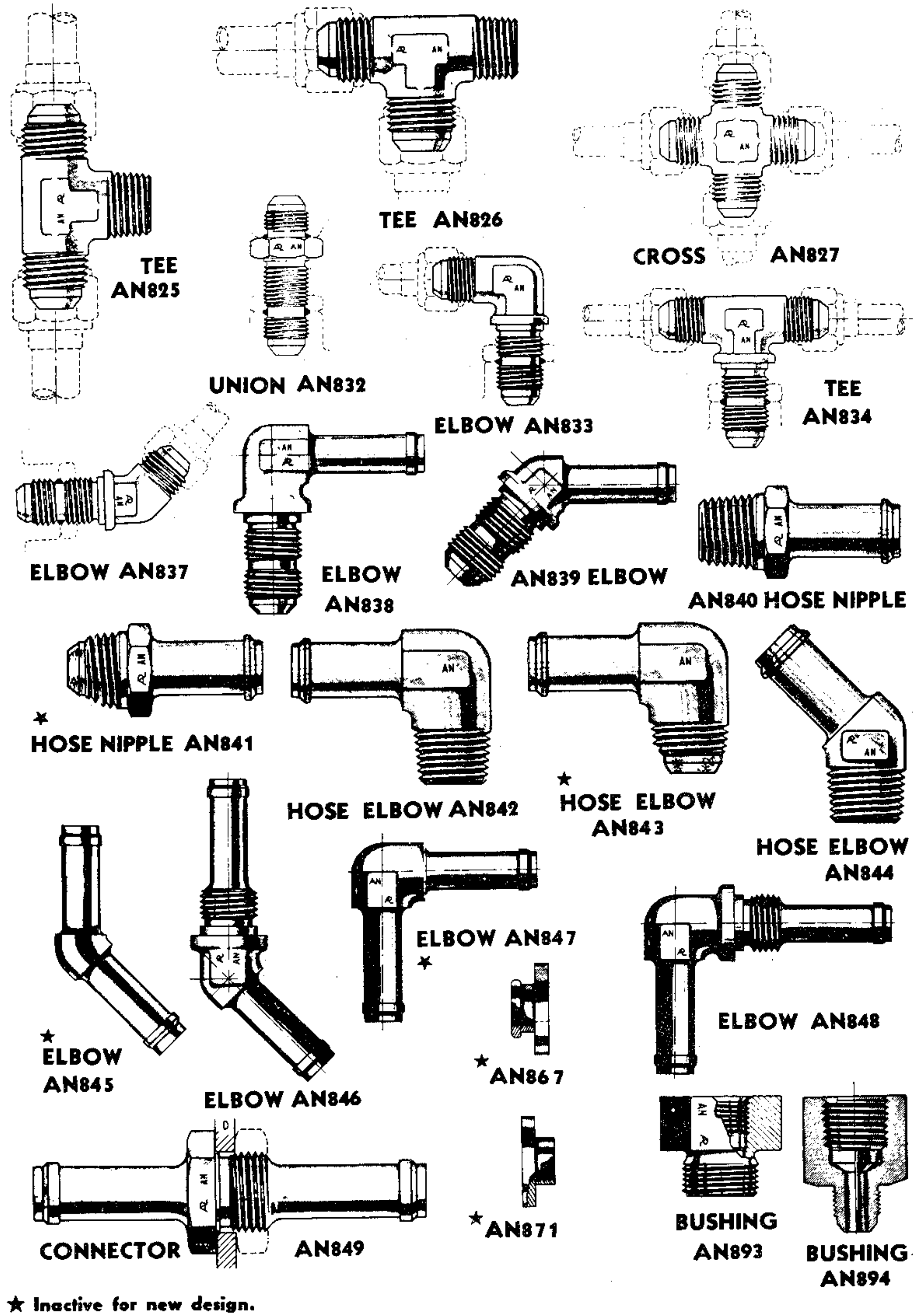


FIGURE 5–8. AN plumbing fittings.—Continued

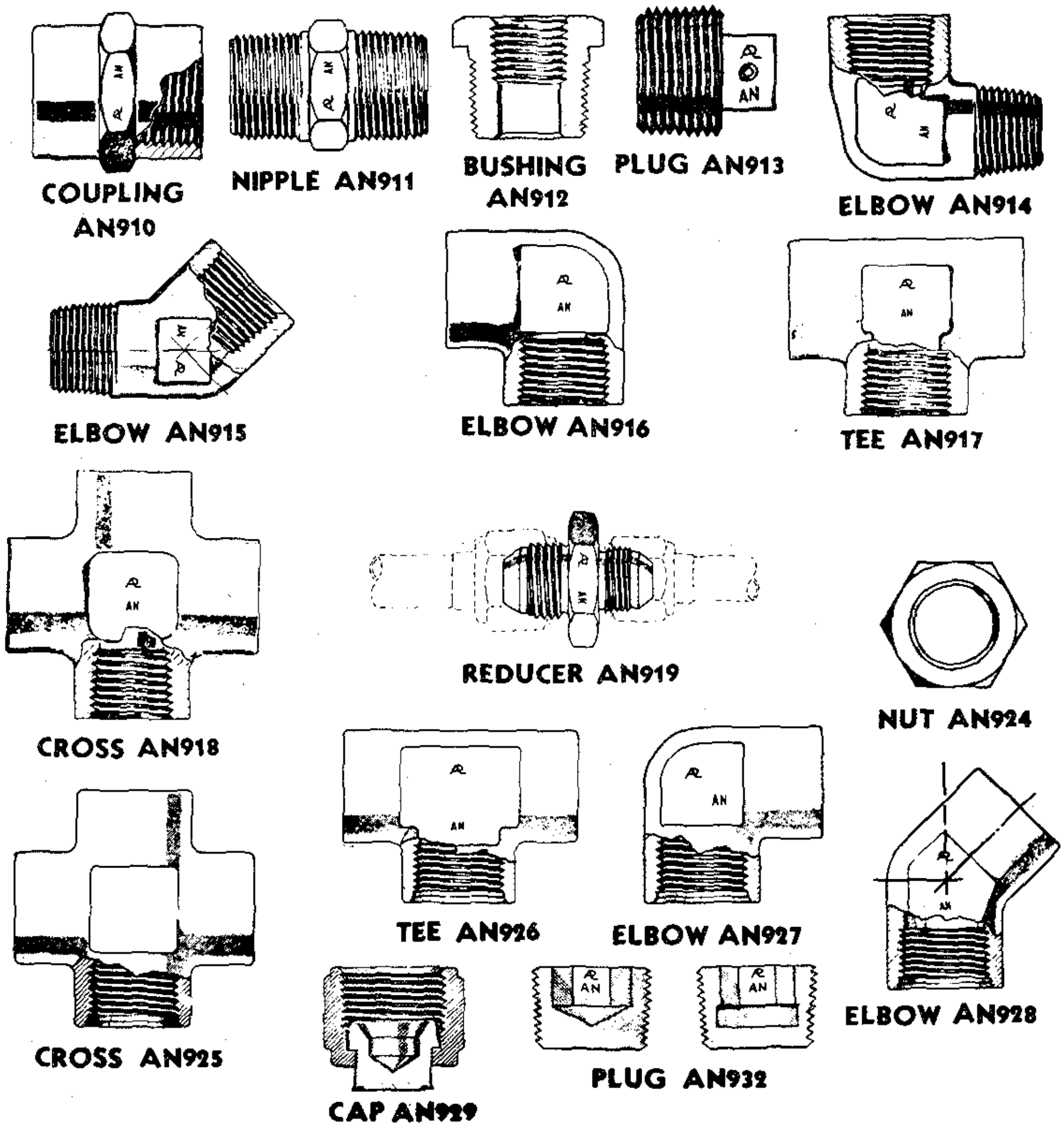


FIGURE 5–8. AN plumbing fittings.—Continued

sleeves, and tube flares are allowed to make up a complete fitting assembly. The use of dissimilar metals should be avoided since their contact will cause corrosion.

When combining AC and AN end connections, nuts, sleeves, or tube flares, if the nut will not move more than two threads by hand, stop and investigate for possible trouble.

The AN standard fitting is the most commonly used flared-tubing assembly for attaching the tubing to the various fittings required in aircraft plumbing systems. The AN standard fittings include the AN818 nut and AN819 sleeve. (See figure 5–8.) The AN819 sleeve is used with the AN818 coupling nut. All these fittings have straight threads, but they have different pitch for the various types.

Flared-tube fittings are made of aluminum alloy, steel, or copper base alloys. For identification purposes, all AN steel fittings are colored black, and all AN aluminum alloy fittings are colored blue. The AN 819 aluminum bronze sleeves are cadmium plated and are not colored. The size of these fittings is given in dash numbers, which equal the nominal tube outside diameter (O.D.) in sixteenths of an inch.

Threaded flared-tube fittings have two types of ends, referred to as male and female. The male end of a fitting is externally threaded, whereas the female end of a fitting is internally threaded.

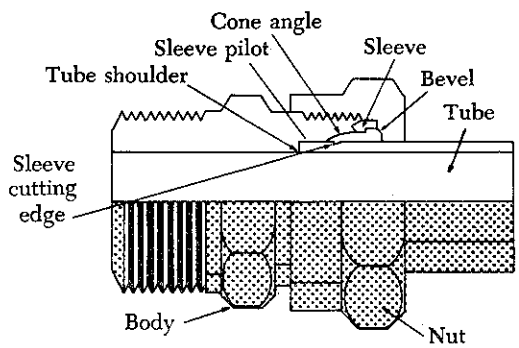


FIGURE 5–9. Flareless-tube fitting.

Flareless-tube Fittings

The MS (Military Standard) flareless-tube fittings are finding wide application in aircraft plumbing systems. Using this type fitting eliminates all tube flaring, yet provides a safe, strong, dependable tube connection. The fitting consists of three parts: a body, a sleeve, and a nut. The body has a counterbored shoulder, against which the end of the tube rests. (See figure 5–9.) The angle of the counterbore causes the cutting edge of the sleeve to cut into the outside of the tube when the two are joined. Installation of flareless-tube fittings is discussed later in this chapter.

Quick-disconnect Couplings

Quick-disconnect couplings of the self-sealing type are used at various points in many fluid systems. The couplings are installed at locations where frequent uncoupling of the lines is required for inspection and maintenance.

Quick-disconnect couplings provide a means of quickly disconnecting a line without loss of fluid or entrance of air into the system. Each coupling assembly consists of two halves, held together by a union nut. Each half contains a valve that is held open when the coupling is connected, allowing fluid to flow through the coupling in either direction. When the coupling is disconnected, a spring in each half closes the valve, preventing the loss of fluid and entrance of air.

The union nut has a quick-lead thread which permits connecting or disconnecting the coupling by turning the nut. The amount the nut must be turned varies with different style couplings. One style requires a quarter turn of the union nut to lock or unlock the coupling while another style requires a full turn.

Some couplings require wrench tightening; others are connected and disconnected by hand. The design of some couplings is such that they must be safetied with safety wire. Others do not require lock wiring, the positive locking being assured by the teeth on the locking spring, which engage ratchet teeth on the union nut when the coupling is fully engaged. The lock spring automatically disengages when the union nut is unscrewed. Because of individual differences, all quick disconnects should be installed according to instructions in the aircraft maintenance manual.

Flexible Connectors

Flexible connectors may be equipped with either swaged fittings or detachable fittings, or they may be used with beads and hose clamps. Those equipped with swaged fittings are ordered by correct length from the manufacturer and ordinarily cannot be assembled by the mechanic. They are swaged and tested at the factory and are equipped with standard fittings.

The fittings on detachable connectors can be detached and reused if they are not damaged; otherwise new fittings must be used.

The bead and hose clamp connector is often used for connecting oil, coolant, and low-pressure fuel system tubing. The bead, a slightly raised ridge around the tubing or the fitting, gives a good gripping edge that aids in holding the clamp and hose in place. The bead may appear near the end of the metal tubing or on one end of a fitting.

TUBE FORMING PROCESSES

Damaged tubing and fluid lines should be replaced with new parts whenever possible. Sometimes replacement is impractical and repair is necessary. Scratches, abrasions, and 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 later in this chapter under "Repair of Metal Tube Lines." 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: (1) Cutting, (2) bending, (3) flaring, and (4) beading. If the tubing is small and of soft material, the assembly can be formed by hand bending during installation. If the tubing is ¼-inch 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 5–10.

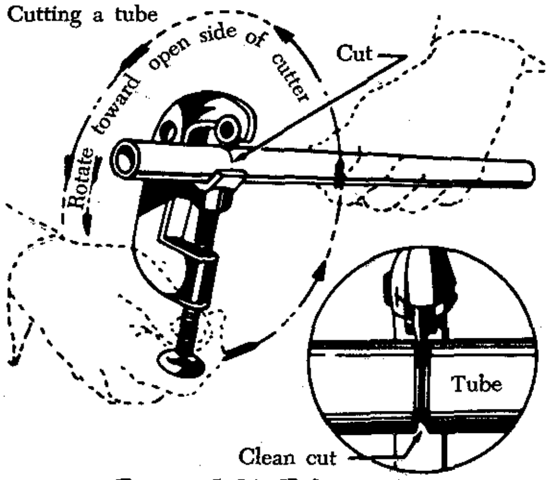


FIGURE 5–10. Tube cutting.

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

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. A fine tooth file can be used 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 one-fourth inch in diameter usually can be bent without the use of a bending tool. For larger sizes, a hand tube bender similar to that shown in figure 5–11 is usually used.

To bend tubing with the hand tube bender, insert the tubing by raising the slide bar handle as far as it will go. Adjust the handle so that the full length of the groove in the slide bar is in contact with the tubing. The zero mark on the radius block and the mark on the slide bar must align. Make the bend by rotating the handle until the desired angle of bend is obtained, as indicated on the radius block.

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. Examples of correct and incorrect tubing bends are shown in figure 5–12.

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 tube bender is an example of this type of machine.

The ordinary production tube bender will accommodate tubing ranging from ½-inch to 1½-inch 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 tubing diameter. The radius of bend is usually stamped on the block.

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 length is for inserting a plug (which may be wooden) in each end.

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. The tube can also be closed by flattening the ends or by soldering metal disks in them. After the ends are closed, bend the tubing

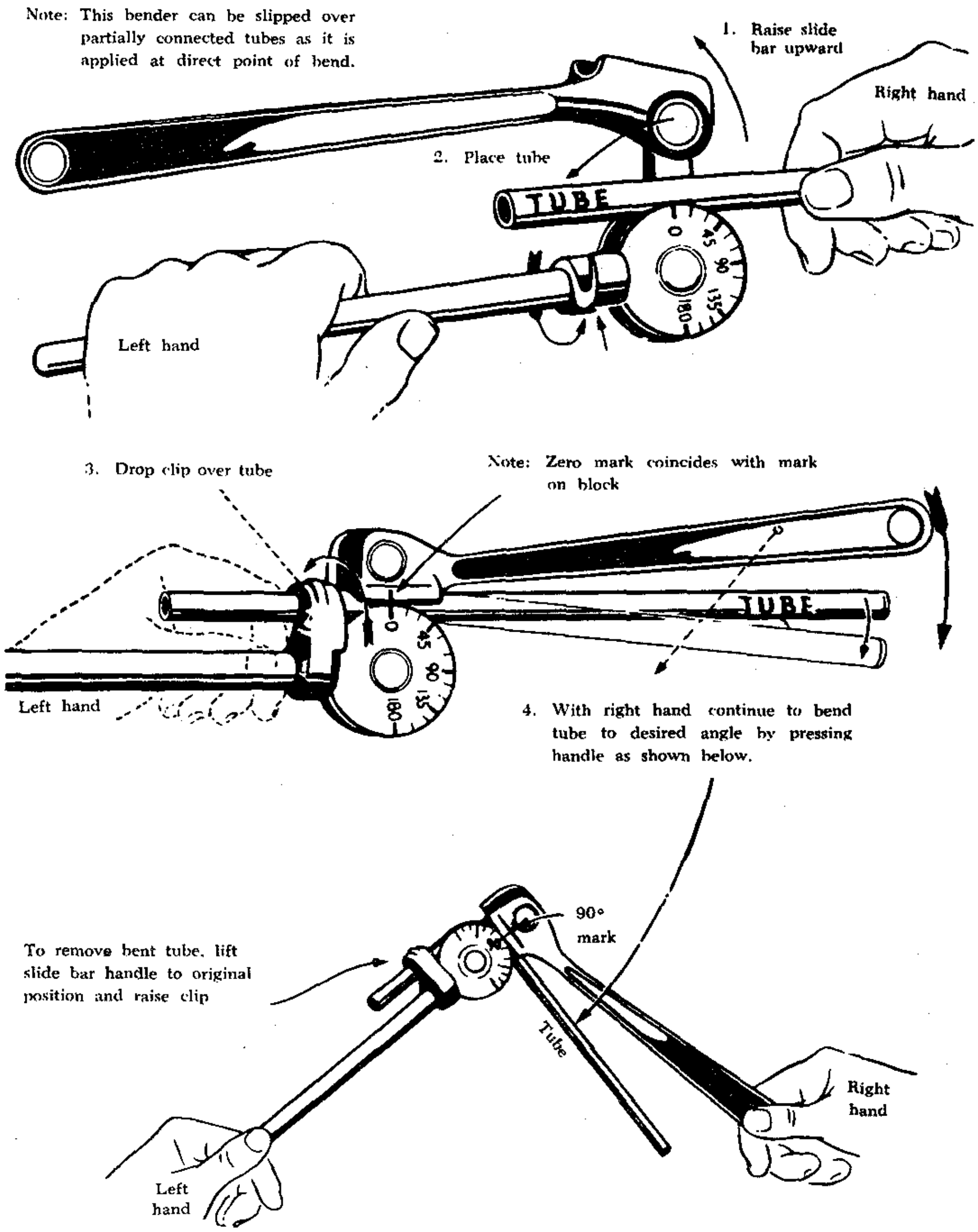


FIGURE 5–11. Tube bending.

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 method, make certain that all particles of the filler are removed so that none 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

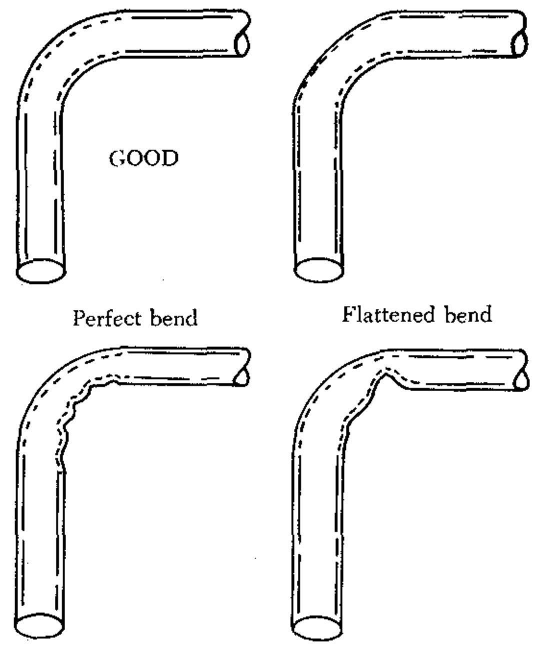


FIGURE 5–12. Correct and incorrect tubing bends.

re-melted and re-used as often as desired. Never heat this filler in any other 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 plumbing systems, the single flare and the double flare. 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 circumstances is it permissible to use an automotive type flaring tool which produces a flare of 45°.

Single Flare

A hand flaring tool similar to that shown in figure 5–13 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.

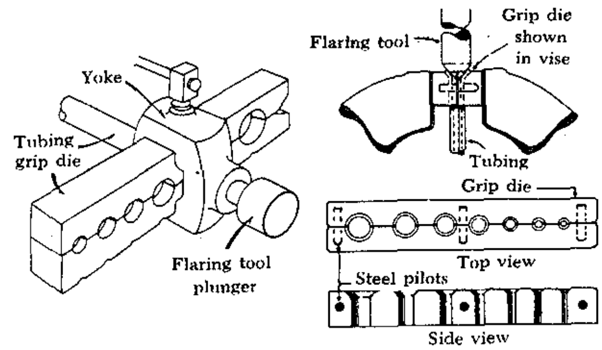


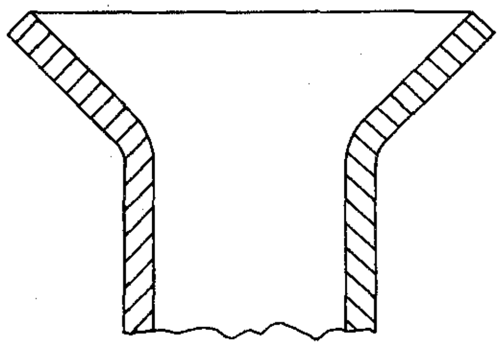
FIGURE 5–13. Hand flaring tool (single flare).

To prepare a tube for flaring, cut the tube squarely and remove all burrs. Slip the fitting nut and sleeve on the tube and place the tube in the proper size hole in the flaring tool. Center the plunger or flaring pin over the end of the tube. Then project the end of the tubing slightly from the top of the flaring tool, about the thickness of a dime, and tighten the clamp bar securely to prevent slippage.

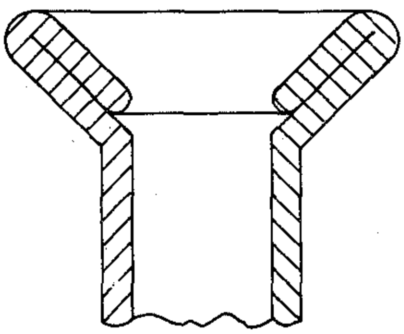
Make the flare by striking the plunger several light blows with a lightweight hammer or mallet. Turn the plunger a half turn after each blow and be sure it seats properly before removing the tube from the flaring tool. Check the flare by sliding the sleeve into position over the flare. The outside diameter of the flare should extend approximately one-sixteenth inch beyond the end of the sleeve, but should not be larger than the major outside diameter of the sleeve.

Double Flare

A double flare should be used on 5052-O and 6061-T aluminum alloy tubing for all sizes from 1/8- to 3/8-inch outside diameter. This is necessary to prevent cutting off the flare and failure of the tube assembly under operating pressures. Double flaring is not necessary on steel tubing. See figure 5–14 for an illustration of single- and double-flared tubing. The double flare is smoother and more concentric than the single flare and, therefore, seals better. It is also more resistant to the shearing effect of torque.



A. Single-flared end



B. Double-flared end

FIGURE 5–14. Cutaway view of single- and double-flared tube ends.

To make the double flare, separate the clamp blocks of the double-flaring tool and insert and clamp the tubing with the burred end flush with the top of the clamp. Insert the starting pin into the flaring pin guide and strike the pin sharply with a hammer until the shoulder of the pin stops against the clamp blocks. Remove the starting pin and insert the finishing pin; hammer it until its shoulder rests on the clamp block.

Beading

Tubing may be beaded with a hand-beading tool, with machine-beading rolls, or with grip dies. The method to be used depends on the diameter and wall thickness of the tube and the material from which it was made.

The hand-beading tool is used with tubing having $\frac{1}{4}$- to 1-inch outside diameter. The bead is formed by using the beader frame with the proper rollers attached. The inside and outside of the tube is lubricated with light oil to reduce the friction between the rollers during beading. The sizes, marked in sixteenths of an inch on the rollers, are for the outside diameter of the tubing that can be beaded with the rollers.

Separate rollers are required for the inside of each tubing size, and care must be taken to use the correct parts when beading. The hand-beading tool works somewhat like the tube cutter in that the roller is screwed down intermittently while rotating the beading tool around the tubing. In addition, a small vise (tube holder) is furnished with the kit.

Other methods and types of beading tools and machines are available, but the hand-beading tool is used most often. As a rule, beading machines are limited to use with large-diameter tubing, over $1\frac{15}{16}$ inch, unless special rollers are supplied. The grip-die method of beading is confined to small tubing.

Flareless-Tube Assemblies

Although the use of flareless-tube fittings eliminates all tube flaring, another operation, referred to as presetting, is necessary prior to installation of a new flareless-tube assembly. Figure 5–15 (steps 1, 2, and 3) illustrates the presetting operation, which is performed as follows:

(a.) Cut the tube to the correct length, with the ends perfectly square. Deburr the inside and outside of the tube. Slip the nut, then the sleeve, over the tube (step 1).

(b.) Lubricate the threads of the fitting and nut with hydraulic fluid. Place the fitting in a vise (step 2), and hold the tubing firmly and squarely on the seat in the fitting. (Tube must bottom firmly in the fitting.) Tighten the nut until the cutting edge of the sleeve grips the tube. This point is determined by slowly turning the tube back and forth while tightening the nut. When the tube no longer turns, the nut is ready for final tightening.

(c.) Final tightening depends upon the tubing. For aluminum alloy tubing up to and including $\frac{1}{2}$-inch outside diameter, tighten the nut from one to one and one-sixth turns. For steel tubing and aluminum alloy tubing over $\frac{1}{2}$-inch outside diameter, tighten from one and one-sixth to one and one-half turns.

After presetting the sleeve, disconnect the tubing from the fitting and check the following points

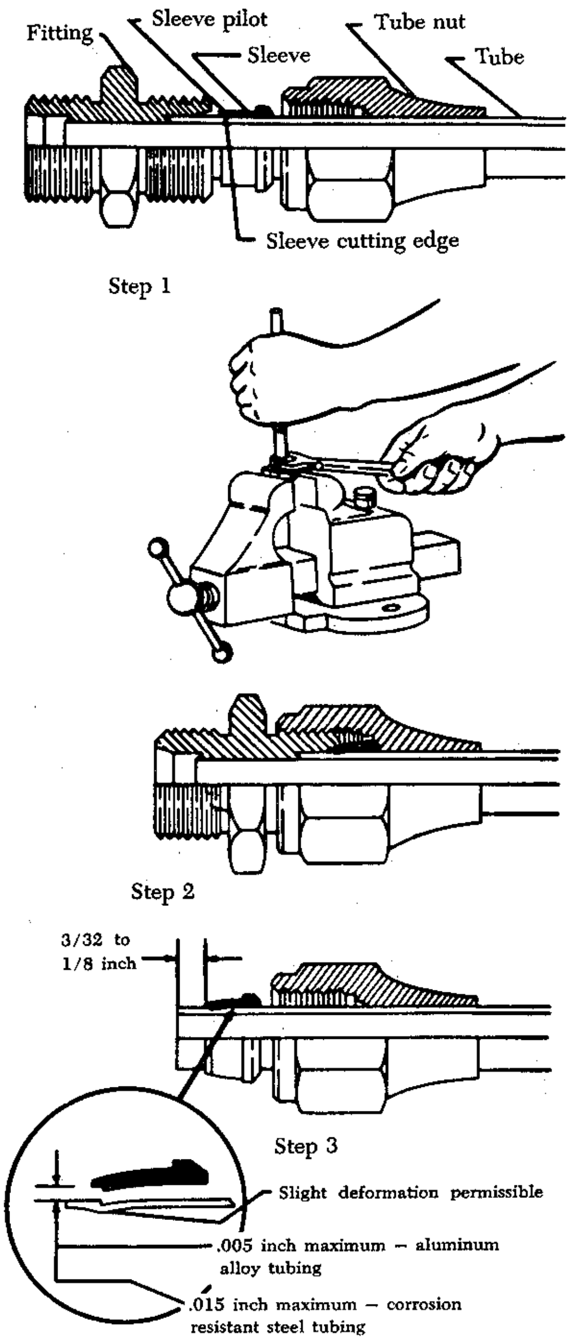


FIGURE 5–15. Presetting flareless-tube assembly.

(illustrated in step 3):

(a.) The tube should extend 3/32 to 1/8 inch beyond the sleeve pilot; otherwise blowoff may occur.

(b.) The sleeve pilot should contact the tube or have a maximum clearance of 0.005 inch for aluminum alloy tubing or 0.015 inch for steel tubing.

(c.) A slight collapse of the tube at the sleeve cut is permissible. No movement of the sleeve pilot, except rotation, is permissible.

REPAIR OF METAL TUBE LINES

Scratches or nicks no deeper than 10 percent of the wall thickness in aluminum alloy tubing may be repaired, if they are not in the heel of a bend. Replace lines with severe die marks, seams, or splits in the tube. Any crack or deformity in a flare is also unacceptable and is cause for rejection. A dent of less than 20 percent of the tube diameter is not objectionable, unless it is in the heel of a bend. Dents can be removed by drawing a bullet of proper size through the tube by means of a length of cable.

A severely damaged line should be replaced. However, the line can be repaired by cutting out the damaged section and inserting a tube section of the same size and material. Flare both ends of the undamaged and replacement tube sections and make the connection by using standard unions, sleeves, and tube nuts. If the damaged portion is short enough, omit the insert tube and repair by using one union and two sets of connecting fittings.

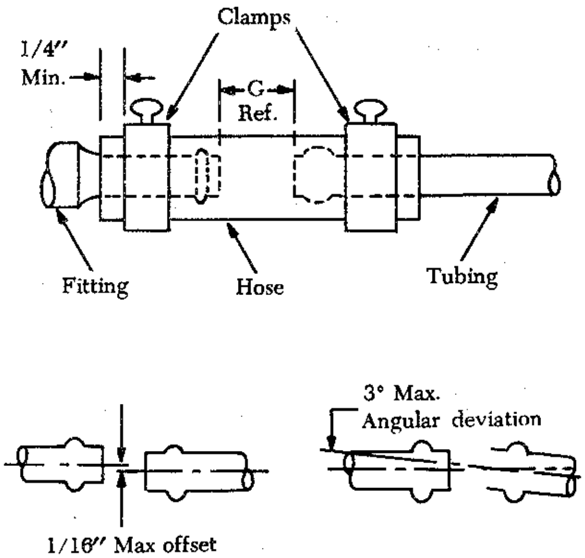
When repairing a damaged line, be very careful to remove all chips and burrs. Any open line that is to be left unattended for some time should be sealed, using metal, wood, rubber, or plastic plugs or caps.

When repairing a low-pressure line using a flexible fluid connection assembly, position the hose clamps carefully in order to prevent overhang of the clamp bands or chafing of the tightening screws on adjacent parts. If chafing can occur, the hose clamps should be repositioned on the hose. Figure 5–16 illustrates the design of a flexible fluid connection assembly and gives the maximum allowable angular and dimensional offset.

Layout of Lines

Remove the damaged or worn assembly, taking care not to further damage or distort it, and use it as a forming template for the new part. If the old length of tubing cannot be used as a pattern, make a wire template, bending the pattern by hand as required for the new assembly. Then bend the tubing to match the wire pattern.

Never select a path that does not require bends



Minimum gap 'G" shall be 1/2" or Tube OD/4, whichever is greater.

Maximum gap "G" is not limited except on suction lines using other than self-sealing hose. On such suction lines, maximum G shall be 1-1/2 inch or one tube diameter, whichever is greater.

FIGURE 5–16. Flexible fluid connection assembly.

in the tubing. A tube cannot be cut or flared accurately enough so that it can be installed without bending and still be free from mechanical strain. Bends are also necessary to permit the tubing to expand or contract under temperature changes and to absorb vibration. If the tube is small (under one-fourth inch) and can be hand formed, casual bends may be made to allow for this. If the tube must be machine formed, definite bends must be made to avoid a straight assembly.

Start all bends a reasonable distance from the fittings, because the sleeves and nuts must be slipped back during the fabrication of flares and during inspections. In all cases the new tube assembly should be so formed prior to installation that it will not be necessary to pull or deflect the assembly into alignment by means of the coupling nuts.

FABRICATION AND REPLACEMENT OF FLEXIBLE HOSE

Hose and hose assemblies should be checked for deterioration at each inspection period. Leakage, separation of the cover or braid from the inner tube, cracks, hardening, lack of flexibility, and excessive "cold flow" are apparent signs of deterioration and reason for replacement. The term "cold flow" describes the deep, permanent impressions in the hose produced by the pressure of hose clamps or supports.

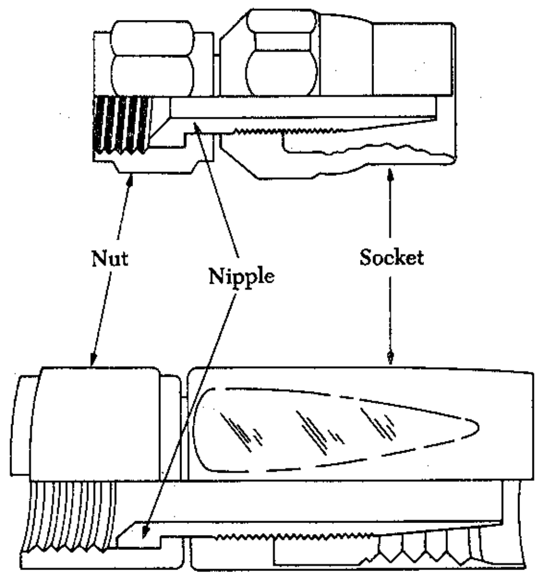


FIGURE 5–17. Sleeve-type fittings.

When failure occurs in a flexible hose equipped with swaged end fittings, the entire assembly must be replaced. Obtain a new hose assembly of the correct size and length, complete with factory-installed end fittings.

When failure occurs in hose equipped with reusable end fittings, a replacement line can be fabricated with the use of such tooling as may be necessary to comply with the assembly instructions of the manufacturer.

Assembly of Sleeve-Type Fittings

Sleeve-type end fittings for flexible hose are detachable and may be reused if determined to be serviceable. The inside diameter of the fitting is the same as the inside diameter of the hose to which it is attached. Common sleeve-type fittings are shown in figure 5–17.

To make a hose assembly, select the proper size hose and end fittings. Cut the hose to the correct length using a fine-tooth hacksaw. Place the socket in a vise. Screw the hose into the socket counterclockwise until the hose bottoms on the shoulder of the socket (figure 5–18); then back off one-quarter turn. Lubricate inside of hose and nipple threads liberally. Mark the hose position

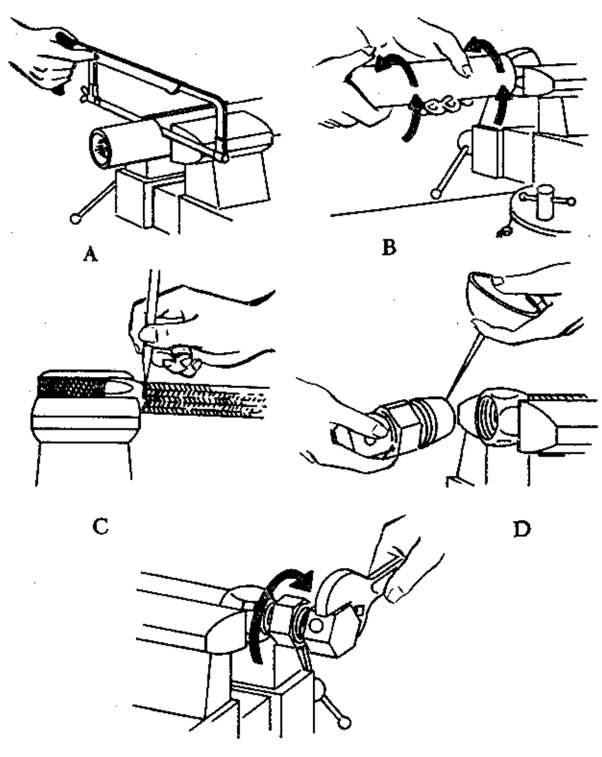


FIGURE 5–18. Assembly of MS fitting to flexible hose.

around the hose at the rear of the socket using a grease pencil or painted line. Insert the nipple into the nut and tighten the nipple and nut on the assembly tool. If an assembly tool is not available, a mating AN815 adapter may be used. Using a wrench on the assembly tool, screw the nipple into the socket and hose. A $\frac{1}{32}$- to $\frac{1}{16}$-inch clearance between the nut and sleeve is required so that the nut will swivel freely when the assembly tool is removed. After assembly, always make sure all foreign matter is removed from inside the hose by blowing out with compressed air.

Proof-test After Assembly

All flexible hose must be proof-tested after assembly by plugging or capping one end of the hose and applying pressure to the inside of the hose assembly. The proof-test medium may be a liquid or a gas. For example, hydraulic, fuel, and oil lines are generally tested using hydraulic oil or water, whereas air or instrument lines are tested with dry, oil-free air or nitrogen. When testing with a liquid, all trapped air is bled from the assembly prior to tightening the cap or plug. Hose tests, using a gas, are conducted underwater. In all cases follow the hose manufacturer's instructions for proof-test pressure and fluid to be used when testing a specific hose assembly.

Place the hose assembly in a horizontal position and observe for leakage while maintaining the test pressure. Proof-test pressures should be maintained for at least 30 seconds.

Installation of Flexible Hose Assemblies

Flexible hose must not be twisted on installation, since this reduces the life of the hose considerably and may also loosen the fittings. Twisting of the hose can be determined from the identification stripe running along its length. This stripe should not spiral around the hose.

Flexible hose should be protected from chafing by wrapping it with tape, but only where necessary.

The minimum bend radius for flexible hose varies according to size and construction of the hose and the pressure under which the hose is to operate. Bends that are too sharp will reduce the bursting pressure of flexible hose considerably below its rated value (figure 5–19).

Flexible hose should be installed so that it will be subject to a minimum of flexing during operation. Although hose must be supported at least every 24 inches, closer supports are desirable. A flexible hose must never be stretched tightly between two fittings. From 5 percent to 8 percent of its total length must be allowed for freedom of movement under pressure. When under pressure, flexible hose contracts in length and expands in diameter.

Protect all flexible hose from excessive temperatures, either by locating the lines so they will not be affected or by installing shrouds around them.

INSTALLATION OF RIGID TUBING

Before installing a line assembly in an aircraft, inspect the line carefully. Remove dents and scratches, and be sure all nuts and sleeves are snugly mated and securely fitted by proper flaring of the tubing. The line assembly should be clean and free of all foreign matter.

Connection and Torque

Never apply compound to the faces of the fitting or the flare, for it will destroy the metal-to-metal contact between the fitting and flare, a contact

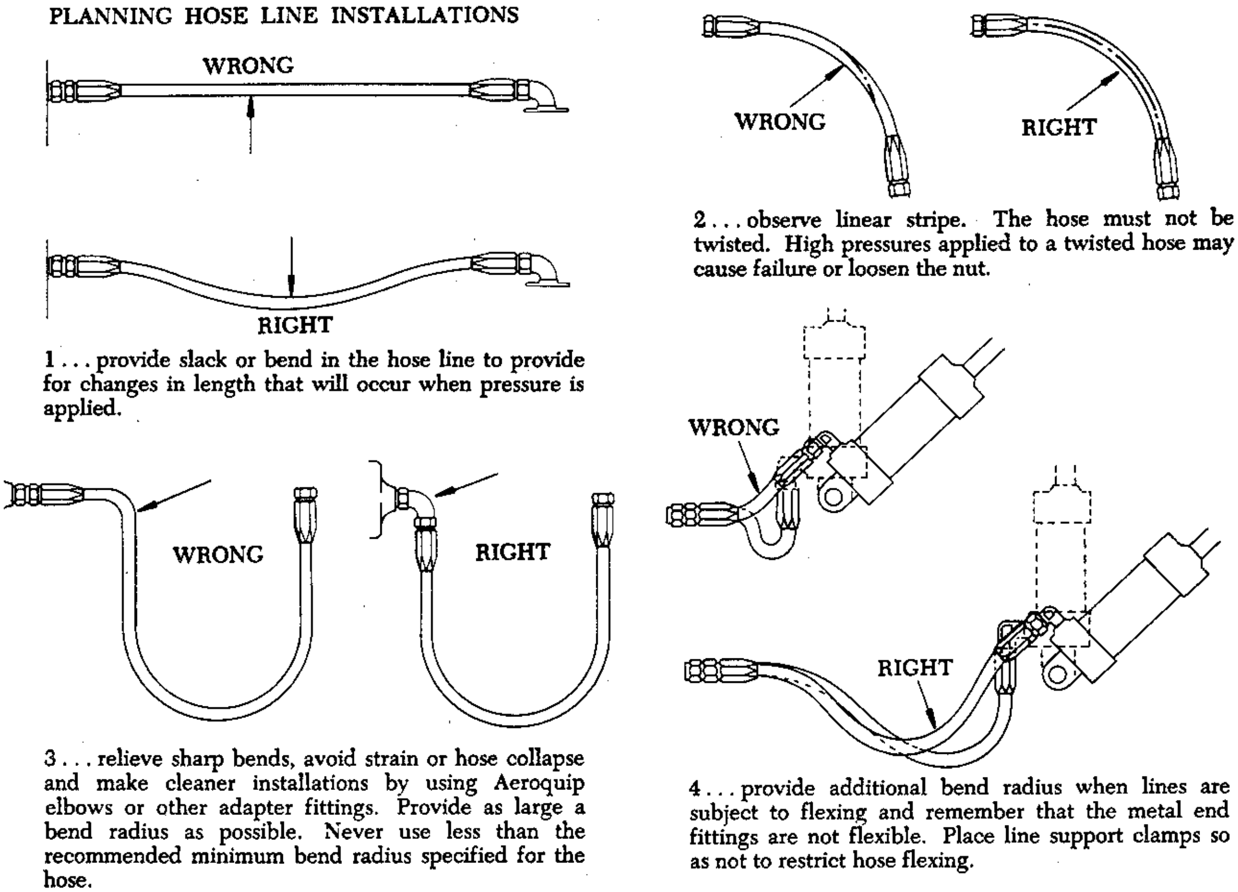


FIGURE 5–19. Flexible hose installation.

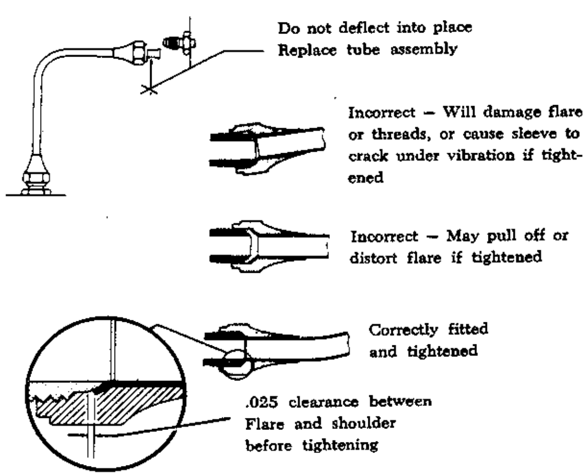


FIGURE 5–20. Correct and incorrect methods of tightening flared fittings.

which is necessary to produce the seal. Be sure that the line assembly is properly aligned before tightening the fittings. Do not pull the installation into place with torque on the nut. Correct and incorrect methods of installing flared-tube assemblies are illustrated in figure 5–20. Proper torque values are given in figure 5–21. It must be remembered that these torque values are for flared-type fittings only. Always tighten fittings to the correct torque value when installing a tube assembly. Overtightening a fitting may badly damage or completely cut off the tube flare, or it may ruin the sleeve or fitting nut. Failure to tighten sufficiently also can be serious, as this condition may allow the line to blow out of the assembly or to leak under system pressure.

The use of torque wrenches and the prescribed torque values prevents overtightening or undertightening. If a tube fitting assembly is tightened properly, it can be removed and retightened many times before re-flaring is necessary.

Tubing O.D.	Fitting Bolt or Nut Size	Aluminum Alloy Tubing, Bolt, Fitting or Nut Torque inch–lbs.	Steel Tubing, Bolt Fitting or Nut Torque inch–lbs.	Hose End Fittings and Hose Assemblies MS28740 or Equivalent End Fitting Minimum	Hose End Fittings and Hose Assemblies MS28740 or Equivalent End Fitting Maximum	Minimum bend radii (inches) Alum. alloy 1100-H14 5052-0	Minimum bend radii (inches) Steel
1/8	–2	20 – 30				3/8	
3/16	–3	30 – 40	90 – 100	70	120	7/16	21/32
1/4	–4	40 – 65	135 – 150	100	250	9/16	7/8
5/16	–5	60 – 85	180 – 200	210	420	3/4	1 1/8
3/8	–6	75 – 125	270 – 300	300	480	15/16	1 5/16
1/2	–8	150 – 250	450 – 500	500	850	1 1/4	1 3/4
5/8	–10	200 – 350	650 – 700	700	1150	1 1/2	2 3/16
3/4	–12	300 – 500	900 – 1000			1 3/4	2 5/8
7/8	–14	500 – 600	1000 – 1100				
1	–16	500 – 700	1200 – 1400			3	3 1/2
1–1/4	–20	600 – 900	1200 – 1400			3 3/4	4 3/8
1–1/2	–24	600 – 900	1500 – 1800			5	5 1/4
1–3/4	–28	850 – 1050				7	6 1/8
2	–32	950 – 1150				8	7

FIGURE 5–21. Flared fitting data.

Flareless Tube Installation

Tighten the nut by hand until an increase in resistance to turning is encountered. Should it be impossible to run the nut down with the fingers, use a wrench, but be alert for the first signs of bottoming. It is important that the final tightening commence at the point where the nut just begins to bottom.

With a wrench, turn the nut 1/6 turn (one flat on a hex nut). Use a wrench on the connector to prevent it from turning while tightening the nut. After the tube assembly is installed, the system should be pressure tested. Should a connection leak, it is permissible to tighten the nut an additional 1/6 turn (making a total of 1/3 turn). If, after tightening the nut a total of 1/3 turn, leakage still exists, the assembly should be removed and the components of the assembly inspected for scores, cracks, presence of foreign material, or damage from overtightening.

NOTE: Overtightening a flareless-tube nut drives the cutting edge of the sleeve deeply into the tube, causing the tube to be weakened to the point where normal in-flight vibration could cause the tube to shear. After inspection (if no discrepancies are found), reassemble the connections and repeat the pressure test procedures.

CAUTION: Do not in any case tighten the nut beyond 1/3 turn (two flats on the hex nut); this is the maximum the fitting may be tightened without the possibility of permanently damaging the sleeve and nut.

Common faults are:

1. Flare distorted into nut threads.
2. Sleeve cracked.
3. Flare cracked or split.
4. Flare out of round.
5. Inside of flare rough or scratched.
6. Fitting cone rough or scratched.
7. Threads of nut or union dirty, damaged or broken.

Some manufacturers service instructions will specify wrench torque values for flareless tubing installations (e.g., see figure 5–22).

PLUMBING ASSEMBLY PRECAUTIONS

Make certain that the material in the fittings used is similar to that of the tubing; for example, use steel fittings with steel tubing and aluminum alloy fittings with aluminum alloy tubing. Brass fittings plated with cadmium may be used with aluminum alloy tubing.

For corrosion prevention, aluminum alloy lines and fittings are usually anodized. Steel lines and fittings, if not stainless steel, are plated to prevent rusting or corroding. Brass and steel fittings are usually cadmium plated, although some may come plated with nickel, chromium, or tin.

To ensure proper sealing of hose connections and to prevent breaking hose clamps or damaging the hose, follow the hose clamp tightening instructions carefully. When available, use the hose clamp torque-limiting wrench. These wrenches are available in calibrations of 15 and 25 inch-pounds. In the absence of torque-limiting wrenches, the finger-tight-plus-turns method should be followed. Be-

Tube Outside Diameter	Wall Thickness	Wrench Torque Inch–Pounds
WRENCH TORQUE FOR 304 1/8 H STEEL TUBES		
3/16	0.016	90 – 110
3/16	0.020	90 – 110
1/4	0.016	110 – 140
1/4	0.020	110 – 140
5/16	0.020	100 – 120
3/8	0.020	170 – 230
3/8	0.028	200 – 250
1/2	0.020	300 – 400
1/2	0.028	400 – 500
1/2	0.035	500 – 600
5/8	0.020	300 – 400
5/8	0.035	600 – 700
5/8	0.042	700 – 850
3/4	0.028	650 – 800
3/4	0.049	800 – 960
1	0.020	800 – 950
1	0.065	1600 – 1750
WRENCH TORQUE FOR 304-1A or 3471A STEEL TUBES		
3/8	0.042	145 – 175
1/2	0.028	300 – 400
1/2	0.049	500 – 600
1	0.035	750 – 900
WRENCH TORQUE FOR 6061-T6 OR T4 TUBES		
1/4	0.035	110 – 140
3/8	0.035	145 – 175
1/2	0.035	270 – 330
1/2	0.049	320 – 380
5/8	0.035	360 – 440
5/8	0.049	425 – 525
3/4	0.035	380 – 470
1	0.035	750 – 900
1 1/4	0.035	900 – 1100

FIGURE 5–22. Torque values for flareless fittings.

Hose clamp tightening, finger-tight-plus turns method		
Initial installation only	Worm screw type clamp 10 threads per inch	Clamps—radial and other type—28 threads per inch
Self sealing hose approximately 15 inch-pounds	Finger-tight-plus 2 complete turns	Finger-tight-plus 2-1/2 complete turns
All other aircraft hose approximately 25 inch-pounds	Finger-tight Plus 1¼ complete turns	Finger-tight Plus 2 complete turns
Retightening of Hose Clamps		
If Clamps do not seal at specified tightening, examine hose connections and replace parts as necessary		
The above is for initial installation and should not be used for loose clamps		
For re-tightening loose hose clamps in service proceed as follows:		
1. Non-self-sealing hose – If the clamp screw cannot be tightened with the fingers do not disturb unless leakage is evident. If leakage is present tighten 1/4 turn.		
2. Self-sealing hose – If looser than finger-tight, tighten to finger tight and add 1/4 turn.		

FIGURE 5–23. Hose clamp tightening.

cause of the variations in hose clamp design and hose structure, the values given in figure 5–23 are approximate. Therefore, use good judgment when tightening hose clamps by this method. Since hose connections are subject to "cold flow" or a setting process, a followup tightening check should be made for several days after installation.

SUPPORT CLAMPS

Support clamps are used to secure the various lines to the airframe or powerplant assemblies. Several types of support clamps are used for this purpose. The rubber-cushioned and plain are the most commonly used clamps. The rubber-cushioned clamp is used to secure lines subject to vibration; the cushioning prevents chafing of the tubing. The plain clamp is used to secure lines in areas not subject to vibration.

A Teflon-cushioned clamp is used in areas where the deteriorating effect of Skydrol ® 500, hydraulic fluid (MIL–0–5606), or fuel is expected. However, because it is less resilient, it does not provide as good a vibration-damping effect as other cushion materials.

Use bonded clamps to secure metal hydraulic, fuel, and oil lines in place. Unbonded clamps should be used only for securing wiring. Remove any paint or anodizing from the portion of the tube at the bonding clamp location. Make certain that clamps are of the correct size. Clamps or supporting clips smaller than the outside diameter of the hose may restrict the flow of fluid through the hose.

All plumbing lines must be secured at specified intervals. The maximum distance between supports for rigid fluid tubing is shown in figure 5–24.

Tube OD (in.)	Distance between supports (in.)	
	Aluminum Alloy	Steel
1/8	9½	11½
3/16	12	14
1/4	13½	16
5/16	15	18
3/8	16½	20
1/2	19	23
5/8	22	25½
3/4	24	27½
1	26½	30

FIGURE 5–24. Maximum distance between supports for fluid tubing.